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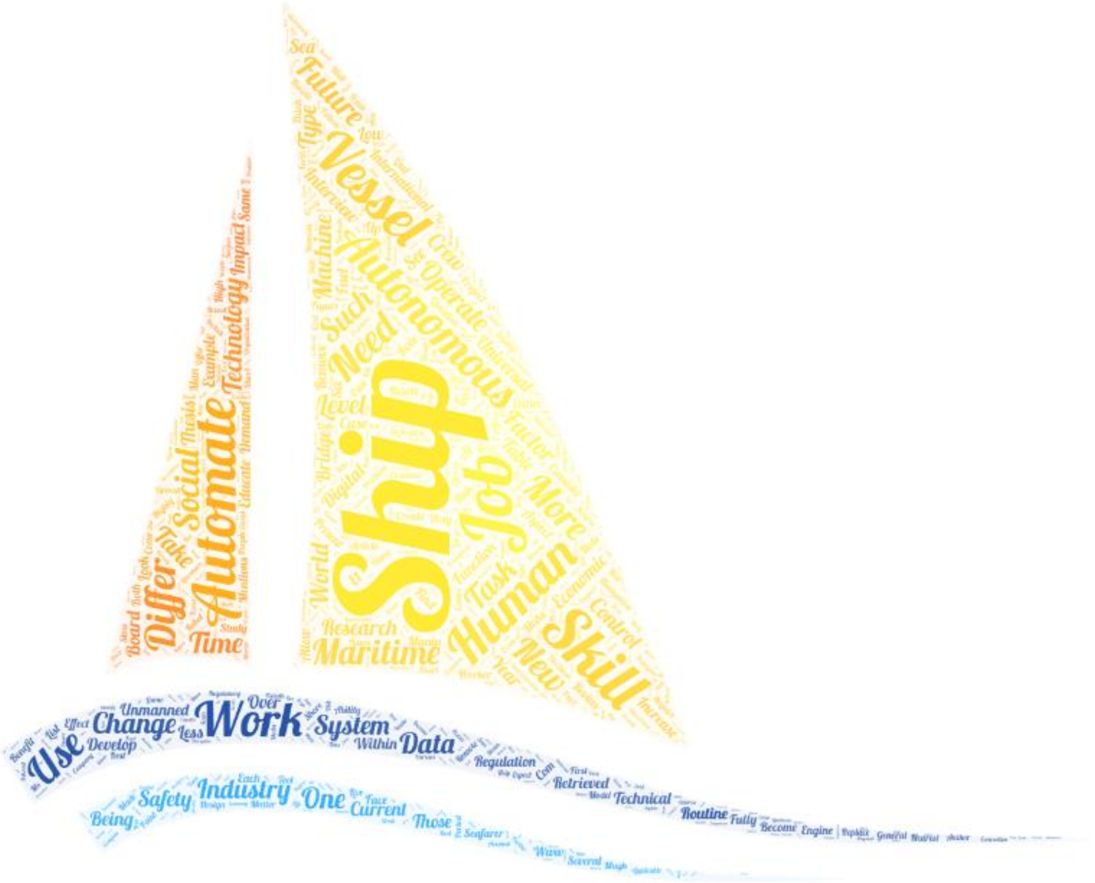

Social and economic impacts of Maritime Automated Surface Ships

Transformation of jobs, future skills and competences Master thesis in Maritime Management Programme

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Cover: Wordcloud image in the shape of a sail-ship made up from words used in the thesis.

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Abstract

With the dawn of maritime autonomous surface ships, more and more development projects aimed at utilizing and exploring the possibilities of autonomous AI driven vessels have begun. There are several innovation projects from the industry that explore the potential, suitability and benefits of autonomous ships. These include, slow steaming, fuel efficiency, new propulsion options, new vessel design, and technologies to aid in the navigation and traffic coordination of vessels. While these technological advances are indeed important and challenging, there is little work on the effects of this transition on social and economic elements such as vocational competencies and skillsets and how task and job descriptions will evolve.

Recently the reality of these types of ships has been made apparent. Projects such as MAXCMAS (Queen's University Belfast, 2018)have shown that the autonomous ships are capable of following COLREGs (International Maritime Organization, 2003) just as well as, if not better, than humans. The IMO is looking into implementing amendments for autonomous ships into their instruments (International Maritime Organization, 2018, 2019). Amidst the technological advancements there exists uncertainty, fears of losing jobs, livelihoods and being ¨left behind¨ by the developing technology.

This study explores what impact we can expect on the shipping industry by digitalization and automation. Specifically, those who are part of the operations surrounding and within the merchant fleet. The study also discusses what the most desirable skillsets for the industry could be in the future. An extensive literature search together with interviews and data from popular media form the main basis for this thesis.

Low-skill and medium-skill groups are at the highest likelihood of automation with a large part of the jobs tasks being possible to be replaced by automated functions in the future, and that the change is expected to be evolutionary rather than revolutionary. Another finding is that highly routine tasks (whichever skill level they belong to) are most apt to automate, be they cognitive or manual while non-routine tasks would be less likely to soon be automated. Skillsets that face the highest demand in the future appear to be belonging to the cognitive and social categories.

When it comes to the economic impact from shifting to autonomous ships we can see that the change also could facilitates new technology. The ships type could benefit from less moving parts and thus also from alternative types of propulsion or energy sources, especially if unmanned. This could facilitate for greener options that use energy which doesn’t require combustion.

The results from this study show that highly autonomous vessels will most likely not be a radical game changer in terms of impacting employment for the nearest decades. The scope of the deployment of the autonomous vessels will most likely be limited to domestic trades by 2040, with some of the autonomous benefits being applied to other vessels for decision-making support.

Keywords: Maritime Shipping, Levels of Automation, Disruptive Technologies, Social and Economic Change

Acknowledgements

I wish to express my gratitude to my supervisor, Scott Netson MacKinnon, who has helped me learn and grow as a researcher during the course of this Master Thesis process. My examiner Monica Lundh for her great feedback. I also wish to extend my thanks to friends and family for their moral support.

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List of Abbreviations

Abbreviation	Written in full
AL	Automation Level (level of automation)
AR	Augmented Reality
CAPEX	Capital Expenditure
COLREG	Convention on the International Regulations for Preventing Collisions at Sea 1972
ICS	International Chamber of Shipping
ILO	International Labour Office
IMO	International Maritime Organization
IoT	Internet of Things
MASS	Maritime Autonomous Surface Ships
MAXCMAS	MAchine eXecutable Collision regulations for Marine Autonomous Systems
OPEX	Operational Expenditure
SCC	Shore Control Center
STCW	Standards of Training, Certification, and Watchkeeping
VR	Virtual Reality
WMU	World Maritime University

Contents

1. Introduction

Shipping has been and continues to undergo changes in technology use that affects the daily operation of ships and supporting work-functions. Right now, we are facing major technological changes that will also affect shipping. To get a perspective on the development in shipping, we first take a look back at the development in society.

Society developed quickly from the wealth generated from the Industrial Revolution, starting in the mid-18th century, and urbanization quickly occurred. By 1820, the income per capita witnessed a sustained growth in industrialized countries. Before the Industrial Revolution most economies had seen fluctuations hovering in the one percent mark known as the “Malthusian Trap”. If we fast forward to today, the “real incomes per capita” has risen “ten-to-fifteen-fold” (Clark, 2014) something referred to as the “Great Divergence”.

A game-changer emerged in 1971 when the micro-processor was developed (Laughton & Warne, 2007)). The evolution of the microprocessor has been impressively quick. Testament to this is Moore’s law which states that roughly every two years the number of transistors on a microprocessor are doubled (see Figure 1). The development of transistors is closely tied with computing power, which means that in the last fifty years the computing power has increased exponentially enabling an immense increase in the spectrum of this technological exploitation. The microprocessor, coupled with fast, reliable, wireless communication began a trend that eventually manifested itself as the ¨Internet of Things¨. This has enabled artificial intelligence and machine learning, technologies that create the core of many, if not most, of the things developed and witnessed in everyone’s day-to-day activities.

From 1993 to 2007 it was found that industrial robots in warehousing increased overall productivity and mainly replaced low- and medium-skilled workers(Gratz & Michaels, 2015; Stephens, 2015), but these innovations didn’t seem to have considerable effect on overall employment levels. Wages in robotic warehouses increased more than comparable non-robotic warehouses, likely as a result that higher skilled (and paid) supervisors were needed to monitor and manage these new technologies and supporting processes. The robotic introduction meant overall positive economic returns to a certain extent after which diminishing returns could be seen as robot density increased.

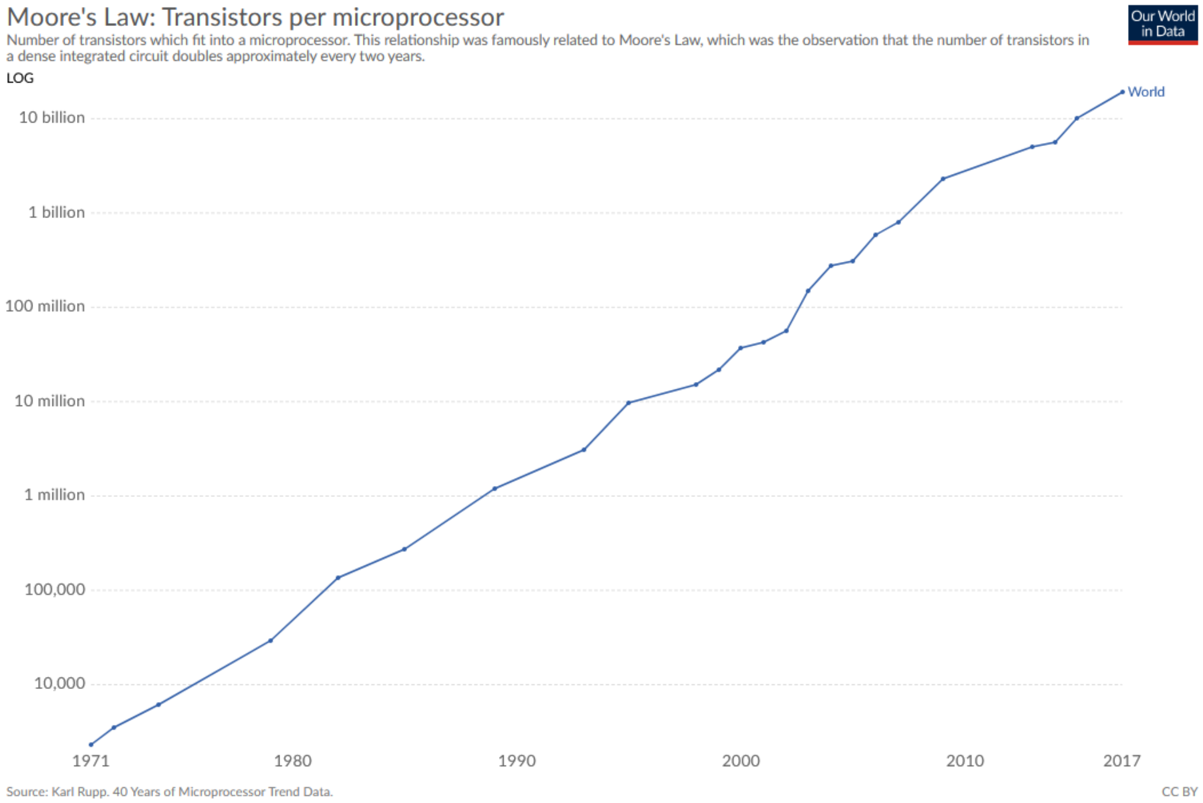
Gene Zaino in “The Impact of Automation on the Independent Workforce” (2017) cites several examples of job transformations and replacements due to automation, such as check-in kiosks becoming automated and “self-serve” at airports and warehouses where machines are installed to allow humans and robots work together. The automated kiosks in this case offer decision making support to the customer. In some examples, in this case Amazon, the human workforce increased by roughly 50%, despite the introduction of robotization and automatization(Zaino, 2017). If current jobs are to be replaced through automatization humans will still be needed for such roles as supervising and “exception-handling”. Exception handling events are for example; where the automated process fails to serve or understand the customer's needs (i.e. does not understand context) and requires the presence of a human to serve the customer directly or instructs its digital counterpart on how to approach the issue.

Our sensorimotor skills are difficult to understand how they work and much harder to reimplement by AI which makes it sometimes very complicated to replace the human being. Automation with AI tools and programs are today advanced when it comes to logic but have been behind when it comes to basic human thinking such as to see, hear and move. This is called the Moravec paradox and was discussed in the 1980s by Hans Moravec (Moravec, 1988) . As Moravec describes it: "it is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility" Byron . Byron Reese (2018) elaborates on this topic and is even bringing it so far that he is talking about a new age if humanity can achieve to use computers to outsource thought and emotion, the very essence of what humanity is. He says that before we can talk about what jobs a robot can take from a human we need to ask "what is a human" (Reese, 2018).

The shipping industry is no stranger to the technological development. Historically we can look back on the disruptive changes that happened at the advent of the steam engine. No longer reliant on prevailing currents, manpower (e.g. oars) and wind driven sails but the ability to "steam ahead" under all environmental conditions. Such technological advances shaped the steam ships as a major driver of the first wave of globalization, allowing an unprecedented increase in international trade by the 1800's (Brynjolfsson & McAfee, 2014).

In the late 1950s, a major innovation for trade and cargo handling occurred, namely the introduction of a certain "box"- the shipping container (Coşar & Demir, 2018; Levinson, 2016). While not technologically challenging, this disruptive innovation allowed a much more efficient, effective way of applying intermodal transport logistics solutions (i.e. the point to point transportation of goods using several modes of transportation, such as a ship, truck, railway and/or airplane) which in turn meant that the moving of boxes effectively connected the seaside with inland transport. This is commonly known as "door-to-door" transport.

Moreover, the innovation of the microprocessor catapulted development forward also on ships (see Figure 2). With new technologies and digital tools supporting or replacing traditional ones or offering new ways to support the work on the bridge and elsewhere on a vessel, began a rapid transition of the way ship operations occur.



Moore's Law: Transistors per microprocessor

Number of transistors which fit into a microprocessor. This relationship was famously related to Moore's Law, which was the observation that the number of transistors in a dense integrated circuit doubles approximately every two years.

Source: Karl Rupp. 40 Years of Microprocessor Trend Data.

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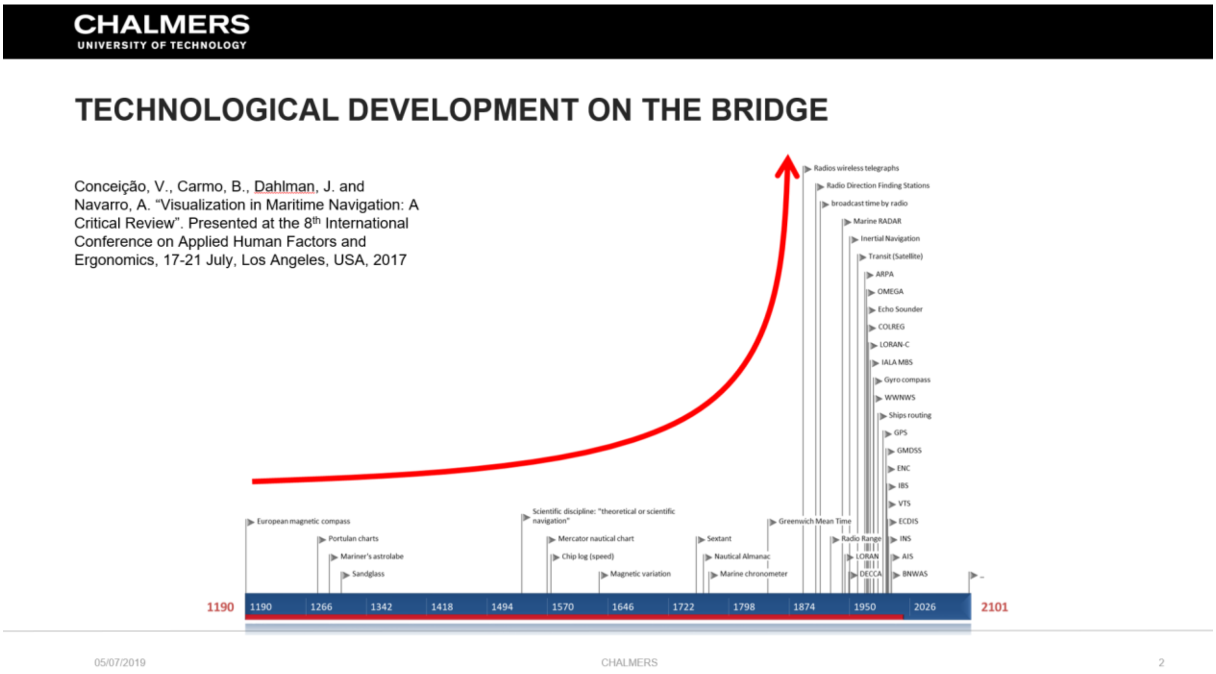
Figure 1 Moore's Law transistors per microprocessor (Our World in Data, 2018) - Open-access and open-source.

