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Risks and Benefits of Crew Reduction and/or Removal with Increased Automation on the Ship Operator: A Licensed Deck Officer's Perspective

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Abstract: As autonomous technologies proliferate in the shipping industry, limited research has been conducted on its potential implications on the Licensed Deck Officer. This research examines the potential benefits and risks of increased onboard automation with the reduction and/or removal of onboard crew on the Licensed Deck Officer. Qualitative methods of literature review, survey, and individual semi-structured interviews were used. The rating scale method and Likert Bar Graph scaling approach convey survey results. A Theoretical Thematic Analysis was used to analyze interview data. Reliability, validity, and objectivity of Subject Matter Experts (SMEs) interviewed are part of the research strategy. It was found that many barriers exist to the implementation of autonomous vessels, mostly revolving around crew and vessel safety. Reducing crews and increasing shipboard automation have potentially negative effects on the Licensed Deck Officer, including sensor over-reliance, decreased situational awareness, and increased complacency, while providing no reduction in onboard duties or fatigue. Changes in navigational, manning, and liability regulation must be addressed by maritime authorities first. The shipping industry's mindset is slow to change, but with this inevitable technology, the mariner will adapt. Insights generated from this research will benefit involved stakeholders to better understand and prepare for changes in the maritime industry due to the onset of autonomous shipping.

Keywords: autonomous shipping; maritime operations; human error; crew safety; seafarer skills; maritime education and training

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1. Introduction

Autonomous vessels are expected to be the next major step in the shipping industry [1]. Modern ships are being built larger with more advanced operating systems, and manned by a smaller, more specialized crew; unmanned vessels will be introduced globally in only a matter of time [2]. Two of the principal driving forces behind these developments are maritime safety and cost savings [3].

The relationship between human error and automation is widely discussed. IFully and semi-autonomous ships can potentially reduce human-error-caused navigational accidents [2] but theBut the concept of removing onboard crew can also be seen as transferring human error from personnel physically onboard a vessel to personnel controlling the vessel from a Remote Control Center (RCC). This would result in no actual reduction of human error within the chain, as humans are still in the loop [2]. A substantial gap exists between the future autonomous vessel's system operator, most likely a seafarer, and the system designer, who most likely does not come from a maritime background or have operational seagoing experience [4]. The smaller the gap between these two entities, the more beneficial the safety of Maritime Autonomous Surface Ships (MASS) will be. This can be said for regulation as well. All stakeholders, which includes mariners, should be included and collaborated with for MASS legal, training, and operational implications [5].

The purpose of this research is to answer the following research question: what are the potential risks and benefits of reducing and/or removing vessel crew while increasing vessel automation on the Licensed Deck Officer? As the ship operator, this role is imperative to the safe operation of an ocean-going vessel. This paper firstly explores why the maritime industry is leaning towards automation. Secondly, it identifies maritime industry movements towards autonomous shipping. Thirdly it defines current roles, responsibilities, and training of Licensed Deck Officers for unlimited, ocean-going vessels. Fourthly, it explores the potential risks and benefits to crew and to vessel safety caused by the reduction and/or removal of onboard crew due to an increase of shipboard automation. This is completed by literature review and by objectively analyzing data collected from SME interviews and anonymous surveys in the field of ship operation and management, with a focus on the Licensed Deck Operator's perspective.

This research finds that reducing and/or removing vessel crew and increasing automation have potentially negative effects on the Licensed Deck Officer. This includes overreliance on sensors, increased information overflow, and increased job complacency. It is also concluded that there will not be a reduction in their daily duties, nor a decrease in the overall amount of navigational accidents. Vessels are not currently perceived as having the practical potential to be safely operational as fully autonomous. Less traditional Licensed Deck Officer positions may exist in the future, an increase of IT skills will be needed to adjust, andcurrent sailing License Deck Officers may not be adequately prepared for industry changes. However, new jobs requiring this experience, such as Remote Control Operators, will emerge, and mariners will adapt.

This topic is relevant to the industry and to academia as research has proven that autonomous vessels are feasible, but there is no one clear answer as to when or how they will be safely executed [2]. It is crucial to understand how human operators will co-exist with these new autonomous technologies [6].