The rapidly changing socio-technical landscape in shipping, driven in part by unprecedented changes in technology exploitation, raises many questions about the vocational needs, requirements and delivery systems to support this evolving industry and transportation landscape. What knowledge and skillsets will be necessary in the future; how will the academy educate people entering the industry; and how should recurrent training and professional continuing education be delivered by industry to keep pace with both industry and societal pressures?

Education during the first third of one’s professional life will not likely be sufficient for a professional to remain technically prepared to cope with the operational demands for the rest of a career. Currently the educational and training aspects are mandated by the Standards of Training, Certification, and Watchkeeping (STCW) and is maintained and reviewed by the IMO. This current context is in stark contrast with how personnel aboard an unmanned vessel, perhaps monitored by a shoreside control entity for example in an “SCC” (a shoreside control center) would be trained and operationalized. While the IMO undertakes to review the STCW criteria regularly (Neumann & Weintrit, 2013) the latest significant change was in 2010 and entered into force in 2012 (International maritime Organization, 2011). Even less than 10 years ago this update does not consider autonomous vessel operations. This lag in training results in a situation where autonomous vessels operations in the beginning would have to rely on case-by-case decisions with local and concerned authorities for their deployment at sea within nationally governed waters. In the future there could be codes properly standardized and regulated that would allow for alternate types of watchkeeping such as a shore control center or system-based monitoring.

The shipping industry is impacted by global trends in digitalization and automation and the low- and medium-skilled groups are at the highest likelihood of having their jobs disturbed by automation(World Maritime University, 2019). The pace of transformation and replacement/substitution will vary depending on local factors such as technological, regulation and demographic aspects. The future skills demanded within the shipping industry are likely to increasingly be focused around problem-solving, social and cognitive abilities (MacKinnon & Lundh, 2019; World Maritime University, 2019) .

According to CMA CGM S.A., a French leading world-wide shipping company, 5G technologies are able to handle greater volumes of data and offer increased speeds along with reduced latency (Caitlin McGarry, 2019; McGarry, 2019). The industry is thus embarking on what CMA CGM calls a “shipping revolution” (CMA CGM, 2019), which would allow real-time supply chain management. The different generations (e.g. “4G LTE-M” and “5G NB IoT”) could see different uses based on their different ranges and speeds. The company CMA CGM’s web page (https://www.cmacgm-group.com/en/news-medias/5G-CMA-CGM-at-the-Forefront-of-the-New-Shipping-Revolution) reports that 5G would be used on the cargo containers, while 4G would be used for the autonomous vessels themselves, hence both technologies complement each other.



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TECHNOLOGICAL DEVELOPMENT ON THE BRIDGE

Conceição, V., Carmo, B., Dahlman, J. and Navarro, A. “Visualization in Maritime Navigation: A Critical Review”. Presented at the 8th International Conference on Applied Human Factors and Ergonomics, 17-21 July, Los Angeles, USA, 2017

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Figure 2 Technological development on the bridge (Conceicao, Carmo, Dahlman, & Navarro, 2017)

The next generation of changes in the technological and operational evolution of shipping is aptly named “smart” shipping. Ultimately this evolution would be (is) heading towards highly autonomous vessels (Laurinen, 2016). This evolution has been termed by the International Maritime Organization (IMO) as Maritime Autonomous Surface Ships (MASS) and addresses a concept of the future of global shipping. MASS is “a ship which, to a varying degree, can operate independently of human interaction” (International Maritime Organization, 2018). Their scoping exercise is based upon defined levels of autonomy which starts at Level 1 (being least automated) to Level 4 (being fully autonomous) as follows:

1. ”Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated. ”
2. ”Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location, but seafarers are on board.”
3. ”Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.”
4. ”Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.”

While education requirements for smart vessels needs to be better understood, so does the nature of how work is to be done on board a vessel. There are examples from other industries of how the introduction of robotics and automation into operational processes have transformed the role of human operators. In some instances, work conducted by humans has changed, some functions have been removed and new roles have emerged due to innovations within artificial intelligence, machine learning, robotics and automation (Awad et al., 2018; Gratz & Michaels, 2015; Sengupta, Donekal, & Mathur, 2016; Wahlström, Hakulinen, Karvonen, & Lindborg, 2015)

Several research and industrially funded projects related to the concept of autonomous ships are underway or completed, such as the explorative, simulation-based concept bulker from MUNIN (MUNIN, 2016) and the world’s first physical autonomous cargo ship the Yara Birkeland (KONGSBERG, 2019). The Yara Birkeland is an electric container ship that will commence with manual sailing and progressively become more automated and autonomous by 2022, when the bridge module is intended to be removed in the final stages of development (Ship-technology.com, 2017).

Autonomous ships, their deployments and the organizations that have regulatory oversight still require development and coordinated timelines. The Danish Maritime Authority, among other industry stakeholders, recognized the need for development of operational and legal frameworks for safe operation of autonomous ships (Sonderstrup, 2017) and addressed this within the IMO structures. The IMO indicated that they were taking steps towards regulatory amendments necessary for the emergence of autonomous vessels, recognizing the needed to take a “proactive and leading role” (International Maritime Organization, 2019). A regulatory scoping exercise is being undertaken and was planned to be completed by 2020. The purpose is to identify what provisions in current regulations are or aren’t applicable to the ships with different levels of autonomy. Then, to analyze and determine how to approach and address MASS taking “human elements, technology and operational factors” into account.

Laws and regulations largely control the development and strongly influence social and economic factors for autonomous ships. IMO will be making amendments to their regulations which will encompass autonomous and highly autonomous vessels, as current regulations are not designed for autonomous vessels (International Maritime Organization, 2018). Other industries are visited to see if any lessons can be learned that are relevant for an eventual highly automated shipping industry. There is a lot of insight to be derived from the automotive and the aviation industries.

When it comes to liability, who is at fault when accidents happen? It’s one thing when management of the onboard systems fails, and an operator on board can be faulted for inattention, inadequate communication and lacking situation awareness (Pazouki, Forbes, Norman, & Woodward, 2018), when we go to remote controlled ships however, will the operator in the SCC be considered as “master”? When it comes to autonomous ships where the SCC does monitoring and exception handling solely, will it be down to the systems on board and trigger strict liability for the shipowner to ensure someone can be found liable (in the absence of a humans direct fault) (Insurance Marine News, 2018)? It could be argued that a transposition of the answer from the automobile sector could be employed where the manufacturer would be kept liable during automatic operation, such as Tesla has been, despite the technology being developed (though in many cases together with Tesla) by other companies like Nvidia and MobilEye. Similarly, in an article published by GARD (Fosen, 2019; Howse, 2019) they refer to a statement as follows; “December 2015, Volvo's CEO announced that it will accept full liability if any of its cars crash while in full autonomous driving mode”. While not claiming this would be the right way, necessarily, for autonomous ships, it is among many others an avenue interesting to explore.

Another point the article by GARD brings up is that while autonomous ships may be starting to appear now, the current projects are planned to be used in domestic trade along shorter distances. Local authorities, flag state and class, as in the case of the Yara Birkeland evaluation period of sailing, will clear the ship for their intended purposes. International trade, with more complicated regulations and laws is most likely much further away. The GARD article continues that the interim first generation of guidelines may be deployed within the next 3-5 years (Howse, 2019) which in the context of autonomous ships is not at all a particularly long time.

This thesis will consider how new job descriptions, skillsets and business models might influence social and economic change in shipping. This work specifically positions these interpretations based on current knowledge and technologies and extrapolates to a world 20 years into the future, when the shipping industry will certainly evolve due to automation-based pressures, but it is not in the too distant future where technologies, as we exploit and understand them today, are substantially evolved. There will be a need to manage disruptive technologies and their impacts upon the industry. These changes may be technical (e.g. energy storage, energy sources, propulsion systems, data management and exchange), organizational (e.g. business models, corporate structures) or social (e.g. education, regulation) in nature. Changes to the technology will inevitably also impact the need of human intervention. If the social aspects are not properly considered, possible benefits of MASS may be doomed to be lost in the pursuit for development in the shipping industry.

In order to grasp the concepts from a higher vantage point, a socio-technical system viewpoint is explored. The socio-technical systems theory has its origins in the coal mining industry in Great Britain in the 1950s where Eric Trist and Ken Bamforth researched organizational issues and opportunities (Trist & Bamforth, 1951). The workers in the coal mining industry were at that time told to carry out the work in a new and mechanized way. This new work method, however, did not seem to have been developed by anyone who knew what it was like to work in the mines.

Under the new working conditions it was difficult for the workers to do their jobs which led to dissatisfactory results, and a higher rate of accidents was also reported. In certain mines the management did not listen to the workers explanations about what was wrong and problems persisted with lower productivity as a consequence. In the mines where the management listened to the workers the problems could be solved. By this Eric Trist understood the importance of social aspects in the work. This was in sharp contrast to Taylorism which assumed that the management alone would find out the best way to perform the tasks. The Taylorism was about workers following strict instructions and to perform exactly in accordance with the instructions on the intended time (Taylor, 1911). The socio-technical systems theory is, as can aptly be surmised by the name of the theory, based on the interaction between social factors, which would be the people involved, and technical factors such as, but not limited, to material technology. This theory can be applied to both work related spheres but also on the society as a whole.

In this thesis maritime automated surface ships, and their automation technology in particular, are discussed both from the social and economic perspective. The purpose is to bring forward how the technical developments in maritime automated surface ships relates to the people within the industry and how it may turn out for those skilled workers and their jobs within a not too distant future.

1.1 Aim and objectives

The aim of this thesis is to understand how the evolution of the shipping industry towards increasing levels of digitization, automation and levels of autonomy will impact social and economic factors important to industry stakeholders.

The following objectives will be undertaken to address the aim of this thesis:

1. A literature reviews, including academic journals, industry media and popular media relevant to changes related to the shipping industry, as well as, academic and popular media sources related to understanding socio-economic changes related to digitalization and automation in industrialized societies.
2. Interviews with subject-matter experts in the shipping industry. These will be conducted using semi-structured approach followed by an analysis of the content.

1.2 Research questions

The following research questions will be addressed in this thesis:

1. Will this emerging new socio-technical order create social change in the shipping industry?
2. Will this emerging new socio-technical order create economic change in the shipping Industry?

1.3 Delimitations & Limitations

The scope of the research will be limited to approximately 20 years into the future, a forecast to 2040. While this still is very much a crystal ball forecast, the rapid changes in technologies, many which are unknown or even difficult to predict, will influence considerably how the shipping actors are positioned within this complex and evolving socio-technical system.

While the evolution of a MASS has an industry-wide focus, the technical and social characteristics of the various shipping segments (for example tankers, bulk carriers, containerships, offshore ships, survey ships, cruise vessels, passenger ferries) are quite different in shipping activity. This study considers container and to a lesser extent bulk carrier ships.

The main limitations of the study are due to the lack of published empirical evidence. This makes it difficult to come up with generalizable scientific conclusions. However, based on the findings in the research it is possible to elaborate on speculative and exploratory conclusions.

2. Background

With the dawn of maritime autonomous surface ships, more and more development projects aimed at utilizing and exploring the possibilities of autonomous AI driven vessels have begun. There are several innovation projects from the industry that explore the potential, suitability and benefits of autonomous ships. These include, slow steaming, fuel efficiency, new propulsion options, new vessel design, and technologies to aid in the navigation and traffic coordination of vessels. While these technological advances are indeed important and challenging, there is little work on the effects of this transition on social and economic elements such as vocational competencies and skillsets and how task and job descriptions will evolve.

Shipping has undergone and continues to undergo changes in the use of technology that affect the daily operation of ships and supportive work functions. Recently the reality of the autonomous types of ships has been made apparent. Projects (such as MAXCMAS (Queen's University Belfast, 2018)) have shown that the ships are capable of following COLREGs, the "convention on the International Regulations for preventing collisions at sea" (International Maritime Organization, 2003), just as well as, if not better, than humans. The IMO is looking into implementing amendments for autonomous ships into their instruments. Amidst the technological advancements there exists uncertainty, fears of losing jobs, livelihoods and being" left behind" by the developing technology.

This thesis is about highly autonomous vessels that have not yet been deployed, which makes projecting into the future fairly complex. More specifically this thesis mission is to study human and social aspects of automation in highly autonomous vessels which is even more difficult as the data that was found almost solely referred to the technical aspects of automation.

2.1 Towards autonomous vessels

Automated ships can be classified from vessels with traditional seafarers using automation through fully unmanned and autonomous and depends upon ship type, voyage conditions, vessels operation needs and jurisdictions. Essentially, different levels of manning and different types of manning are appropriate for different levels of autonomy and the ability of the ship to operate independently from human interaction.

To better understand the technical evolutions of automation in shipping the levels of automation and the types of crewing organizations need to be further deliberated upon and operationally defined. There are several models that have been suggested for the purposes of this work, with many similarities but certain differences (International Maritime Organization, 2018; Lloyd's Register, 2017a, 2017b; Norwegian Forum for Autonomous Ships, 2017). The definitions used for the word "autonomous" in this thesis will consider the NFAS definitions (Norwegian Forum for Autonomous Ships, 2017) and are presented in Table 1. This table describes the difference between an automatic ship and an autonomous ship.

Table 1 Definitions of autonomous and automatic used in the thesis. Source: (Norwegian Forum for Autonomous Ships, 2017)

Automation	**“The processes, often computerized, that implement a specific and predefined method to execute certain operations without a human controlling it”.**
Automatic	“The system has automation functions that can complete certain operations without human control”.
Automatic bridge	“Automatic bridge, with crew always on the bridge”.
Automatic ship	“Ship is supervised by SCC and executes automatic functions”.
Autonomy	“The system has control functions that can use different options to solve selected classes of problems”.
Autonomous ship	“Ship with some form of autonomy”.

Lloyd’s Register’s (Lloyd's Register, 2017b) description of the ¨levels¨ of automation (see Table 2) will be used in this thesis. Which level of automation is reasonable or suitable for any given purpose depends on a number of different aspects and factors such things as; cost, how the vessel is to be used, trade and where the vessel will be deployed. Essentially Autonomy Level 6 describes how the vessel can operate entirely independently from human contact, as proposed in the Yara Birkeland concept (Ship-technology.com, 2017). How extensive the autonomy the vessel will use will be seen after the pilot deployment. Perhaps it will oscillate between levels of automation depending on various factors, as the vessel will be deployed in a small area on a short trade route (KONGSBERG, 2019).

Table 2 Levels of automation. Source: (Lloyd's Register, 2017; World Maritime University, 2019; Johns, 2018)

Levels of Autonomy	Description
AL 0: Manual.	Entirely manual operation, no autonomous functions. Human(s) control all functions.
AL 1: On-board Decision Support.	All actions are taken by a human operator, but decision support tools can present options and by other means affect decision making. Data may be provided by systems on board.
AL 2: On & Off-board Decision Support.	All actions taken by a human operator, but decision support tools can present options and by other means affect decision making. Data may be provided by systems on or off-board.
AL 3: "Active" Human in the Loop.	Decisions and actions performed with human supervision. Data may be provided by systems on or off-board.
AL 4: Human on the Loop, Operator/Supervisory Role.	Decisions and actions are performed autonomously with human supervision. At high impact decisions human operators can still intercede and over-ride.
AL 5: Fully Autonomous.	Rarely supervised operation where decisions are entirely made and actioned by the system.
AL 6: Fully Autonomous.	Unsupervised operation where the decisions are entirely made and actioned by the system during mission.

Table 3 provides an explanation for the different types of crewing that may be required for the different types of autonomous operations of a vessel. It is possible that a single vessel on one or more journeys may implement one or several of these types depending on the need considered for a particular part of a journey. As an example, presence of active crew manning may increase during challenging parts of the journey, while long periods of easy shipping (e.g. trans ocean legs) may only require reduced to no crewing.

Table 3 Types of crewing (Norwegian Forum for Autonomous Ships, 2017)

Types of crewing	Description
Autonomy Assisted Bridge (AAB) /Continuously manned bridge	"The ship bridge is always manned, and the crew can immediately intervene in ongoing functions. This will not generally need any special regulatory measures except perhaps performance standards for new functions on the bridge"
Periodically Unmanned Bridge (PUB)	"The ship can operate without crew on the bridge for limited periods, e.g. in open sea and good weather. Crew is on board ship and can be called to the bridge in case of problems."
Periodically Unmanned Ship (PUS)	"The ship operates without bridge crew on board for extended periods, e.g. during deep-sea passage. A boarding team enters, or an escort boat arrives to control the ship, e.g. through the port approach phase. For regulatory purposes, this would probably be the same as CUS."
Continuously Unmanned Ship (CUS)	"The ship is designed for unmanned operation of the bridge at all times, except perhaps during special emergencies. This implies that there is no one on the ship that is authorized to take control of the bridge, otherwise, the ship would be classified as PUB. There may still be persons on the ship, e.g. passenger or maintenance crew".

The “SCC” is a “Shore Control Center”, where monitoring, supervising, exception handling, decision-support and possibly even remote control could be undertaken to support vessels of varying degrees of autonomy (Eriksson, 2020). It may be appropriate for deep-sea vessels that do not have completely autonomous systems and that might require frequent maintenance and repairs to retain human personnel aboard to attend to these tasks. From both a safety (e.g. maintaining propulsion systems) and cost (e.g. system redundancy) perspectives, a mixed machine/human model might be the most efficient. Furthermore, regular maintenance tasks (i.e. tasks that may be difficult to automate) are best done underway rather than during more costly port calls.

Advancing levels of automation will create changes in the social and economic fabric of those engaged in shipping, both on board and onshore. It is expected that the evolution towards autonomous vessels will change the nature of the work from the physical daily interactions towards more supervisory roles and artificially intelligent systems and computers will become more independent decision-makers. Independent in this context is defined as not needing constant input from humans to act or react. The desired future skillsets of employees within the industry are also likely to change. While there may be a loss of jobs anticipated by the automation of routine tasks, new roles, tasks and responsibilities will likely emerge. How automation in the shipping industry will impact low-, medium- and high-skilled tasks and those persons that perform them requires further study. Table 4 contains the following definitions in regards to these “skill-levels” which can be extracted and adapted from the data found in the “International Standard Classification of Occupations, ISCO 08” (International Labour Office, 2012).

Table 4 Skill levels, and their definition. Adapted from (International Labour Office, 2012)

Skill level	Explanation
High Skill	Complex tasks, generally requiring college degree or equivalent.
Medium Skill	Semi-complex tasks, may require high school education.
Low Skill	Simple and routine tasks, primary education may be required.

These definitions are very general, and there are jobs where the term “low-skilled” can be applied to very routine work but that may require education beyond the formal schooling period (including possibly specialist courses). Examples of these cases are truck drivers or crane operators in a container terminal or, as welders or other hot-work, especially in an energy terminal. These jobs require special instruction and certification in a port despite being considered routine.

2.2 Feasibility considerations for automation at sea

Although 2040 seems like it is far away in time, it is not too distant into the future if one considers that a vessel in in service for at least 25 years before being decommissioned. This creates inertia to change and implies that the change in the automation of vessels will be gradual and slower over a greater period of time (World Maritime University, 2019).

Automation may be more or less appropriate depending on the type of trade the vessel is supposed to undertake. For example, it may be appropriate for deep-sea vessels undertaking longer journeys to not have completely crew-less autonomous systems as they might require maintenance and repairs while underway. Different levels of automation and levels of manning will likely be dependent upon the types of trades. The vessel Yara Birkeland, is intended to begin as manned but then as operations are verified by the maritime authority she is planned to be running completely unmanned autonomous operations with the bridge module eventually removed (KONGSBERG, 2019). In the MUNIN case (MUNIN, 2016), the automation of a break bulk Handymax gave calculated cost savings of seven million USD for the 25 years the vessel was expected to be in service. This wasn't just salary savings, but also took into consideration fuel efficiency savings compared to a reference bulker. The vessel was still calculated to be managed manually in congested or restricted waters.

We may see an evolution of propulsion methods for future ships. Those on short distances may utilize battery supplemented or battery-based energy sources to remove or minimize mechanical moving parts, as electrical versus conventional systems allows. Ships that are intended as being deployed CUS (Continuously Unmanned Ship) and fully autonomous for the entire duration of a voyage or assignment, could be designed in such a way as to not only be equipped with modern means of propulsion but also with fuel efficiency as main aspect instead of allotting space for a crew and bridge while reducing air drag, chassis weight and material costs in the hull.

2.3 Social and economic impacts of transformation

Social effects considered in this thesis are the factors that concern the workers of the shipping industry. It is about how they are affected professionally by automation in terms of who are at risk of losing their jobs, or having their jobs transformed due to digitalization and automation of evolutions.

The low- and medium-skilled workers are at the highest likelihood of having their jobs impacted to a great degree by automation, while high-skilled jobs are less likely to be affected (World Maritime University, 2019). This includes having the job completely changed or removed (such as bridge removal would create) but also moved such as when a SCC (Shore Control Centre) takes over functions where the bridge is removed or at periods unmanned (Eriksson, 2020),. While some retraining and further education is possible for the ranks that have their jobs automated (or partially automated), a risk exists that some may find themselves becoming redundant within the traditional shipping workforce. "The Second

Machine Age" (Brynjolfsson & McAfee, 2014) describes some nuances which also helps us further unpack where automation is likely to have the strongest impact upon shipping, based on findings that point to routine tasks being automated while non-routine tasks remaining in human hands; be they tasks that require cognitive or manual work.

As far as seafarers are concerned, they will continue to be in higher demand than supply in the foreseeable future. But the nature of the work may change and the demands on education and guidance may increase (Johns, 2018). This means that families for whom shipping has been a family profession that has been inherited for generations may need to consider their children's needs for education and guidance (Johns, 2018).

The highly automated ships won't be outcompeting the seafarers any time soon. As far as engineering crews in the machinery departments are concerned, it will likely take even longer. The issues with traditional, mechanical systems remain, and the environments that the ships exist are taxing on materials and systems which require regular maintenance. In many trades, the vessels will require maintenance and engineering crew onboard under-way and thus will still require their presence of a human for the time being. As an example, most larger ships on longer trade routes face the risk of a small problem becoming more critical if left unattended. To make matters more complicated, to travel unmanned, the sheer distance to the nearest landmass may not allow the option of fly-in technicians due to cost, time or even rough weather. It may become somewhat easier and cheaper to provide fly-in assistance once a critical mass of ships that could benefit from it is reached, assuming automation gains traction. Maybe SCC's can supervise several ships which need the same type of service thus bringing down the costs. However, this imply that skills must be available at the SCC.

2.4 Skills and training

Different tasks earlier performed on the vessels are expected to be transferred to the SCC. The new jobs in the SCC would need to be performed by experienced seafarers to have people on site that understand ships behaviors, not only with on-call technicians or consultants but probably also the operators. This will be necessary at least until there are academy-trained people whose skills are at an acceptably high level to interpret the data that comes through existing mediums such as visuals with displays fed by cameras, audio from the vessel etc. (Wahlström et al., 2015). There are a number of risks with automation when the understanding of the technology is insufficient or the ability of the operator to deal with these complex and uncertain data streams is challenged.

There is also a risk that systems will be designed and implemented without consideration for simplicity or transparency. This could cause a variety of issues, which include over-reliance on the systems, misinterpretation of the data provided, information overflow, degradation of skill due to lack of on-hand work etc. On the other hand, automation can also avoid human error related factors such as bad decision making, delayed action, personal skill and amongst other things experience and age related factors through decision support mechanisms or automated anomaly detection strategies (Bainbridge, 1983; Burmeister, Bruhn, Rødseth, &

Porathe, 2014; Mercer et al., 2016; Wahlström et al., 2015) . These authors suggest that solutions to these issues can be addressed in the training and education of personnel and, more importantly, a human centered design approach that considers operator capacity and usability needs.

Future training could take advantage of technology that exists and is on the rise, in the realm of VR, AR and games. For example, in “Advances in Human Factors, Business Management and Society” (Kantola, Barath, & Nazir, 2018) it is discussed how different video games are used to increase hand-eye coordination, precision, knowledge and quality in medical professions, such as surgery, leading to decreased numbers of mistakes committed and increased overall efficiency. Similarly, in fighter pilots used to control drones, an interviewee that had served in the military mentioned that “The best drone pilots are gamers… they exceed the fighter pilots performance by far.” (I3, 2019). This speaks to the fact that current training may be replaced by more current technologies and delivery systems, and academies may need to address critical educational outcomes. A key in this type of gaming, which Kantola et al. (2019) also found, is that it is possible to receive the training regularly which gives the best result.

3. Method

3.1 Research approach

In this thesis, maritime automated surface ships are discussed from the social and economic perspective. The reasoning is based on a socio-technical systems perspective. Socio-technical theory is about joint optimization, i.e. designing the social system and the technical system so that they work smoothly together. (Pasmore, Winby, Mohrman, & Vanasse, 2019)

A qualitative, abductive approach (Dubois & Gadde, 2002) was used as a research framework to answer the research questions. A literature review, review of popular media including theme-related YouTube presentations on the topics of automation and interviews with subject matter experts (SMEs) were undertaken to derive the information and data considered in this analysis.

3.2 Information collection

Data were collected through literature related to automation and the skills surrounding the operations and deployment of autonomous surface ships. The purpose was to build a knowledge framework including definitions from which to further discuss and consider the objectives of the research. Data were also collected through interviews to gain a deeper understanding of the reality of these emerging technologies. The interviews allowed the researcher to gain new directions for literature searches, through newly discovered search words or topics revealed by the interviewees. The interview questions were semi-structured and open-ended which allowed the interviewee freedom to discuss their perspectives on the topic. The planned questions were emailed to the interviewee beforehand. The SMEs were approached based on their experiences with respect to technical, mechanical and commercial aspects of autonomous shipping.

3.2.1 Literature and media reviews

The literature review was used to assemble data from different areas, with a focus on automation and human factors. The search itself was conducted using several different databases such as Web of Science, Google Scholar and Summon via the Chalmers library website.

The main keywords used were: *Automation in merchant fleet, vessel automation, MUNIN Project, AAWA Initiative, automated warehouse, automated ships, human factors automation, workers in automated industries, socioeconomic effects of automation, value from autonomation.*

A large amount of data sources were obtained. Those most relevant to the research questions are pertaining to automation and automation, in particular concerning automated surface ships. Articles concerning information on environmental or regulatory perspectives in the automation-sphere were also chosen if the content was deemed relevant enough to the social and economic key themes. From these articles, new avenues of inquiry arose, and new searches were made to go deeper into understanding certain aspects such as skills, human factors and errors surrounding increased levels of autonomy. Consideration was given first to peer-reviewed journals and articles, books and then on to news outlets, social media presentations (e.g. TED talks), and finally company websites and downloadable brochures and articles from those websites.

The below flow diagram shows the general process as adapted from PRISMA 2009.

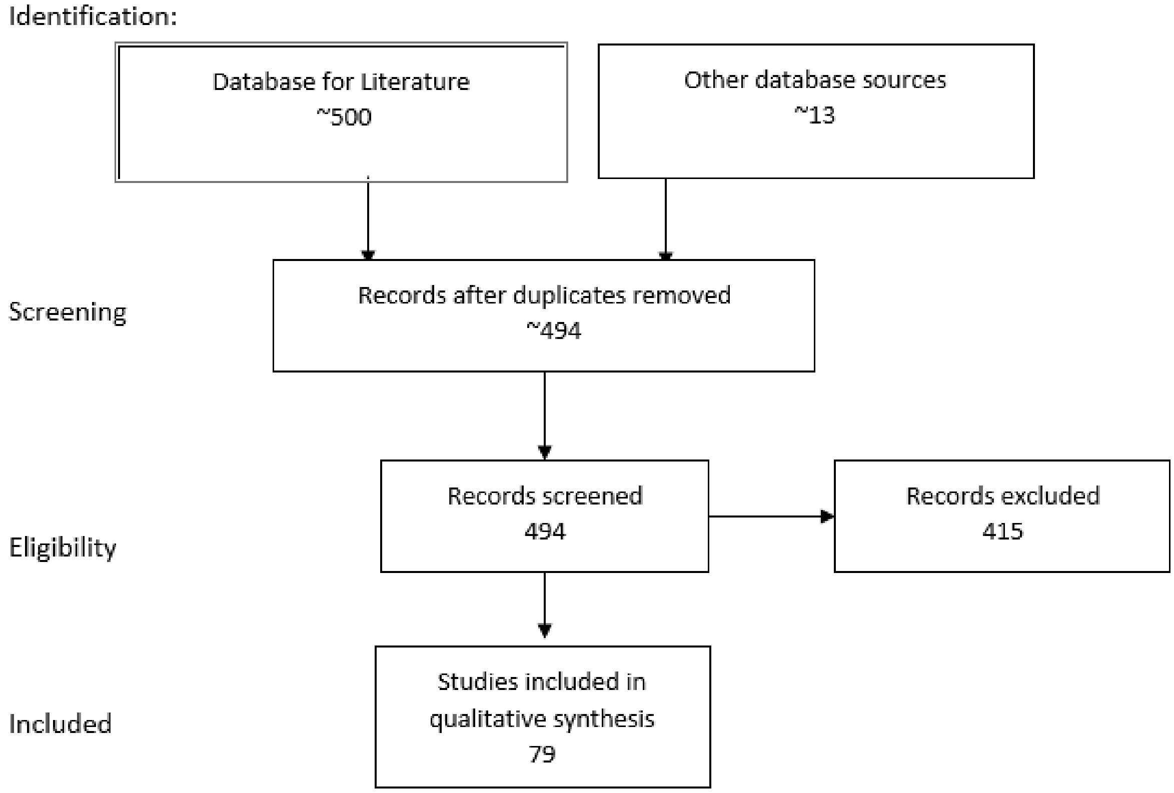


Figure 3 Process adapted from PRISMA 2009 (Moher D, 2009)

3.2.2 Interviews

Persons were selected for one-on-one interviews based on their positions of employment within the shipping industry. All interviews were conducted in English. Generally, the interviews were performed by the author of this thesis. The exception was the interview with interviewee I3, where two interviewers were present (this person was co-interviewed for two different thesis research activities). A description of those interviewed are found in Table 5.

Table 5 Interviewees with their positions, experience and companies

Position	Experience	Type of Company	Interviewee number
Director of Logistics	All operational functions of vessel and fleet management.	Large shortsea commercial shipping company active in European waters.	I1
Chief Engineer	Shipboard engineer on a number of vessels using different types of electrical, conventional and automatic systems.	Tanker company.	I2
Vice President of Strategic Partnerships	Commercial and business-oriented partnerships and strategy.	Commercial company producing consumer and business products.	I3

Contact was made with participants informing them of who the interviewer was, what the purpose was and what it was for as well as a list of questions and themes that the interview would be about.