2. Background

Autonomous shipping is an important and significant topic for the maritime industry [7]. Sea trials and tests are underway, attracting international attention. Research and development is proliferating at a faster rate than previously expected in areas such as Norway, Sweden, and the United Kingdom, and also in China, Japan, and Singapore [8]. The number of autonomous shipping publications produced per year has also substantially grown in the past decade [9].

The Danish Maritime Authority (DMA) has defined four levels of automation. These levels have been unofficially adopted by the International Maritime Organization (IMO) for their Maritime Safety Committee's Regulatory Scoping Exercise (RSE). The RSE has been undertaken to identify the gaps and assumptions of existing IMO codes with the conceptual implementation of autonomous shipping. These levels currently have no legal implications or mandatory requirements for use. According to these definitions, traditionally manned merchant ships of today are at autonomous Level 1, or Manual "M". Level 2 is Remote Controlled with Crew Onboard "R". Level 3 is Remote Controlled without Crew Onboard "RU", and level 4 has no crew onboard "A" [10].

2.1. Why Autonomous Shipping

The possibility of reducing human error-caused maritime accidents and the potential to reduce operating costs are the main driving forces behind research and development in autonomous shipping technology [11]. Traditional technical and operational solutions to reduce costs, such as building larger ships and reducing ship speed, have reached their limitation in their ability to overcome economic, social, and environmental challenges [9]. Autonomous vessels are a linchpin to future competitiveness and sustainability within the European shipping industry; they are a potential cure for the current difficulties facing the maritime sector [12].

A study conducted by the German international financial services company Allianz determined that 75–96% of maritime related accidents from 1912 to 2012 were caused by human error [13]. Autonomous vessels may positively affect the safety of ship navigation and relieve the burden of fatigue, which is a major contributing factor to human-error-caused accidents [14]. Autonomous vessels may also have cost savings. A cost benefit analysis conducted by Maritime Unmanned Navigation through Intelligence in Networks (MUNIN) found that the cost of owning and operating an autonomous bulk carrier versus a conventional manned bulk carrier would save a total of $4.3 million USD over a 25-year period [12].

Societal advantages may also be achieved by autonomous shipping. Flexibility of operations brought on by autonomous technologies could improve service coverage for goods distribution [9]. The supply chain could be optimized, leading to an increase in cost efficiency; environmental preservation could increase due to a reduction in fuel usage, food waste, garbage disposal, and sewage; and infrastructure could be improved for areas of larger volumes of shipping traffic [9].

It is not certain to what extent the maritime industry will adopt automation [7]. A 2019 study conducted by the World Maritime University predicted that human supervised autonomous vessels will reach between 11–17% of global shipping by 2040 [15], and MASS trials continue to gain speed around the globe.

2.2. Autonomous Shipping Projects

There are multiple autonomous shipping projects currently underway and recently completed. These projects are laying the building blocks to make autonomous ships possible, but algorithms and control systems are still in the development phase [16]. This review is not exhaustive. The key takeaways are that projects are wide-ranging and on their own trajectory.

The MUNIN concept ship is an ocean going bulk carrier, unmanned for its sea passage, and is remotely controlled by an RCC [17]. This vessel is not made to operate autonomously on congested, coastal waters, as it would require crew to embark for port departures and arrivals. It can be controlled by an RCC for evasive maneuvers or during times of emergencies [18]. It is environmentally friendly, cost efficient, and, if operated correctly, expected to be 10 times less likely than a traditionally manned vessel to be involved in a collision, grounding, or sinking [18]. Its operating system is low in complexity to reduce hidden errors and development costs [17].

Novel Iwt and Maritime Transport concepts (NOVIMAR) is being developed for the short sea shipping and inland waterways sectors, reducing manning and increasing automation of ships [19]. This four-year project started in 2017 with 9 member countries and is funded by the European Commission's Horizon2020 program. Its vision is to use a vessel train concept with ship "trains". A fully-crewed lead vessel is digitally linked to minimally crewed/crewless follower vessels. The main goals of NOVIMAR are to reduce vessel operational costs, increase environmentally sustainable transportation, and to optimize inland navigation by expanding the transport chain. Within the EU, there has been no significant shift of cargo transport from truck and rail to waterway in the past 20 years. This vessel train concept could lead the way in this modal shift [20]. It is said that NOVIMAR will shape a new way of transportation in the next decade [21].