The interviews started with a personal introduction, and then went on to cover several main themes including but not limited to:

- General physical and technical (such as shore control center design)
- Skills (of the future worker and current workers involved)
- Human-machine interaction issues
- Economic
- Energy and propulsion technology and techniques
- Active systems functions
- Security
- Vision versus version (what can be done now vs what is desired to be achieved and when/how to get there).

No direct script for each interview was used, but rather a semi-structured approach was used as the same questions couldn't be used for all the interviewees as they had very different backgrounds and vocational responsibilities. The Interviews took place from 20th February 2019 to 24th May 2019. While the interviews didn't have a restricted time schedule, the aim was to be completed within an hour. Semi-structured interviews can be done in slightly different ways as they are flexible in form. A semi-structured interview technique is often used when looking for why rather than how many or how much. The interview technique means that you have a special area that you are interested in and a number of questions and very good knowledge about which area or areas you want to cover. The discussion is fairly free and can develop in different ways depending on who you are interviewing. (Miles & Gilbert, 2005)

3.3 Data management

3.3.1 Literature review data management

The literature results were reviewed with keywords considered and put into categories. Articles that were directly and only related to shipping were primarily considered but also articles concerning other industries were taken into account when relevant.

The main pursuit was to find common denominators to paint a picture for what the future could hold. These points were then boiled down and dissected to see what could be relevant for the research questions. The scope of the various findings were considered, as some effects may be different depending on geographical location as well as technological, social and other developmental levels.

The key aspects for the main themes that would guide the analysis were
1: Social – such as the extent of what jobs (of low, mid and high-skill tiers) including desired future skillsets
2: Economic – cost-saving of different kinds or if it would be increased costs

3.3.2 Interview data management

All interviews were from a single high-quality recording device placed between the interviewer(s) and the interviewee. Once the interview was over, the file was uploaded to a private and secured filesystem where the data management mostly took place. The transcriptions were made within the same system. Once a transcription was complete, a version was made where the surrounding "noise" was cut from the transcription, such as "uhm", and varied vocal thinking noises, repeatedly restarted responses where the informant would start a sentence, then to cancel it and "restart" their answers were also cut. All context surrounding the answers was kept.

For confirmation from the responders the transcription of the oral interviews was returned to the interviews for confirmation of the content and for review to ensure they do not feel things are misrepresented. A consent form was signed by the informant and received by the researcher.

4. Results

In this section results will be presented and attempt to answer the research questions:

1. Will this emerging new socio-technical order create social change in the shipping industry?
2. Will this emerging new socio-technical order create economic change in the shipping Industry?

The results will be split into several segments. First the review of literature, then of the interviews and finally a segment summarizing the results.

4.1 Literature review

From the literature review the following information was identified as relevant to address the research questions:

i. What jobs will be affected both shipboard and shore-side?
ii. Is there a need for new competencies and skills in the industry, social change and economic models?

4.1.1 What jobs will be affected?

The highest likelihood of job loss and job transformation is faced by the low and medium-skilled workers (World Maritime University, 2019). However, the jobs do not necessarily entirely disappear. Rather, many are likely to change and possibly become remote controlled from a shoreside control centers of some kind. However, it will take a long time before automation and unmanned vessels would have a significant impact on the industry. A slower and more evolutionary shift rather than a revolution is in progress.

The “Transport 2040” (World Maritime University, 2019) report notes that the development and employment of autonomous vessels will be regionally uneven wherein more developed countries further along the automation path will go deeper into the same path, sooner and reach higher levels of automation earlier. It considers the distribution of work amongst different skill levels and how they are likely to be affected. There are some points of contrast to “Transport 2040” made by Brynjolfsson and McAfee (2014) in their book “the second machine age”. It looks broadly on what has happened before and is currently happening across different fields and industries and the argument it makes is that work can be split into segments of cognitive vs manual and routine vs non-routine and perhaps this can be considered in a shipping context. This contrasts (while not contradicting) the strict segmenting of low- medium- and high-skill tiers of the Transport 2040.

Within different skill groups there are routine or non-routine tasks and cognitive or manual tasks. With this in mind automation will most likely remove the routine and often menial tasks from each of the skill-groups and allow the employee to focus more on what humans are better at compared to computers. This is more eloquently described by Moravec's Paradox (found in page 2, Introduction). How this redistributes the types of tasks between existing operators, future, newly defined actors and automation will be highly subject to the exploitation of current and future technologies.

4.1.1.1 On board personnel

In autonomous and unmanned vessel concepts there are several crewing systems that could be appropriate for different types of operations or trades that different vessels are employed in(Burmeister et al., 2014; Ghaderi, 2019; KONGSBERG, 2019; LützhÖft & Oltedal, 2018) (refer to Table 6).

Table 6 Effects of automation and the source related (adapted from sources in 4.1.1.1 above)

Effect		Source
a.	**Removal the bridge and sail with only the engineering and maintenance crew on board**	Fully autonomous or remote-controlled navigational and maneuvering processes.
b.	**Reduce crew size in all departments**	By means of fully autonomous, remote-control. Dispatchable maintenance- and engineering-crews and drones. Legislation and regulations that allow decreased presences on account of advanced systems present being able to keep or improve the navigational and safe progress abilities of the vessel.
c.	**change of roles, competencies and responsibilities**	Remote-control jobs (shoreside) and jobs with supervisory functions to autonomous ships.

Paradoxically, less crewing on board may lead to increased safety if automation is employed to undertake certain navigation tasks. Examples can be taken from both sea, such as the MAXCMAS project (Queen's University Belfast, 2018; Wahlström et al., 2015) but also lessons from other domains (Awad et al., 2018; Sengupta et al., 2016). Increased safety occurs if human error is controlled or eliminated. However, a balance needs to be established between working and supervising so that the humans that do need to be present as contingencies do not become "rusty". It is important that they do not fall out of the loop of decisions that computers take and that they do not rely exclusively on the systems they are supposed to supervise(Bainbridge, 1983; Sengupta et al., 2016).

4.1.1.2 Shoreside

New jobs and operational challenges will likely be created within shoreside control or monitoring systems inside shoreside control centers. The level of automation of a ship may also differ during the progress of a mission depending on the operational parameters, such as local legislation and regulation and appropriate level of autonomy for certain types of traffic and waters. Education, training and job design (and the support towards the one conducting work) needs to keep pace with increases in automation to ensure that the shore-side personnel are properly in- or on-the-loop to deal with problems that need to be solved and to avoid deterioration of skills and overreliance on the technology (Bainbridge, 1983; Sengupta et al., 2016; Wahlström et al., 2015).

4.1.2 Will there be a need for new competencies and skills for those engaged in the shipping industry?

Most of the current literature suggests that cognitive, creative and social skills(Johns, 2018; Kantola et al., 2018; MUNIN, 2016) will play increasing roles in the competency requirements of seafarers within a vocational environment that is becoming more globally connected, networked and virtual. This could mean that emerging new jobs will require more trust, cooperation and relationship building skills than before. Furthermore, give the complex sociotechnical system in which the shipping industry lives, the need for cognitive abilities suitable towards problem-solving, systems-understanding and leadership will be in demand. MacKinnon and Lund (2019) classify these genre of skills (Table 7).

Table 7 Predicted changes in skill demand (MacKinnon & Lundh, 2019) adapted from the 4th Industrial Revolution(Brynjolfsson & McAfee, 2014)

Core work-related skills	Scale of skill demands in 2020	Core work-related skills	Growing skill demand 2015-2020
Complex problem solving	36 %	**Cognitive abilities**	52 %
Social skills	19 %	**Systems skills**	42 %
Process skills	18 %	**Complex problem solving**	40 %
Systems skills	17 %	**Content Skills**	40 %
Cognitive abilities	15 %	**Process skills**	39 %
Resource Management Skills	13 %	**Social skills**	37 %
Technical Skills	12 %	**Resource Management Skills**	36 %
Content Skills	10 %	**Technical Skills**	33 %
Physical Abilities	4 %	**Physical Abilities**	31 %

The most in-demand skill by 2020 is complex problem solving, expected to grow by 40% in from 2015 to 2020. This shift in skill set demands compliments the growth of digitalization and automation observed (and predicted) in many of today’s industries and vocations.

4.1.3 Social impact

Technologies such as virtual reality and augmented reality will play a larger role in workplace. Work-related interactions in a virtual space will drive the development of social skills in the workforce. Another aspect to consider is how the decreasing presence of humans in the workplace (including direct human contact) can affect workers' (Johns, 2018) mental wellbeing. This is not a new phenomena in shipping, as social isolation has been identified as a problem within international shipping. Most of the activities that seafarers identified as making them happy at home were not available to them at sea (many involved interactions and activities with families and friends, for example) (Samson & Ellis, 2019). As the levels of automation increase, the social isolation may be further impactful for those who remain onboard.

4.1.4 Economic impact

The chance for slow-steaming (which is more fuel efficient) and other optimizations increases as shore-based control centers (World Maritime University, 2019) take over certain job functions. Fuel efficiency affects both economic and environmental factors, where less fuel burnt is a dollar saved and less fuel burnt is that much less emissions into the atmosphere.
Essentially this is the definition of sustainable. Less or more efficient fuel consumption offering lower fuel cost. Less emissions per ton/KM offering a more environmentally friendly transport. Ultimately cleaner transport that offers end consumers are more environmentally conscious transport chain with reduced impact on the air they breathe and their quality of life.

Third-party employment may become more prevalent, such as call in consultants and the use of different other forms of employment such as described in an article in Forbes (Zaino, 2017), rather than the current standard forms of employment. How this could be represented in the maritime sector is that whenever a ship in any geographical location is experiencing difficulties which the SCC or redundancy systems on board is unable to solve, a nearby team of independent engineers could be deployed by means of air or sea transport. In the direct future this would be most applicable to vessel deployed along coastal waters or in short-sea traffic. It would be quite an undertaking to deploy a team to a ship adrift in the middle of the Atlantic, in the case of deep-sea. Maybe in the future there will be open sea stations that could take care of that problem.

As per the YouTube presentations, a similar point of view on the future of the economies are that they should be less focused on humans pulling the cart of the economy (although we will largely and continually be needed for the consumption of goods). Rather, have the technology to drive it and humans reaping the benefits of the advancements and developmental levels and find new jobs that automation helps to create (David Lee (TEDtalk), 2017; Ford Martin (TEDtalk), 2017; Shane Lewin (TEDxtalk), 2017).

4.2 Interviews

Each interview was held with different types of subject matter experts (see Table 5). The different interviewees were chosen to obtain a broader spectrum of input. While the questions concerned several areas as described in Chapter 3.2.2, effort was put in finding common talking points and positions of what they see in automation going forward until 2040.

4.2.1 What jobs will be affected?

The interviewees shared some similar insights into the potential factor of job loss. All of them were of the opinion that the loss of jobs did not seem immediate. The advent of highly autonomous vessels being deployed in other capacities than mostly project and experimental capacities, is roughly fifteen years away or more *“There are a lot of things that are unanswered. We will not see the answer to this in the next ten, twelve, fifteen years”* (Interviewee 3), *“with the current ships on the sea you’re looking already towards 2045”* (Interviewee 1) and in limited trades such as coastal and short-sea “*…you’ll also see in the future you will mostly see completely unmanned ships most likely only in shortsea shipping. It’s not financially sustainable to do a deep-sea vessel fully autonomous and unmanned.”* (Interviewee 3). When describing a fully autonomous vessel on deep-sea shipping respondents mentioned it to be unlikely from financial and safety-concern aspects *“It’s a big gamble if you use it in that type of shipping.”* (Interviewee 2). As far as the jobs themselves were concerned, the responses were that it would be a transformative process rather than a revolutionary one (which is in line with what was found in the literature (World Maritime University, 2019)) where a Master would still at least initially be needed *“You have to have experience as a Master of real vessels, on manned vessels.”*(Interviewee 3). In addition, certain roles such as Chief Engineers are most likely needed on SCC’s, while engineers and maintenance crew may still be needed on board for the vast majority of vessels for the purposes of cleaning, changing filters and painting the vessels according to all sources; *“It’s cheaper to have a guy going around doing small maintenance all the time rather than taking the ship out of service for a week just to paint it”* (Interviewee 2).

For example, a goal of autonomous shipping is to remove the bridge modules and conduct the operations fully autonomously or at different degrees of autonomy. With the only human interaction being from remote supervisory control systems and exception handling from a SCC when appropriate. However, at least the first generation of autonomous vessels need to progress through the different levels of automation to be allowed to perform their duties without engineering crew whenever possible. In the very first tests there are multiple sets of redundancies to cover for fears that exist in regards to a fully autonomous vessel, but it may not always be necessary to compensate so much *“…since it’s the first mover, we’ve added on a lot of extra things that you will not find on the next vessel. Extra sensors, extra this, extra that, because of the manned phase to start with” (Interviewee 3).*

The vessels are ultimately intended to be able to, if need be and regulations as well as other factors allow, operate entirely independently from human interaction during normal sailing (Interviewee 3). For higher levels of autonomous sailing especially where the bridge is removed, all shipboard roles, at least on the bridge would thus be transformed or be removed. Those functions that remain will at least initially be served from shore-side instead. Engineers and officers that are experienced in seafaring on manned ships may be employed to serve as supervisors and remote-control operators. Over time this may change to include people more freshly from Universities as they become able to produce operators that are in-tune with the systems and operations (Interviewee 2 & Interviewee 3).

However, a chief engineer has to deal with many issues in the daily work from false alarms to maintenance and emergency fixes. Therefore, ships with the current propulsion and energy technology that are deployed on longer journeys will most likely have to have an engineering crew onboard to deal with issues that arise from mechanical moving parts, saltwater and water wear, electrical issues, filters etc. Why they're required to be onboard is discussed by Interviewee 2 with the following quote, in regards to why entirely unmanned autonomous vessels may not be appropriate for deep-sea: *"…you can't fly to the middle of the Atlantic with a helicopter … it's going to take 2 weeks to chase after it with a ship".* Hence, even if the bridge is removed, it might be necessary to keep some functions manned on board. Essentially creating a scenario where different degrees of automation and unmanned are reasonable for different purposes.

Ultimately, a new set of roles will be needed such as supervisors and operators, which at least initially use personnel that have ship-board experience for on-shore jobs in the Shore Control Centers. The SCC's will house functions which could even include remote control which otherwise would have been handled on a bridge shipside. Respondent Interviewee 3 gives their view on remote control as follows: *"In the initial plans we looked at the operational phase where we agreed with authorities on a manual phase and then doing a remote phase and then a fully-autonomous phase, but the risk increased in the remote phase. So, we're going directly from manual phase to autonomous phase. There will be no master in the shore control center sitting there with levers and controlling the vessel"*. More risk and higher insurance premiums mean less reasons to pit-stop at the remote-control stage before employing the fully autonomous operations.

4.2.2 Will there be a need for new competencies and skills for those engaged in the shipping industry?

The new job functions and the transformed jobs, namely the operators, remote controllers and supervisors would possibly need less technically detailed know how (though, some functions would need to retain a high level of technical expertise such as an engineer that can be called in when necessary as given in examples from Interviewee 2 and 3 in other paragraphs) and more towards social skills for teamwork and trust between the different roles. In addition, quick decision-making skills and problem-solving skills would be needed to make sense of issues that pop up while physically removed from the problem that a person is dealing with, meaning that cognitive abilities will play an increasingly important role going forward. This is more clearly explained by the following statements from respondent:

"…definitely need to be educated as a master and have experience as a master. And also, most likely be a chief engineer in the shore control center. We think that these two are able to control a fleet of between 5-10 vessels, depending on the nature of the operation" and goes on to say that an operator would have to be *"…very qualified… also have an extra education in IT"* as well as *"they need to be able to multi-task, you need to be really good at communication because you will handle several vessels. So, you will look for a lot of the same skills as you would look for in an air-traffic controller. That's for sure"*. While highlighting language as a key point *"language is very, very important"* (Interviewee 3).

4.2.3 Social aspects

The social aspects are revealed relate to the fear for one's job and to become obsolete. There is an opportunity for companies to re-educate their employees from shipside to shore-side and use their knowledge to form a bridge between the past and the future of the work to make. Instead of off-loading employees, at least some can be found useful in alternative functions. Key factors for this have been brought up in above sections of the thesis, mentioning that rather than a loss there is likely to be a transformation of the jobs. Education needs to catch up with the developments. One respondent mentions that the Academy is falling behind and not catching up on how quickly the need for new skills arise (Interviewee 3). Shipping has historically been pre-dominantly male oriented, going forward some respondents see the mix of genders becoming closer to a 50/50 mix stating examples from the military *"in the military, they have 50/50 units with shared shower and bathrooms and those units are much better in KPI than pure male units"* (Interviewee 3).

4.2.4 Economic aspects

The respondents (Interviewee 1, Interviewee 2) discuss options that could offer fuel efficiency in a different way with less crewing or no crewing onboard, where routing and speed management is handled entirely by a system. In addition, with no salaries to think of tied to the vessel, going slower for fuel efficiency does not have to contrast salaries onboard. The advantages in having less mechanical moving parts (as electrical versus conventional allows) may offer further incentives to choose more environmentally sustainable methods for propulsion and sources for energy. Interviewee 1 also mentions investments in LNG fuel technology to manage environmental impact and long-term fuel cost savings.

According to one of the respondents the most important driver for autonomous vessels are financial ones, but also that security and safety matters highly on the agenda (which in turn can be related to economic factors) *"I think it's fair to say that the main motivation for autonomous shipping is based on financial motifs. It's to reduce costs but it's also to reduce the environmental impacts, and also increase safety"* (Interviewee 3). Adding to the furthering of the benefits beyond what was brought up before, such as the insurance-premiums being lower with autonomous vessels. Where a SCC can offer exception-handling and monitoring to fully autonomous ships in shortsea and coastal deployment, it could also for deep-sea offer a decision-support for the crew onboard and to monitor parts of the journey that could be undertaken autonomously (Interviewees 1,2 &3).

All respondents worded in different ways that shortsea would have a certain set of benefits and deep-sea may have others and the economic impacts would be different in some cases in the different applications. When mentioning on how their data gathering looked, one respondent (in a context of domestic container shipping) mentioned that *"…there have been different calculations but they think 25-30% reduction in your CAPEX, and depending on the nature of the operation you will have an OPEX reduction of everything from 15-40% depending on the need for crew onboard, which is quite substantial"* (Interviewee 3).

4.3 Summary of results

The two main research questions in this thesis are whether this emerging new socio-technical system with marine automated surface vessels will within shipping lead to a social change and an economic change, respectively. To begin, we can summarize that while highly autonomous ships sooner or later may be inevitable, they are unlikely to have a massive impact on shipping before 2040, neither from the perspective of the employees on board or the companies employing the ships. However, we will see automation appearing gradually in shipping as the change is likely to be gradual instead of revolutionary.

Each level of the skill groups low, mid and high is likely to face some form of automation of their more routine tasks, whether cognitive or manual. The groups that rely more on routine tasks may see more of their jobs being transformed or entirely automated and they may face a shrinking market for employment. Routine tasks that can be automated are very likely to be automated. This means that employees on board could to a certain extent be replaced by computers, cloud or shore control centers. It is unlikely that remote controlling will take place on any larger scale, but other tasks which demand knowledge from captains and chief engineers will be needed on shore in the SCC's to oversee, supervise and monitor. Therefore the need for captains and chief engineers will remain, as they will be needed both on sea and in the shore control centers. This is likely to prevail at least until such knowledge that is required in the SCC's can be taught by universities. Moreover, the teaching at the universities must be designed so that the students learn how to solve problems that arise on ships they may never have been on board. Future skillsets will also have to broaden into systems understanding and including cognitive abilities and social skills. New task requiring these skills will for example be created within supervision, emergency management and monitoring. As all these changes will come gradually, we will most likely see a gradual change in the socio-technical order. Shipping has for a long time been a profession that has been inherited for generations. Knowledge and skills relevant to the profession has been passed on to each new generation. This will no longer be enough, we are now seeing a change in the industry which requires higher education as it will no longer be sufficient to learn from previous generations as the difference between of what will be done and what has been done is increasing.

For the second question, if this emerging new socio-technical order will create economic change in the shipping Industry, we can conclude that with the correct application of automation of ships, both safety and security can be improved and costs can be reduced.

With reduced crew or no crew onboard the case for slow steaming can be made, salary would not be an argument to not slow steam and wouldn't have to be taken in consideration against saved fuel costs of slow steaming. The removal of a bridge unit and accommodations for crew may also save some drag and possibly build costs.

While looking into economic factors, there exists opportunities for shore control centers where companies can set these up and offer their services to several different ship owners. They can offer companies to either supervise or remote control (or both) their vessels. It's likely that a couple of ships would be needed in order to turn a profit given the advanced technology that would go in to building a center like that, as well as operating it. The chance for slow-steaming (which is more fuel efficient) and other optimizations increases as shore-based control centers(World Maritime University, 2019) take over certain job functions. Fuel efficiency affects both economic and environmental factors, where less fuel burnt is a dollar saved and less fuel burnt is that much less emissions into the atmosphere.

There are also some regulatory obstacles today when it comes to automated vessels, but in the long run the regulatory system is expected to be adapted to include automated vessels by the time they're a relevant factor.

5. Discussion

"*Transport 2040: Automation, Technology, Employment - The Future of Work*" *(World Maritime University, 2019)* states that *"economic benefits, demographic trends and safety factors are catalysts for automation".* Conversely, it can also be argued that automation can act as a catalyst for economic benefits and changes in demographic trends and as a harbinger of safety factors. Automation can provide a shift in labor by changing and creating jobs.

With each new facet or advent of technology, there are new safety considerations to make, or safety benefits to take advantage of. The question becomes, do you automate because it will give you these benefits, or did you gain a number of previously unseen benefits because you automated? It could likely be a mixture of both, the long-term consequences and benefits are hard to predict. Very few people at the advent of the industrial revolution around 1760 could probably foresee what the path they were embarking on would open the door for hundreds of years later.

This chapter will analyze the different impacts automation can have on the roles usually connected with merchant shipping, on board and where those roles would go, transform or be removed. It will also discuss the found requisite vocational and interpersonal skills important to the evolution of autonomous shipping, and the economic factors that are advantageous and disadvantageous to the evolution of automation.

5.1 The impacts on different jobs

Jobs, and their components, can be assessed by the types of skills and tasks required to complete assigned work. Broadly, this is exemplified in Figure 4. The figure does not attempt to show a detailed distribution of tasks within the role, just a general span of level of skill as per the definitions given in table 4.

The jobs that may most likely be changed or lost are those with the highest automation potential, which means the likelihood and suitability for the jobs within that group to be automated is high. The likelihood of automation is seen somewhat differently in different sources, but the largest impact is likely to land on highly routine work such as described in chapter 4.1.1. Adapting this to what the WMU (World Maritime University) mentions as low-skill and medium-skill work (traditionally viewed as per Table 4), which in their report would be the ones most likely to have a large share of their tasks automated. If we combine these two sources, we can extrapolate that routine skills most likely become a larger share of the daily tasks in the middle and low-skill tiers. However, it is likely that the industry will continue to demand shipboard personnel for the coming decades (Johns, 2018).

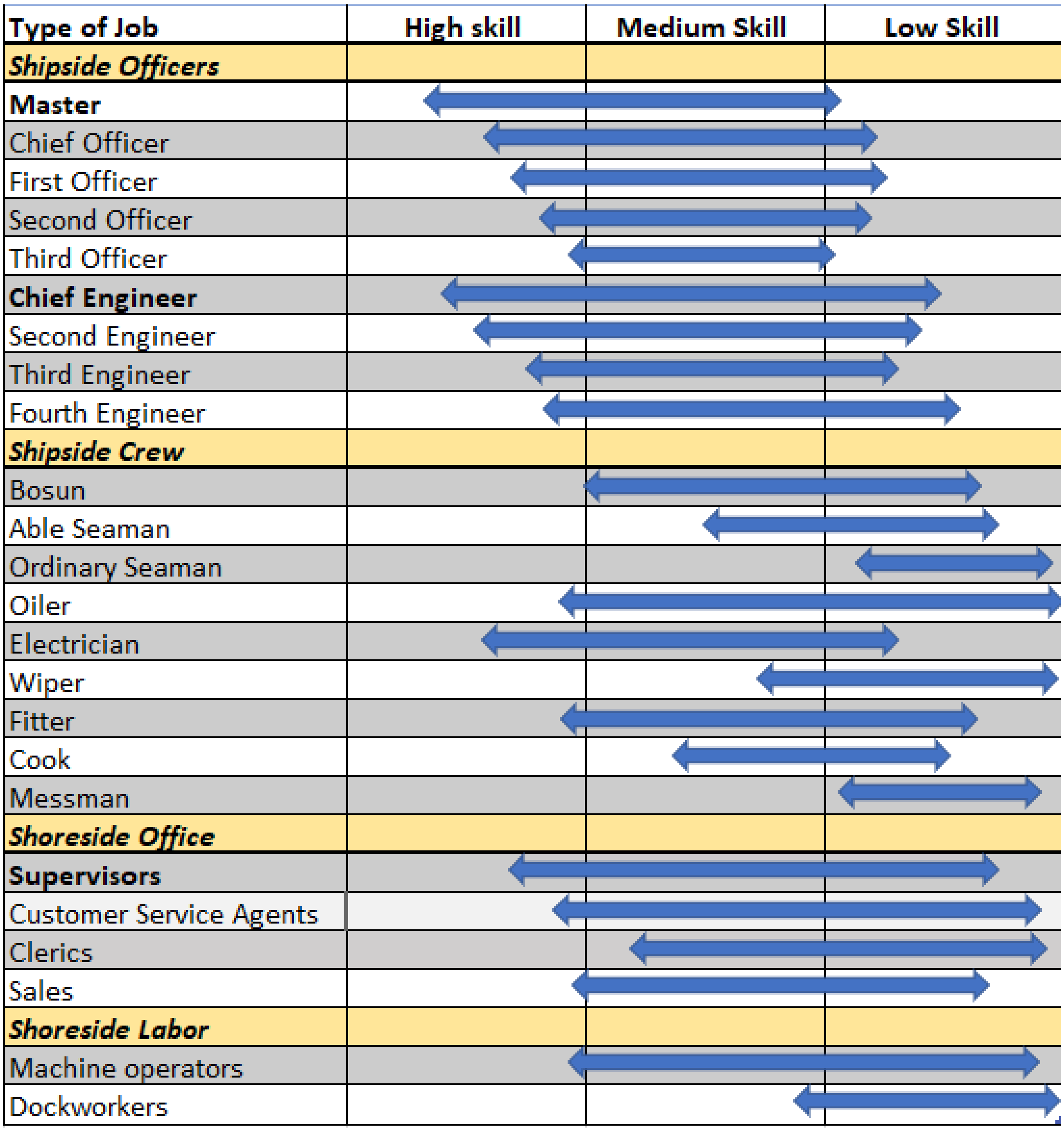


Figure 4 Typical roles in the shipping industry (on board and ashore) and a hypothetical range of the level of skills required to perform job tasks. Adapted from ILO, articles, interviews and research material (International Labour Office, 2012)

If we look at other industries, such as warehousing (see Chapter 1, p.7), we can see that some tasks are automated while others continue to remain in human hands. Some tasks change instead of being eliminated. We can also see that some tasks or jobs remain largely the same. Simple routine tasks risk being eliminated or automated, as they can be handled by a computer. The automation of routine tasks may leave more time for the employee to focus on the non-routine tasks.

While maintenance and certain such roles may be seen as lower skill tier, they’re less likely to be automated than higher skill roles on the bridge (see literature review and interview review in this thesis Ch. 4.1.1 & 4.2.1) as navigational duties may largely be switched to automated systems and the shore control center is to be used in a supervisory capacity in a vast range of tasks including non-technical decision making, such as deciding what issues to prioritize.

All in all, for seafarers in the period under consideration, 2019-2040, the demand for seafarers is increasing in absolute numbers. While the increase is slowed down somewhat by highly automated ships beginning to deploy on the seaborne trade (World Maritime University, 2019), an ICS study finds that there will be a lack of seafarers the upcoming decade (Johns, 2018); and that the demand will outpace supply. These data are reinforcing that the implementation of highly automated ships into the merchant fleet will have a limited impact on employment of seafarers within the nearest future.

5.2 The skills needed in the future workforce

As different levels of automation emerge and evolve, current roles will either change or new roles will emerge, and the vessel will become part of a larger socio-technical system. The skills needed to handle them are also likely to change. Going forward it looks to be social (including leadership), (Kantola et al., 2018) and cognitive skills such as creativity (Johns, 2018; World Maritime University, 2019) which will be desired (see table 7). These suggestions are also in line with Section 5.1, which says that medium and low-skilled labor are the ones at the highest risk of automation, whereas cognitive and social abilities largely relate to the domains of the higher skilled groups. However, the terms low-medium-high skill is a bit limiting and could benefit from being taken into context and in comparison with findings from “The Second Machine Age”(Brynjolfsson & McAfee, 2014), where the routine vs nonroutine tasks can be examined.

There are those in the middle-skilled group who can be retrained or further educated and thus retained and transferred to more advanced work. This is positive from several aspects, among other things because in this way you can benefit from their experiences and skills. A part could possibly also be relieved of their tasks or join the lower skilled group. The largest skill- and educational-distance to the high-skill group exists for the lower skilled group which would practically have to try and jump two steps up (in skill and education) to join the highly-skilled group. While not impossible, this is unlikely to happen as it is very difficult to facilitate.

Automation currently happens very quickly, and that avenues right now not facing the risk of automation, such as medicine, may very well be automated in the future. As an example, by the time someone who embarks on a journey to become a medical professional graduates, they may find themselves challenged or their profession wildly changed as the profession gradually becomes more automated (David Lee (TEDtalk), 2017; Shane Lewin (TEDxtalk), 2017) It’s unlikely that shipboard or land-based jobs in relation to shipping and the merchant fleet would be much different.

However, automation in itself does not have to be a negative thing, as automation often removes the overhead monotonous and menial tasks. It should perhaps not be considered a zero-sum game. Opportunity exists for new jobs to materialize and for the development of further advancement of the industry. A comparison can be drawn between the agricultural industry moving from providing about 40% of the employment possibilities to today accounting for approximately 2%, and at the same time, we today have jobs such as software engineers, astronauts, robotics supervisors, mechanical engineers and astrophysicists.

In addition, the trends found in the book “The Second Machine Age”, considered in the light of the chapters 5.1, 4.1.1, 4.1.2, certainly seems to aim at jobs becoming more non-routine and requiring more cognitive skills (example, farmer vs software engineer). That data is hence in line with Table 7 which has the cognitive and social skills at the very top of the list of demanded skills. These could be considered to more commonly belong in the realm of non-routine tasks rather than routine tasks. To use examples in the shipping realm, from manual navigational control and manual watchkeeping, to exception handling and monitoring of systems.

5.3 Safety of navigation and keeping up with the regulations

Even if legal requirements and regulations are not among the main issues in this report, it cannot be completely avoided. Legal requirements and regulations govern the development.

Regulations do not currently address the needs of a future industry including autonomous vessels, this is something that the IMO are currently working on to implement into their instruments (International Maritime Organization, 2018). An example of how regulations that currently exist can be a hurdle is the Yara Birkeland, who due to the complexity of regulations will need to start out manned in a verification program with the local maritime authorities (she is employed in Norwegian waters), to allow the intended fully autonomous and continuously unmanned (including the machine room in this case) operations.
The COLREGs are also a point that has previously been considered to possibly be in the way of smooth implementation of highly automated ships. However, a project known as “MAXCMAS” has found that an automated system could employ the COLREGs as safely if not better than a normal bridge-crew, by having this system “behavior” assessed in a way that is the same as they would a human (I.R., 2018; MAREX, 2018; Queen's University Belfast, 2018).