Mitsui Osk Lines (MOL) is a collaboration between Rolls-Royce Marine and Kongsberg and is backed by the Japanese government. It is currently testing to improve the autonomous docking and undocking operations of passenger ferries, with the purpose of achieving seagoing voyages via vessel operation monitoring systems. MOL is driven to reduce human error-related accidents and to reduce crew workload [22]. According to Rolls-Royce Marine, autonomous ships will be not uncommon by 2030 [23].

Vard Holdings Limited plans on delivering vessel Yara Birkeland to Norwegian chemical company YARA. Working with Kongsberg's advanced monitoring and control systems designed for unmanned operations, *YARA BIRKELAND* strives to be the first

zero emission container ship capable of sailing crewless [24]. It is designed for short sea shipping, and is said to launch manned in 2020 and evolve to fully autonomous by 2022. With a max speed of 13 knots it will hold up to 120 TEUs, replacing 40,000 conventional truck trips per year [25].

Ocean Infinity's Armada is a fleet of autonomous underwater vehicles (AUVs) and unmanned surface vessels (USVs) that can launch and be remotely operated by experienced mariners via satellite from an RCC. Operational in 2020 for ocean surveying and underwater data collection [26], its driving factors include environmental sustainability and reduction in manpower at sea. Its small carbon footprint and unmanned design is aimed at reducing costs while increasing the safety of ocean survey evolutions. These vehicles contain many sensors that can be used for other purposes aside from ocean floor mapping, such as searching for missing objects, moving freight upwards of 60 tons, and surveying conditions and environments for laying cable and wind farms [27].

The Mayflower Autonomous Ship (MAS) is set to recreate its historical journey in spring 2021. This is to commemorate 400 years since the original *MAYFLOWER* set sail from Plymouth, UK, and landed at Plymouth Rock, Massachusetts, bringing pilgrims to the new world. This ambitious plan, created by a collaboration from the lead partners of IBM and ProMare, will bring a fully self-navigating, solar powered trimaran across the Atlantic. Using edge computing technology, IBM's Operational Decision Manager (ODM), multiple onboard sensors, weather input, and a Safety Manager function among other technologies, the *MAYFLOWER* can fully sense its environment with no humans onboard. It will navigate in compliance with the international collision avoidance regulations (COLREGs) [28].

The Belgian company Seafar is currently running trials with its vessel DESEO, a 110 m 5500 dwt containership, between Antwerp and Zebrugge. This vessel, using 4G and 5G networks, has the capability of being controlled from the shore via its RCC, located in Antwerp. There are still crew present on board, as legislation does not currently permit the controlling of a vessel from the shore, hence Seafar has applied for a permit from the Flemish government and other responsible parties to conduct its trials under strict conditions [29]. This project, focused on succeeding at semi-autonomous inland shipping, is motivated by reducing the amount of crew needed onboard from five persons to three [30].

2.3. Defined Officer and Crew Positions

Before crews are removed from vessels, they most likely will be reduced to minimum operating levels while certain tasks are automated. Reducing a vessel's crew while increasing onboard automation does not automatically reduce the amount of duties required of the remaining onboard crew. For this concept to be fully understood, one must be cognizant of all of the duties and responsibilities of a ship's crew.

Ocean going merchant ships of unlimited tonnage, which are typically vessels over 1600 gross tons, have minimal crewing requirements. This may be as few as 12 to 17 crew members onboard. These crewmembers are generally divided into three departments: Deck, Engine, and Steward. Specific manning requirements for vessels are detailed by the Minimum Safe Manning Certificate (MSMC). This is required under IMO's Standards of Training, Certification, and Watchkeeping (STCW) Convention, STCW Code, and Safety of Life at Sea (SOLAS) and is issued by the vessel's country of registry. The MSMC takes into account a vessel's size, cargo, power, and nature of her work, while also abiding by IMO's Resolution A 1047(27) Principles of Minimum Safe Manning, MSC. 1/Circ.1598 Guidelines on Fatigue, Merchant Shipping (Manning and STCW) Regulations 2014 (SD 2014/0238), Merchant Shipping Regulations 2013 (SD 0234/13), and other regulations set forth from the country of registry to determine the safe number of personnel to operate a vessel. Below is a brief overview of the positions generally required onboard a vessel to ensure its safe operation.