Continuing on the note of safe navigation, other projects (MUNIN, 2016), were also looking at the autonomous functions as a tool to reach higher safety of navigation. In a segment of industry where the human error factor can account for 64% to as high as 96% (Burmeister et al., 2014) of the accidents this is an highly interesting factor to reduce. Several more common reasons that could benefit greatly from greater levels of automations are such as fatigue, inadequate communication, poor design of the automation functions that the humans interact with, poor decision-making on the human’s part etc. With this factor reduced or eliminated, costs can be mitigated or avoided in social, economic and environmental spheres.

An aspect with systems that present some issues is that, as implied above, the human-system interaction part. The extent of the systems capabilities and their potential flaws need also be realized, so as to not induce over-reliance, systems complacency, lack of situation awareness, etc. (Pazouki et al., 2018; Sengupta et al., 2016; Wahlströma, Hakulinenb, Karvonena, & Lindborg, 2015) as well as the need to for any human intervention to be done, the human benefits of proper information for their decision-making (Mercer et al., 2016). Hence, rather that the human and the system help each other be better in those situations. A human can be, and arguably should be, kept maintaining some roles for supervision such as exception handling and similar functions. This consideration should also contain the knowledge that a human that does not hone their skills (by training, practice, hands-on) will start to have their skill degrade over time.

5.4 Economic and environmental factors concerning automation

5.4.1 Economic factors

Economic factors to consider exist in both the production of a ship capable of automation, as well as in the operation thereof. Building a highly autonomous ship is costly, which the MUNIN project(MUNIN, 2016) (a Handymax Dry Bulker) gives some insight into . Things that can cause it to be more expensive initially are such things as the redundancies and extra supporting structure. On the other hand, if it's entirely autonomous and reduced crewing or unmanned, the crew costs would be cheaper.

The sophisticated systems onboard would also allow greater fuel optimization and efficiency, judging from the tests run by the project. While conventional ships can also take advantage of some of the fuel efficiency approaches that an autonomous vessel have, the implementation and operation would be easier for a highly autonomous ship.

With reduced crew or no crew onboard the case for slow steaming can be made, salary would not be an argument to not slow steam and wouldn't have to be taken in consideration against saved fuel costs of slow steaming. The removal of a bridge unit and accommodations for crew may also save some drag, in the case of the small Yara Birkeland that would only be expected to account for a few percentages (but the interviewee had no direct numbers or percentages as it has not been deployed yet) where on a larger ship it may matter more. At any rate those few percentages can translate to a lot of money and emissions saved over time.

While looking into economic factors, there exists opportunities for work in Shore Control Centers where companies can set these up and offer their services to several different ship owners. They can offer companies to either supervise or remote control (or both) their vessels. It's likely that a couple of ships would be needed in order to turn a profit given the advanced technology that would go in to building a center like that, as well as operating it. The interviews let us understand that three vessels or so in one SCC were needed to turn a profit. This would further be depending on type of contract and service as well as operations needed for the ship from the hiring companies. The center would need to expand as there exists a limit to how many vessels one person can deal with at any given time, with a mix of undertakings that limit was seen as somewhere around 8-10.

As the interviews have let us in on, the fully autonomous vessels deployed where they are most appropriate (coastal and short-sea trade) offer a reduction in costs both CAPEX and OPEX, with the insurance premiums being lower for the fully autonomous vessels where only exception handling and monitoring is done by a SCC. However, the advent of such highly autonomous ships to be used as anything more than project and experimental deployments remains far in the future. Somewhere between 2035 and 2045 according to the interviewees (see 4.2).

5.4.2 Environmental factors

Consideration for our environment is today an element that cannot be overlooked in the development of future ships. What can be gleaned from the reports and from the above segment is that some economic benefits are coupled with fuel efficiency. Interestingly enough the Yara Birkeland is using systems that are considered ”greener” (more environmentally friendly than conventional sources of energy) overall, the electric battery. Another project, which may be further away from being realized, but that is aimed at a bigger context of inter-European shortsea trade is the SeaShuttle project (Samskip, 2018) which is also going to be autonomous vessels that are intended to use hydrogen fuel cells instead of conventional sources for propulsion power. While fuel efficiency in itself is a step towards environmental benefits, changing to a ”greener” source seems to be a part of the goal when designing autonomous ships.

The reason why larger ships on longer journeys aren’t too likely to use groundbreaking green technology for their propulsion, is simply that the energy density of many greener solutions is low. The sources generally lack the energy density to provide safe amount of energy to allow a large and heavy ship to transport itself with cargo from point A to point B over great distances. However, fuel cells in shortsea and perhaps nuclear reactor options for deep sea could spell that at least a mixture of energy sources could be possible in the future. By 2040 however, these vessels will, if present at all, likely be few.

5.5 Summarizing the research questions

Both shipboard and onshore jobs will be affected but in different ways. The jobs within the medium- and low-skilled tiers face the highest risk of automation, while jobs in the higher tier may also face automation, but this is not expected to be as significant by 2040.
The type of effect on jobs is more likely to be a transformation than a revolution, and transfer of jobs instead of a complete removal of jobs (although some jobs may be removed too). However, within the nearest decades this is not expected to make a huge impact on total amount of seafarers onboard vessels, as they are likely to still be in larger demand than supply in the nearest decade.

In a report by the WMU looking towards 2040, (World Maritime University, 2019) it is mentioned that conventional ships most likely won’t be replaced by highly autonomous vessels in any significant capacity by 2040, a view that was also held as likely by the respondents in interviews.

The change and transformation of jobs needs to be considered, and the skills that are poised to be in highest demand and mentioned most often are related to the social and cognitive domain, with complex problem solving, systems thinking, and social skills being particularly attractive.

Those employed in the current era and those that are remaining by 2040, which may have seafaring as a “family-job” which generation after generation undertakes might need to think ahead. These who get their children around the time this thesis is released may need to consider how to best prepare their children for the changes that may come and are currently under way. It is not certain that their offspring will be able to find the same type of job when they come of age. While things may not change dramatically by 2040, there are no certainties for what lays in store after. However, most indicators point to that a large amount of jobs will remain the same for the nearest foreseeable future as far as long distance, deep-sea ships, are concerned which will continue to be a source for employment of those types of employees.

The future economic impacts, with the autonomous projects MUNIN, SeaShuttle and Yara as guidance, look to afford an economic considerations that benefits from sustainable improvements (slow steaming and fuel efficiency to save on both environment and wallet). The newer projects (SeaShuttle and Yara) are additionally looking to employ greener propulsion energy sources, where the SeaShuttle has an outspoken aim for the ”green shipping” category by employing fuel cells and Yara is using battery power.

5.6 Future research: important aspects

Future research should go into depth and numbers of the innovational and technical projects mentioned within this thesis such as SeaShuttle and Yara, especially research with more resources and time that may be able to conduct a case study to compare these endeavors to conventional ones – with the added advantage of them possibly being deployed and having data available that doesn’t exist yet. A couple of examples comes to mind, where the fuel saving by slow steaming could be explored and put in contrast in real numbers. An especially interesting case lies in the in the cases which will be going through several different levels of automation and manning. Comparing the early stages with manning and a bridge module to the late stage where the ships are autonomous or (and) remote controlled with the bridge module removed can offer insights that will be valuable when considering building larger sized ships.

6. Conclusion

This thesis set out to explore a time frame of 2019 to 2040 within a certain set framework consisting of a number of research questions (as per chapter 1.2) relating to the shipping industry. More specifically, the maritime autonomous surface ships. In order to achieve this an extensive search into existing literature (both shipping and transport related but also from other domains) was made coupled with interviews conducted with subject matter experts from different realms within the shipping industry as well as taking in lessons from other domains, much of it the tech industry.

One of the questions this thesis address is if this emerging new socio-technical order will create societal change in the shipping industry. The answer to this is that the automation of ships is likely to affect those who work onshore and offshore in more ways than one. But this will take time. Today there exists fears of losing one’s job regardless of skill tier when automation is mentioned, however, this study shows that in the nearest decades, the total demand for the seafarer demand is likely to increase and stay above supply, which has been the normal situation the recent years. However, some jobs may change as routine tasks face automation. Social and cognitive skills are expected to be more attractive in an employee going forward than the directly technical skills.

The overarching theme is that technology for highly autonomous ships is developing and intended to be deployed within the timeframe, and that while low- and medium-skill tiers (see table 4) are at the highest current risk, there is not necessarily any job that is entirely ”safe” from automation. Current seafarers that has seafaring as a family trade may want to consider how to best prepare their children for the future, if they get children in the near future. By 2040 however, while some changes likely will happen, most of the merchant fleet, in terms of autonomous operation on any greater scale, will probably remain largely unchanged. One needs to keep in mind that little empirical evidence as this technology is not yet deployed. There are possibly unforeseen advantages found from the success of the deployed projects which could cause the industry to speed up on automation. The current projects look to be underway or fully deployed by 2022 with Yara and an unknown date for SeaShuttle, but once they are up and running it should be possibility to gain more real-world data on what needs extra attention and research.

The second research question this thesis address is whether this emerging new socio-technical order create economic change in the shipping industry. An important element to understand this is that the change is expected to be evolutionary rather than revolutionary, which means that it will be a gradual change instead of a radical one. The change also facilitates some room for the higher level of automation vessels to employ more sustainable methods and sources for propulsion, which has been a troublesome gap to address (shipping endeavors to be sustainable transport but which uses massive amounts of fuel) and may look to be able to somewhat close over the time of the further development and implementation of highly autonomous ships. The fuel efficiency related approaches gain a simplified procedure to be implemented in these types of ships. The ships type could benefit from less moving parts and thus also from alternative types of propulsion or energy sources, especially if unmanned. This could facilitate for greener options that use energy which doesn't require combustion. At the moment those types of energy sources are somewhat lacking in energy density which limits their usefulness making them unlikely to be employed widely by 2040.

Finally, describing and looking into the future is a difficult matter, as there may be disruptive technologies that were unseen that pop up, or that something external appears that may change how the development proceeds, hence the focus was laid on what we can see and reasonably expect from the data that exists and those projects as well as information from the industry to extrapolate a sensible and balanced expectation. Today, there are problems with legal requirements, which may not over time be insurmountable problems. But even though legal requirements may not be that much of a problem when the development is complete and the ships begin their autonomous voyages on a significant scale, other issues or opportunities may arise.

Technological development is something that constantly takes place in human society. The shipping industry is not different in this regard and faces the possibly greatest change in a long time with automation.

7. References

Awad, E., Levine, S., Kleiman-Weiner, M., Dsouza, S., Tenenbaum, J. B., Shariff, A., . . . Rahwan, I. (2018). Blaming humans in autonomous vehicle accidents: Shared responsibility across levels of automation. In.

Bainbridge, L. (1983). Ironies of Automation. *Automatica*(6), 775. Retrieved from http://proxy.lib.chalmers.se/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edsggo&AN=edsgcl.577362&site=eds-live&scope=site

Brynjolfsson, E., & McAfee, A. (2014). *The second machine age : work, progress, and prosperity in a time of brilliant technologies*: W. W. Norton & Company.

Burmeister, H.-C., Bruhn, W. C., Rødseth, Ø. J., & Porathe, T. (2014). *Can unmanned ships improve navigational safety?* Transport Research Arena 2014: Transport Research Arena 2014.

Caitlin McGarry. (2019, July 10, 2019). AT6T 5G Speed Tests: Blazing Fast But Elusive in Las Vegas. Retrieved from https://www.tomsguide.com/news/atandt-5g-speed-tests-blazing-fast-but-elusive-in-las-vegas

Clark, G. (2014). Chapter 5 - The Industrial Revolution. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of Economic Growth* (Vol. 2, pp. 217-262): Elsevier.

CMA CGM. (2019). 5G: CMA CGM at the Forefront of the New Shipping Revolution. Retrieved from https://www.cmacgm-group.com/en/news-medias/5G-CMA-CGM-at-the-Forefront-of-the-New-Shipping-Revolution

Conceicao, V., Carmo, B., Dahlman, J., & Navarro, A. (2017). *Visualization in Maritime Navigation: A Critical Review.* Paper presented at the 8th International Conference on Applied Human Factors and Ergonomics, Los Angeles, USA.

Coşar, A. K., & Demir, B. (2018). Shipping inside the box: Containerization and trade. *Journal of International Economics, 114*, 331-345. doi:10.1016/j.jinteco.2018.07.008

David Lee (TEDtalk) (Producer). (2017). Why jobs of the future won't feel like work Retrieved from https://youtu.be/B905LapVP7I?

Dubois, A., & Gadde, L.-E. (2002). Systematic combining: an abductive approach to case research. *Journal of Business Research*(7), 553. Retrieved from http://proxy.lib.chalmers.se/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edsgao&AN=edsgcl.102101793&site=eds-live&scope=site

Eriksson, G. (2020). *FRAMTIDENS BEHOV AV KVALIFICERAD SJÖFARTSKOMPETENS*. Retrieved from transportforetagen.se:

Ford Martin (TEDtalk). (2017). How we'll earn money in a future without jobs. In. youtube.com: TED.

Fosen, J. (2019). Maritime autonomous surface ships on the horizon. Retrieved from http://www.gard.no/web/updates/content/27107214/maritime-autonomous-surface-ships-on-the-horizon

Gartner. (2019a). Digitalization. Retrieved from https://www.gartner.com/it-glossary/digitalization/

Gartner. (2019b). Digitization. Retrieved from https://www.gartner.com/it-glossary/digitization/

Ghaderi, H. (2019). Autonomous technologies in short sea shipping: trends, feasibility and implications. *Transport Reviews, 39*(1), 152-173. doi:10.1080/01441647.2018.1502834

Gratz, G., & Michaels, G. (2015). Robots at Work. *CEP Discussion Paper*(1335). Retrieved from http://cep.lse.ac.uk/pubs/download/dp1335.pdf

Howse, T. (2019). Maritime autonomous surface ships – identifying and covering the risks Retrieved from http://www.gard.no/web/updates/content/27188643/maritime-autonomous-surface-ships-identifying-and-covering-the-risks

I.R., S. (2018). Codifying Good Seamanship into Machine Executable Rules *The International Journal on Marine Navigation and Safety of Sea Transportation 12*(2). doi:10.12716/1001.12.02.14

Insurance Marine News. (2018). Autonomous ships – zooming in on liability and insurance. Retrieved from https://insurancemarinenews.com/insurance-marine-news/autonomous-ships-zooming-in-on-liability-and-insurance/

International Labour Office. (2012). International Standard Classification of Occupations, ISCO 08. In. Geneva.

International Maritime Organization. (2003). *COLREG : Convention on the international regulations for preventing collisions at sea, 1972* (Consolidated ed. 2003 ed.): International Maritime Organization.

International maritime Organization. (2011, 2019). International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978 Retrieved from http://www.imo.org/en/OurWork/HumanElement/TrainingCertification/Pages/STCW-Convention.aspx

International Maritime Organization. (2018). IMO takes first steps to address autonomous ships. Retrieved from http://www.imo.org/en/MediaCentre/PressBriefings/Pages/08-MSC-99-MASS-scoping.aspx

International Maritime Organization. (2019). In Focus: Autonomous shipping. Retrieved from http://www.imo.org/en/MediaCentre/HotTopics/Pages/Autonomous-shipping.aspx

Irniger, A. (2017). Difference between Digitization, Digitalization and Digital Transformation. Retrieved from https://www.coresystems.net/blog/difference-between-digitization-digitalization-and-digital-transformation

Johns, M. (2018). *Seafarers and digital disruption*. Retrieved from Hamburg / London,:

Kantola, J. I., Barath, T., & Nazir, S. (2018). *Advances in Human Factors, Business Management and Leadership. [electronic resource] : Proceedings of the AHFE 2017 International Conferences on Human Factors in Management and Leadership, and Business Management and Society, July 17–21, 2017, The Westin Bonaventure Hotel, Los Angeles, California, USA*: Springer International Publishing.

KONGSBERG. (2019, 2019). Autonomous ship project, key facts about YARA Birkeland. Retrieved from https://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument

Laughton, M. A., & Warne, D. F. (2007). 15.4.9 Microprocessors. In: Elsevier.
Laurinen, M. (2016). Remote and autonomous ships: The next steps. *Advanced Autonomous Waterborne Application Partnership, Buckingham Gate, London*.
Levinson, M. (2016). *The Box : How the Shipping Container Made the World Smaller and the World Economy Bigger - Second Edition with a New Chapter by the Author* (Vol. Second edition). Princeton, New Jersey: Princeton University Press.
Lloyd's Register. (2017a). Cyber-enabled ships ShipRight procedure assignment for cyber descriptive notes for autonomous & remote access ships. In: LLoyd's Register.
Lloyd's Register. (2017b). *Design Code for Unmanned Marine Systems*. Retrieved from
LützhÖft, M., & Oltedal, H. (2018). *Managing maritime safety*. Routledge: Routledge.
MacKinnon, S. N., & Lundh, L. M. (2019). *Research Requirements to Address Gaps in Regulations, Pedagogic Needs and Human/Automation Interactions in the Shipping Industry*. Retrieved from lighthouse.nu: https://www.lighthouse.nu/sites/www.lighthouse.nu/files/autonomy_webb_slutversion_0.pdf
MAREX. (2018). Autonomous Ships Can Use COLREGs Effectively Retrieved from https://www.maritime-executive.com/article/autonomous-ships-can-use-colreg-rules-effectively
McGarry, C. (2019). What is 5G? The Definitive Guide to the 5G Network Rollout. Retrieved from https://www.tomsguide.com/us/5g-release-date,review-5063.html
Mercer, J., Gomez, A., Gabets, C., Bienert, N., Edwards, T., Martin, L., . . . Homola, J. (2016). Impact of Automation Support on the Conflict Resolution Task in a Human-in-the-Loop Air Traffic Control Simulation. *49*(19), 36-41. doi:10.1016/j.ifacol.2016.10.458
Miles, J., & Gilbert, P. (2005). *A Handbook of Research Methods for Clinical and Health Psychology*: Oxford University Press.
Moher D, L. A., Tetzlaff J, Altman DG,. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ, 339*, b2535.
Moravec, H. (1988). *Mind children : the future of robot and human intelligence*: Harvard University Press.
MUNIN. (2016). MUNIN: Maritime Unmanned Navigation through Intelligence in Networks. Retrieved from http://www.unmanned-ship.org/munin/about/munin-results-2/
Neumann, T., & Weintrit, A. (2013). *Marine Navigation and Safety of Sea Transportation : STCW, Maritime Education and Training (MET), Human Resources and Crew Manning, Maritime Policy, Logistics and Economic Matters*. Boca Raton: CRC Press.
Norwegian Forum for Autonomous Ships. (2017). *Definitions for Autonomous Merchant Ships*. http://nfas.autonomous-ship.org/. Retrieved from http://nfas.autonomous-ship.org/resources/autonom-defs.pdf
Our World in Data. (2018). transistors per microprocessor. Retrieved from https://ourworldindata.org/grapher/transistors-per-microprocessor?time=1971..2017

Pasmore, W., Winby, S., Mohrman, S. A., & Vanasse, R. (2019). Reflections: Sociotechnical Systems Design and Organization Change. *Journal of Change Management, 19*(2), 67-85. doi:10.1080/14697017.2018.1553761

Pazouki, K., Forbes, N., Norman, R. A., & Woodward, M. D. (2018). Investigation on the impact of human-automation interaction in maritime operations. *Ocean Engineering, 153*, 297-304. doi:10.1016/j.oceaneng.2018.01.103

Prause, J. (2016). Digitization vs. Digitalization – Wordplay or World View? Retrieved from https://news.sap.com/2016/05/digitization-vs-digitalization-wordplay-or-world-view/

Queen's University Belfast. (2018). *MAXCMAS project: Autonomous COLREGs compliant ship navigation.* Paper presented at the 16th Conference on Computer Applications and Information Technology in the MaritimeIndustries (COMPIT) 2017.

Reese, B. (2018). *The Fourth Age: Smart Robots, Conscious Computers, and the Future of Humanity*: Atria Books.

Samskip. (2018). Samskip leads the way for Norway's next generation of sustainable shortsea shipping. Retrieved from http://www.samskipmultimodal.com/news/press-release-1

Samson, H., & Ellis, N. (2019). *Seafarers' mental health and wellbeing*. Retrieved from Seafarers International Research Centre: https://www.sirc.cf.ac.uk/SIRC_free_online_reports.aspx

Sengupta, S., Donekal, A. K., & Mathur, A. R. (2016). Automation in Modern Airplanes - A Safety and Human Factors Based Study. *INCOSE International Symposium, 26*(s1), 386-394. doi:10.1002/j.2334-5837.2016.00339.x

Shane Lewin (TEDxtalk) (Producer). (2017). How AI and automation are changing our relationship with work Retrieved from https://youtu.be/cRiuEvZDMiY?

Ship-technology.com. (2017). YARA Birkeland Autonomous Container Vessel. Retrieved from https://www.ship-technology.com/projects/yara-birkeland-autonomous-container-vessel/

Sonderstrup, P. (2017). Autonomous ships on IMO agenda Retrieved from https://www.dma.dk/Presse/Nyheder/Sider/Autonomous-ships-on-IMO-agenda.aspx#

Stephens, R. (2015). Robots at work: The economic effects of workplace automation. *Journals's Resource*. Retrieved from https://journalistsresource.org/studies/economics/jobs/robots-at-work-the-economics-effects-of-workplace-automation/

Taylor, F. W. (1911). *The principles of scientific management*: Harper & Brother.

Trist, E. L., & Bamforth, K. W. (1951). Some Social and Psychological Consequences of the Longwall Method of Coal-Getting:An Examination of the Psychological Situation and Defences of a Work Group in Relation to the Social Structure and Technological Content of the Work System. *Human Relations, 4*(1), 3-38. doi:10.1177/001872675100400101

Wahlström, M., Hakulinen, J., Karvonen, H., & Lindborg, I. (2015). Human Factors Challenges in Unmanned Ship Operations – Insights from Other Domains. *6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015)* *and the Affiliated Conferences, AHFE 2015, 3*, 1038-1045. doi:10.1016/j.promfg.2015.07.167

Wahlströma, M., Hakulinenb, J., Karvonena, H., & Lindborg, I. (2015). *Human factors challenges in unmanned ship operations – insights from other domains*. Retrieved from 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015,:

World Maritime University. (2019). *Transport 2040: Automation, Technology, Employment - The Future of Work*. Retrieved from Malmö:

Zaino, G. (2017, May 2, 2017). The Impact of Automation on the Independent Workforce. *Forbes*. Retrieved from https://www.forbes.com/sites/forbeshumanresourcescouncil/2017/05/02/the-impact-of-automation-on-the-independent-workforce/

Appendix

Definitions

Digitization vs Digitalization

Certain aspects of seafaring can be considered as digitized while other aspects are entirely digitalized.
The difference between these is as follows.

Digitization: is when changes from an analogue form into a digital one are made, for example when sea-charts are exchanged from physical form into electronic sea-charts that you use on a screen. (Gartner, 2019b).
A user works *with* the digitized tools, essentially in the same way as the original purpose.

Digitalization: is when digital technologies are used to change the way operations are conducted. In short, the use of various digitized tools in order to, as an example, simplify the processes (Gartner, 2019a).
The tools can be used to work *for* the user.

From sap.com the following example is made:" if I scan a document, I digitize it. But I would digitalize a factory". (Prause, 2016)
Similarly, while functions can be digitized to e.g. use a digital interface, the greater supply chain can also be digitalized.
In digital transformation (Irniger, 2017) the automation of vessels to different degrees becomes part of the journey to more fully automated supply chains.

Literature overview

Item	Author	Year	Category	Title	Place of Publication
I	Awad, Levine, Kleiman-Weiner, Dsouza, Tenenbaum, Shariff, Bonnefon and Rahwan	2018	Human factors, Safety, Automation	Blaming humans in autonomous vehicle accidents: Shared responsibility across levels of automation	eprint arXiv:1803.07170, Cornell University
II	Bainbridge	1983	Automation, Technical, Human-	Ironies of Automation	Automatica, vol 19, no 6, pp.775-779

			System interaction		
III	Burmeister, Bruhn, Rødseth and Porathe	2014	Navigational Safety, Economic, Environmental, Human error	Can Unmanned Ships Improve Navigational Safety?	Transport Research Arena
IV	Burmeister, Bruhn, Rodseth and Porathe	2014	Safety of Navigation, Regulations, Human-system interaction, Economy	Autonomous Unmanned Merchant Vessel and its Contribution towards the e-Navigation Implementation: The MUNIN Perspective	International Journal of e-Navigation and Maritime Economy
V	Efficensea	2011	Skills, Education	Efficient, safe and sustainable traffic at sea: Current state and future educational needs within the maritime sector	Efficensea.org
VI	Ghaderi	2019	Automation, Economic, Regulatory, Technical	Autonomous technologies in short sea shipping: trends, feasibility and implications	Transport Reviews, Volume 39
VII	Graetz and Michaels	2015	Robotics, Automation, Technical, Workforce, Employment,	Robots at Work	CEP Discussion Paper
VIII	International Maritime Organization	2018	Regulations, Navigational safety,	Regulatory Scoping Exercise for the use of Maritime Autonomous Surface Ships	Maritime Safety Committee, IMO

IX	Johns	2018	Technical, Automation, Human-System Interaction, Economic, Regulations	Seafarers and digital disruption	International Chamber of Shipping, Hamburg School of Business Administration
X	Jokioinen	2016	Technical, Regulations, Safety,	Remote and autonomous ships: The next steps	Advanced Autonomous Waterborne Application Partnership, Buckingham Gate, London
XI	Kantola, Nazir, Barath	2018	Human Factors, Automation,	Advances in Human Factors, Business Management and Society	Springer, Proceedings of the AHFE 2018 International Conference on Human Factors, Business Management and Society, July 21–25, 2018, Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA
XII	KONGSBERG	2019	Automation	Autonomous ship project, key facts about YARA Birkeland	Company Website: km.kongsberg.com
XIII	Liu, Negenborn, Chu and Zheng	2017	Technical, (Autonomous Applications)	Predictive path following based on adaptive line-of-sight for underactuated autonomous surface vessels	Springer

XIV	Lloyd’s Register,	2017	Technical,	Cyber-enabled ships ShipRight procedure assignment for cyber descriptive notes for autonomous & remote access ships	Lloyd’s Register
XV	Lützhöft and Oltedal	2018	Safety, Environmental, Human factors, Automation	Managing maritime safety	Routledge
XVI	MAREX	2018	Regulations, Safety, Automation	Autonomous Ships Can Use COLREGs Effectively	Maritime-Executive.com
XVII	Mercer, Gomez, Gabets, Bienert, Edwards, Martin, Gujral and Homola	2016	Automation, Human-System Interaction, Safety	Impact of Automation Support on the Conflict Resolution Task in a Human-in-the-Loop Air Traffic Control Simulation	NASA Ames Research Center
XVIII	MUNIN	2016	Economic, Technical, Skill, Safety, Human Error, Regulations, Fuel Efficiency (Environmental)	Research in maritime autonomous systems project results and technology potentials	Maritime Unmanned navigation through intelligence in networks Unmanned-ship.org/munin
XIX	Norwegian Forum for Autonomous Ships	2017	Definitions list	Definitions for Autonomous Merchant Ships	nfas.autonomous-ship.org

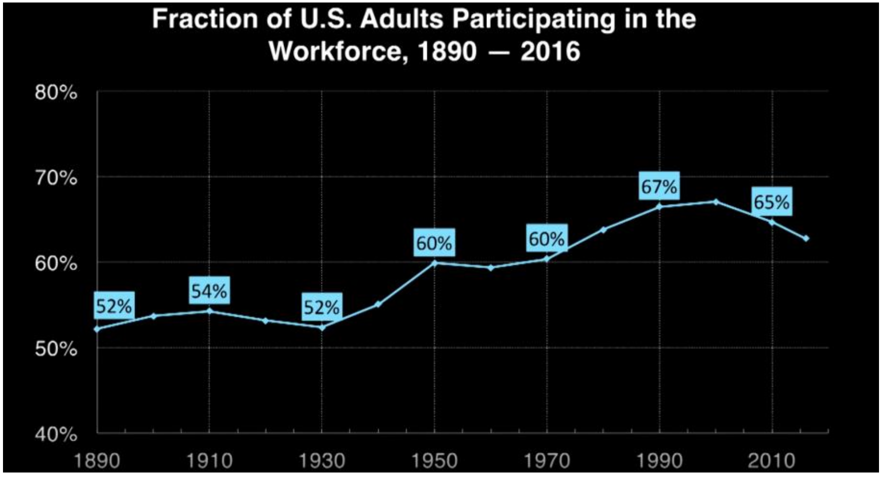
XX	Pazouki, Forbes, Norman and Woodward	2018	Safety, Technical, Human-system Interaction, Economic, Human Error	Investigation on the impact of human-automation interaction in maritime operations	Ocean Engineering
XXI	Queen’s University Belfast	2018	Regulations, Navigational safety,	MAXCMAS project: Autonomous COLREGs compliant ship navigation	16th Conference on Computer Applications and Information Technology in the Maritime Industries (COMPIT)
XXII	Salter	2018	Automation, Safety, Regulations,	Codifying Good Seamanship into Machine Executable Rules	The International Journal on Maritime Navigation and Safety of Sea Transport
XXIII	Sengupta, Donekal, and Mathur	2016	Safety, Human Factors, Human error,	Automation in Modern Airplanes – A Safety and Human Factors Based Study	INCOSE International Symposium
XXIV	Ship-technology	2017	Automation	YARA Birkeland Autonomous Container Vessel	Ship-Technology.com
XXV	Sonderstrup	2017	Automation, Regulation	Autonomous ships on IMO agenda	Danish Maritime Authority
XXVI	Stephens	2015	Automation, Robotics, Economics,	Robots at work: The economic effects of workplace automation	Journalist’s Resource

XXVII	Wahlström, Hakulinen, Karvonen and Lindborg	2015	Economic, Human Error, Technical, Human-system Interaction	Human Factors Challenges in Unmanned Ship Operations – Insights from Other Domains	6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015
XXVIII	Van den Broek, Van Diggelen, van der Kleij, Hueling, van der Was, van Schendel and Langefeld	2017	Autonomous Systems	Adaptive Maritime Automation: Final Report	TNO
XXIX	Wingrove	2019	Regulation, Automation	IMO prepares for autonomous ship regulation amendments	Marine digitalization and Communication
XXX	World Maritime University,	2019	Technical, Economic, Workforce, Employment, Skills,	Transport 2040: Automation, Technology, Employment – The Future of Work	World Maritime University Malmö
XXXI	Vries	2016	Safety, Social	Here be monsters: Investigating sociotechnical interaction in safety-critical work in the maritime domain	Chalmers University of Technology
XXXII	Zaino	2017	Economic, Social, Skills	The Impact of Automation on the Independent Workforce	Forbes

TEDTalks

Here follows the notes from the TedTalks.
David Autor (TEDxCambridge)

Title: Why Are There Still So Many Jobs? | David Autor | TEDxCambridge
Upload date: 28 nov , 2016
Website:
https://www.youtube.com/watch?v=LCxcnUrokJo&list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes:
Replacing human labour, replace inconsistent human handiwork with machined perfection. Replace human calculation by machine reliability.



Tabell 1 David Autor, TEDxCambridge. Youtube.com

Jobs remain due to human ingenuity, greed
Less like checkout clerks, more like sales and problem solvers.
More tellers doing more cognitively demanding jobs.
O-Ring principle: chain of sensitie and weak parts where yours doesn’t matter much, remove human (risk) and replace with machinery/automation to make chain more reliable.
1900: 40% on farms
today Less than 2%
A couple of percent of farmers
Never get enough principle:

➔ New services and products are created to occupy time, attention etc.