Within the Deck Department, the manning requirement for an unlimited tonnage ocean going vessel usually consists of a minimum of three watch standers who are Licensed Deck Officers, or "Mates". This typically consists of a First Officer or Chief Mate (C/M),

Second Mate (2/M), and Third Mate (3/M). The Master typically does not stand watch and holds the highest authority onboard, acting as the vessel's manager. A watch stander, who is the Officer in Charge of the Navigational Watch (OICNW), is physically on the bridge and is responsible for making all decisions regarding the safe navigation of the vessel. Hence, a vessel remains under 24 h direct human control. The Master is responsible for ensuring proper watchkeeping periods. These periods are detailed by IMO's STCW regulation VIII/2 and A-VIII/2. The OICNW is in charge of monitoring all ship systems pertaining to safety, weather, communication, navigation, and traffic management. He/she is certified in Radar, Electronic Chart Navigation, vessel communications, and vessel security among many other things. The OICNW is responsible for executing proper orders in accordance with COLREGs and the Master's standing orders.

Licensed Deck Officers have substantial amounts of daily onboard duties and responsibilities that might not be considered when the topic of reducing manning is addressed. These vary greatly by the type of vessel and the nature of her work. Some of these typical duties include:

- Bridge Watch. Typical watch rotation consists of 4 h on watch, 8 h off watch throughout a 24 h day. 6 h on watch and 6 h off watch [31] is also common, but more so on inland waterways and tug vessels
- 3/M typically stands the 0800–1200 and 2000–2400 bridge watch and is normally the Damage Control Officer. This is the person in charge of all fire-fighting and chemical, biological, and radiological defense (CBR-D) equipment onboard the vessel
- 2/M normally stands the 0000–0400 and 1200–1600 bridge watch and is the vessel's Navigator. These responsibilities include voyage planning and updating and maintaining all navigational equipment onboard. They are also responsible for onboard survival craft equipment, which includes: lifeboats, life-rings, emergency communication devices, and pyrotechnics
- A minimum of two Mates onboard must be licensed to operate and maintain the Global Maritime Distress Safety System (GMDSS), which contains all emergency and routine communication equipment onboard. The GMDSS station is normally located in a designated area on the bridge deck
- C/M normally stands the 0400–0800 and 1600–2000 and is also the Cargo Mate. He/she maintains a Management level license and is in charge of the stability of the vessel in-port and underway as well as cargo operations and cargo inspections. The C/M has many other ancillary duties including crew training, vessel maintenance, waste disposal, and overtime management. The C/M is in charge of all unlicensed Deck crew, which typically consists of three unlicensed Able-Bodied Seamen (AB's) under the guidance of the senior unlicensed seafarer, the Bosun's Mate (BOS'N)

Certain companies, such as Military Sealift Command, which provides support and supply to the US Navy, or large passenger vessels may carry additional Mates onboard. Crews of these vessels are typically larger due to the nature of their work. These additional positions are not required by the MSMC but can be instituted by the company. If additional Mates are a part of the crew, a common scenario is two 3/M onboard as watch standers, and the C/M who does not stand watch will then be available to work the dayshift. Another scenario is an additional Mate onboard, who acts as the Cargo Mate. In this case, the C/M may stand watch, and the Cargo Mate is in charge of all cargo operations. Another scenario is an additional 2/M onboard to act solely as the Navigator; they do not stand watch. On large passenger vessels, there may be a Staff Captain in addition to the Master. He/she is second in command and is head of the Deck Department and bridge, while the Master remains ultimately responsible for all aspects of the vessel.

In addition to Licensed Deck Officers, there are unlicensed personnel in the Deck Department, which include Ordinary Seamen (OS) and Able Seamen (AB). The former are entry level, and the latter are qualified unlicensed watch standers. ABs are typically day workers [32] and take on duties of deck maintenance and operations under the guidance

of the C/M. On the bridge, they may be assigned as helmsman and lookout to assist the OICNW but do not hold the responsibility of the watch.