Comparison: worker of 2015 to reach same standard of living 1915 as XX work only 17 weeks out of a year. Most people want to work harder to harvest technological bounty. Material abundance does not eliminate perceived scarcity

/-Consider this: Social musts, working 17 weeks of a year and living like in the 1915s might be social inexcusable. Humans are pack animals and also aim to breed essentially, would do what's perceived as needed to increase chances of finding mate, living well, and passing on genes? When the average living standard increases, so does pressure to attain that standard or else fall out of social context and face stigma?-/
Using wealth well? Compare Norway and Saudi Arabia.
Middle skilled jobs can be easily codified by developers and put on to computers.
Shrinking size of middle class – more stratified society. Risk: Low skilled and low paid jobs, disappearing middle class, a set affluent class. Lower class becomes in practice, while not institutionally, servant class to the wealthy.
Low skill service jobs remain, middle skilled class gets automated by computers, high skilled and Technology magnifies leverage.

Augie Picado (TED)
Title: The real reason manufacturing jobs are disappearing | Augie Picado
Upload date: 28 Sep, 2017
Website:
https://youtu.be/H03o2WCBoDU?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes: Losses of Jobs due to automation.
Automation spreading to every production line in every industry and country around the world. Shareproduction simplified by automation.
Automation: Improvement in productivity. Jobs gone for good (in that shape).

Daniel Susskind (TED)
Title: 3 myths about the future of work (and why they're not true) | Daniel Susskind
Upload date: 5 apr, 2018
Website: https://youtu.be/2j00U6lUC-c?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh

Notes: "Automation anxiety".
Terminator myth: Humans being substituted by machines.
Replace yes. But also complement. New work is created around it, new tasks need to be done and new roles.
Machine substitution can harm workers but also complement workers, not hurting but helping.
Intelligence myth: Things that you think can't be automated, probably can be.
Belief have to copy humans way to think and reason. Codify human behaviour and automate that. If it's hard to explain, nonroutine and therefor out of reach for automation: Classic cases now for non routine tasks will be or are automated. Diagnosis etc. "Creativity, intuition, hunches" → routine vs non-routine distinction diminishingly useful.

Example: Pattern-recognition software to tell if a mole is cancerous or not. Un-human approach, but as accurate as a medical professional. Non-exhaustable, non-sloppy.

Superiority myth: Humans are best placed to perform new tasks (extra lump of work)
Lump of labour fallacy: is itself a fallacy LOLFF
David Schloss 1892.
Lump of work isn't fixed – lump of work will get bigger.
Likely that machines will take on the extra lump of work, not just machines complement human beings.
Future: Human beings will complement the machines. Or entirely independent.
Demand for task != demand for human labour

Tigran Petrosyan **(TEDx)**
Title: Is Your Job Safe From Automation? | Tigran Petrosyan | TEDxHochschuleLuzern
Upload date: 29 sep, 2016
Website:
https://youtu.be/bSZh8qdKaBc?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes: Advantages of machine/automation, non-cognitive bias. Extreme data handling ability. Finance, law, medical are all at risk of automation. Human resources (recruitment).
New jobs that did not exist in 2008, most popular ones 8 out of 10 belonged to the digital world. App delveoper, data scientist, social media workers.
Shows a trend. Empathy, creativity and innate human skills are needed for certain jobs, and will be unlikely to be automated at least for the nearest future.

Martin Ford **(TED)**
Title: How we'll earn money in a future without jobs | Martin Ford
Upload date: Nov 16, 2017
Website:
https://youtu.be/swB7Ivct8d8?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes: Alarm has been raised repeatedly about automation and machines causing social and economic upheaval. Lynden Johnson in 1962 got a report that claimed thus.
These alarms keep ringing and has been ringing for a long time.

Old jobs removed but new jobs created have been better paid, better type, less laborious.
Is a significant portion of the human workforce become obsolete/redundant in the future? (Like horses have)
Critical thing: machines in the future will be nothing like what has replaced horses.
Thinking, learning, adapting machines, starting to encroach on fundamental human capabilities.

1950→ 2017, 30 doublings of computation power.
IT different: Exponential increase in power and “intelligence” / cognitive abilities (learning, thinking, problem solving).
More and more jobs and tasks will be consumed that we considered safe from automation. Not just lower levels of education, these machines are rapidly climbing the skills ladders (accountants, fin. Analysis, radiologists, journalists etc)

Inequality, unemployment, lower wages? System reliant on consumers, if humans purchasing powers goes down, wages go down, then consumption goes down as they can’t afford the products. Ultimately harming the entire industry.
Rethink jobs as no longer primary driver for distribution of wealth and income?
How to solve the income distribution problem? Decouple income from traditional work. Universal basic income?
Incentives into basic income. How do we find meaning and fulfilment in a world where there is less demand for traditional work?

Anthony Goldbloom (TED)
Title: The jobs we'll lose to machines -- and the ones we won't | Anthony Goldbloom
Upload date: 31 AUG, 2016
Website:
https://youtu.be/gWmRkYsLzB4?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes: 1 in every 2 jobs have a high risk of being automated. Machine learning (most powerful artificial intelligence) is the main reason.
Machines can even grade essays by humans as well as human teachers.
A teacher can read tens of thousands of essays over a 40- year career. An eye-doctor can diagnose thousands of eyes over a career. A machine can diagnose millions of eyes, grade millions of essays, within minutes. On such thing’s humans can’t compete with computers even today in high-volume tasks.
Humans advantage is tackling novel situations, machines are better at things that have happened many times using large volumes of past data. Humans can connect seemingly disparate trends to find solutions to new problems.
Automatable: to what extent reducible to frequent high volume task and to what extent does it have to tackle novel situations?

David Autor (TED)
Title: Will automation take away all our jobs? | David Autor
Upload date: 6 FEB, 2017
Website:
https://youtu.be/th3nnEpITz0?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes: David Autor 1 .

Dani Sandu (TEDxBucharest)

Title: Technological automation can give your work a purpose | Dani Sandu | TEDxBucharest
Upload date: May 26, 2017
Website:
https://youtu.be/MCB1dr4dgPg?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes: Notes: Anecdote: Taxi driver that drives for his daughters sake to give them a better life than he had. Speaker: My dream in conflict with this man. Speakers Dream to have driver-less cars. If the speakers dream came true, no drivers, then this taxidrivers dream would not come true, as he would be left without a job. Complexity.
1st revolution: steam engine
2nd Electricity
3rd 1960 digital technology
4th AI & VR, 3d printing
What happens to the people who get left behind?
30% of the jobs in the entire western world are vulnerable to automation (approx. 200m jobs)
Think of social divide, populism, inequality and broadening gaps between the haves and have-nots. (Own note:To have and to have-not will also change, what is to be had in social context changes, and becomes increasingly unaffordable by those who were already in the have-not and by those fringing on have-not territory. Again, Servant worker and bon vivant chasm).
Marginalization is growing, and all of it is happening because “we are living in the best moment of history”. More college graduates than people living in absolute poverty.
Unconditional and universal basic income. (3rd speaker that mentions this, while others have hinted about it. “I.e let machines and computers pull the economic cart, while humans sit in it and enjoy the fruits”)
Universal income pilots has disproved that giving people money for nothing will have people do nothing. In fact, contrary effects have been seen. People focus on doing what they love, creating new businesses, creating new chances, taking part in the economy.

Other note: “Since the 1960s, the consensus among anthropologists, historians, and sociologists has been that early hunter-gatherer societies enjoyed more leisure time than is permitted by capitalist and agrarian societies;[5][6] for instance, one camp of !Kung Bushmen was estimated to work two-and-a-half days per week, at around 6 hours a day.[7] Aggregated comparisons show that on average the working day was less than five hours.[5]

Subsequent studies in the 1970s examined the Machiguenga of the Upper Amazon and the Kayapo of northern Brazil. These studies expanded the definition of work beyond purely hunting-gathering activities, but the overall average across the hunter-gatherer societies he studied was still below 4.86 hours, while the maximum was below 8 hours.[5] Popular perception is still aligned with the old academic consensus that hunter-gatherers worked far in excess of modern humans' forty-hour week.[6]”

REF: “A 13th century peasant worked 1440 hours/annum

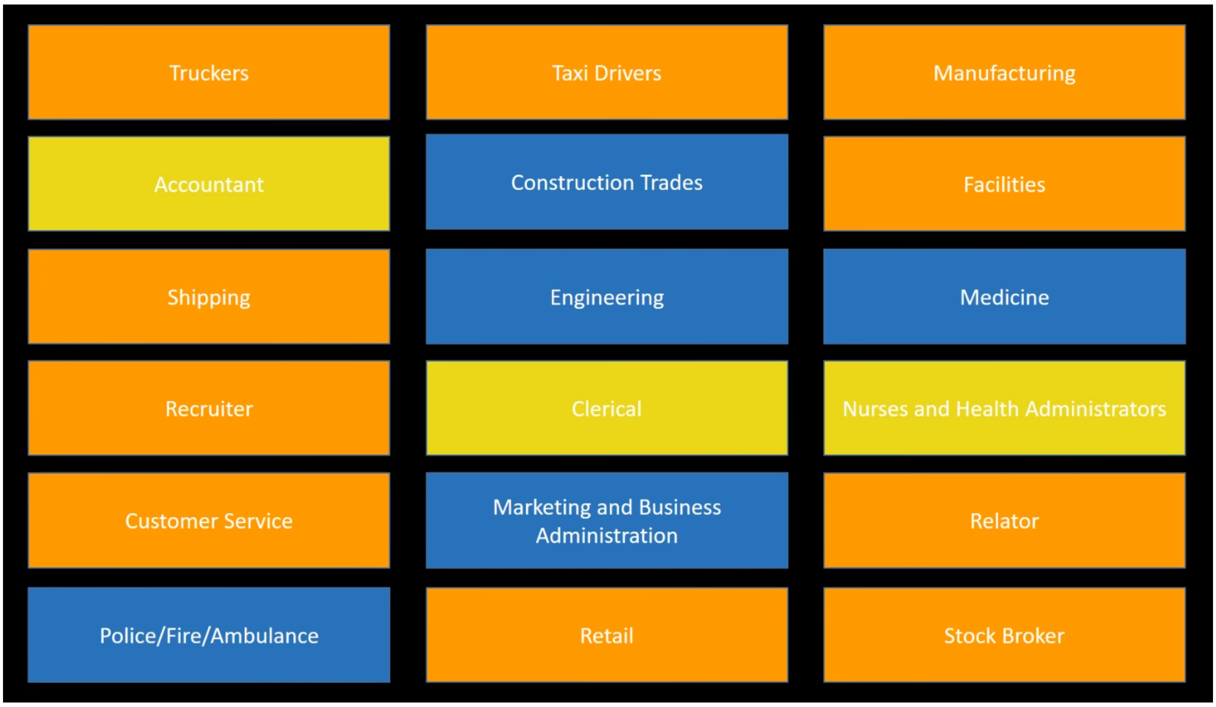
2015 average worked worked 1811 hours/annum.”

Technology doesn’t have to be a threat, we can change how we behave, and we can change how we are, and we can with technology, change the situation for those who are not lucky enough to have even seen the 3rd revolution yet.

A world where you can say: “What would you do if money was not a problem?”
No more going into jobs that they hate to gain money that are used to live a life that they don’t like.

Martin Ford (Lavin Agency Speakers Bureau)
Title: TED Speaker Martin Ford: Which Jobs Are Most Vulnerable to Automation?
Upload date: 20 may, 2016
Website: https://youtu.be/2a5rkBfkQrE
Notes: The college graduates jobs, middle-skilled, crank out same reports every cycle are not that hard to automate. But low skilled “maid, cleaner” is a science fiction thing, jobs that require dexterity are further away from automation. (plumming)
About 50% are susceptible to machine learning in most countries. That would be a staggering impact.

David Lee (TED)
Title: Why jobs of the future won't feel like work | David Lee
Upload date: Nov 3, 2017
Website:
https://youtu.be/B905LapVP7I?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes: Even smartest, highest paid people are at risk for machine learning. Anyone’s job may be done by robots or software in the next decades.
Universal basic income may be a solution.
Farm reference. Farms / Factories. Previously 100 years farm – Factory, 60 years Factory to Service. Now, we may only have ~15 years for the next shift.
Rediscover what makes us human, create new human-centered jobs.
Neither lack of talent nor ideas are the problem, it’s an empowerment problem.
Allow people to be anything they wanted and they will bing all kinds of skills and talents to the problems they’re trying to see.
Humans need to become explorers, inventors, and creators again.”Bring your Saturday self to Wednesdays”
Shane Lewin (TEDxEdgemontSchool)
Title: How AI and automation are changing our relationship with work | Shane Lewin | TEDxEdgemontSchool
Upload date: 19 june, 2017
Website:
https://youtu.be/cRiuEvZDMiY?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes: Deep learn algorithms can outperform radiologists.
Entire factories that had 1000 employees to run, have now 0.



🟧 Truckers	🟧 Taxi Drivers	🟧 Manufacturing
🟨 Accountant	🟦 Construction Trades	🟧 Facilities
🟧 Shipping	🟦 Engineering	🟦 Medicine
🟧 Recruiter	🟨 Clerical	🟨 Nurses and Health Administrators
🟧 Customer Service	🟦 Marketing and Business Administration	🟧 Relator
🟦 Police/Fire/Ambulance	🟧 Retail	🟧 Stock Broker

Figure 6 Shane Lewin, TEDTALK. Youtube.com automated and likelihood of automation

Largest job section in the U.S.

Orange: about to be automated now

Yellow: to be automated soon

Blue: Not currently on track to be automated.

By the time a med school student graduates (medicine), the AI will be competing with them already.(16ish years to graduate and become a professional)

Change from: AI is taking our jobs to → AI is doing our jobs.

45% of a working parent doing monotonous work. Nonparents also around there. AI is coming for those boring tasks, laundry, doing dishes, folding, cleaning, cooking.

AI to take overhead away.

RISK: Crippling unemployment

Advantage: no monotonous tasks

How to solve?

AI Can give us more time with our families, and usher in the most human generation.

WORLD ECONOMIC FORUM

Title: Will You Lose Your Job to Automation?

Upload date: 15, jun, 2018

Website:
https://youtu.be/DY1j2drdl1w?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh

Notes: Both simple and more specialized work may fall to automation.

What jobs will be created? AI. Programming and robot maintenance (small quantity).

Jobs that will be created that we can't think of today.

More and more complex jobs will be more and more replaced over the next 15 years.

Half of our jobs, how long? 10 years, or even 40 years?

At no point before has the transformation been as rapid or as extensive as it is right now.
What if people can’t reinvent themselves? Staying nimble and keeping learning.
What support is there for the worker for skills, retraining, relearning, training programs? Funding shared by companies and the state.
Loss of income and loss of meaning. More human compassion and touch jobs need to be created.
SEP upheaval?
Human purpose is not about working very hard about attaining wealth, it’s about compassion and other humans. We don’t have to protect jobs, we have to protect people.

Andrew McAfee: **(TED)**
Title: Andrew McAfee: Are droids taking our jobs?
Upload date: sep 24, 2012
Website: https://youtu.be/WMF-Z74C1QE?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes: Older, much like the others but about things that were to be taken over that the others have confirmed are taken over since a long time ago. Mentions how somejournalism and similar jobs have been automated.

Avelo Roy **(**TEDxIITBhubaneswar**)**
Title: Automation, jobs, and the future of work | Avelo Roy | TEDxIITBhubaneswar
Upload date: oct 9, 2018
Website: https://youtu.be/HB8bQk21Psk?list=PLklDmQOp0RzS9peaxw1SJNPm5ms41mUYh
Notes: 2030: Example: Go – 1000 times more complicated than chess. A machine (Deep learning) watched people playing Go, figured out how to play it, and beat the world champion in Go.
Example. 90% replaced by automation in case study. 10% that wasn’t replaced, who were they?
Relationship managers, social and cognitive skills. Face of the company.
Trust-based jobs harder to replace with software.
Relationship based jobs are key going forward.