The Engineering Department mimics the Deck Department. For unlimited tonnage vessels, there must be a licensed Chief Engineer onboard, as well as additional licensed engineers such as a First Assistant Engineer (1A/E), Second Assistant Engineer (2A/E), and Third Assistant Engineer (3A/E). The actual number and position required is determined by the MSMC. Their licenses also vary based on the type of propulsion that they have the required experience in, being steam, gas turbine, and diesel.

- Typically the 1A/E through 3A/E stand watch in the engine room
- Unlicensed members of the Engineering Department, similar to that of OSs and ABs, are called Wipers and Qualified Members of the Engineering Department (QMEDs), respectively.
- Unmanned engine rooms still have a Licensed Engineer on shift for standby 24 h a day.

In addition to the Deck and Engine Departments, there is the Steward's Department, which typically consists of a Chief Steward, Stewards, and Assistant Stewards. This department is responsible for food provisions and providing meals to Officers and Crew, as well as maintaining living quarters. The Chief Steward is the Department Head and supervises the galley, tracks overtime, and is responsible for crew living quarters. He/she is also responsible for all food supplies, including inventorying, ordering, and meal planning for a vessel's voyage [33]. Other personnel in this department consist of Stewards and Assistant Stewards (entry level), who bear the responsibilities of cook and cabin cleaning/maintenance [34]. There may be multiple personnel within this department, or as few as a Chief Steward and Cook, depending on the size of the crew onboard, company, and vessel.

2.4. Risks of Reducing Crew on Crew and Vessel Safety

As with any new technology, autonomous shipping poses inherent risks as it has yet to be implemented on a large scale. Current testing has been conducted in a limited and controlled environment. It also runs the risk of new accidents occurring [2]. In this section, the potential risks to crew and vessel safety caused by the reduction in and/or removal of crew onboard merchant ships due to an increase of shipboard automation will be explored.

2.4.1. Navigational Accidents and Human Error

Before onboard crews are potentially moved shoreside, they most likely will be reduced to minimum operating levels as certain tasks and jobs are automated. Reducing crew size while increasing vessel automation does not automatically reduce the amount of duties required of the remaining crew onboard. Moving crew shoreside can also be argued as a transfer of human error with no actual reduction of human error within the chain [2].

Human error is a problem. According to the European Maritime Safety Agency (EMSA), of the 1801 accident events that were analyzed from 2014 to 2019 and took place in EU waters and/or were flying EU member state flags, 54% of the accidents were attributed to "human action". Within these 1801 analyzed accidents, 3640 contributing factors were associated with shipboard operation, which proved to be the highest contributing factor to the accident [35]. Deck Officers are also stated as being a primary cause for navigational casualties, which are defined as collisions, groundings, and/or strandings [36].

Introducing semi and fully autonomous ships could reduce the number of maritime accidents [37]. However, removing experienced personnel from ships could mean that any accident that does occur could be far more severe. A study conducted by Wróbel et al. [2] analyzed 100 marine accidents that occurred between 1999 and 2015 using Human Factors Analysis and Classification System for Maritime Accidents (HFACS-MA). These accidents took place in varied geographical regions, with the majority of them being groundings occurring in Northern Europe. The results from this study concluded that unmanned vessels would decrease human-error-caused accidents 3:1 and eliminate onboard fatalities, but there would be an increase in consequences once an accident occurs. Situational assessment, decision making, and damage control, which are all normally completed by

onboard crew, are no longer possible, thus increasing a vessel's consequences once involved in an accident [2]. Technology risk equates to probability x impact [38]. In this case, this prompts further investigation into weighing up the cons of the probability of a risk of increased impacts outweighing the pros of a decrease in the number of accidents.

2.4.2. Fatigue

The IMO defines fatigue is a state of feeling weary and tired due to extended physical or mental work, lack of sleep, and/or exposure to harsh environments. It can affect anyone regardless of training, experience, or skill [39]. With decreasing crew sizes, mariners are proportionally expected to do more with less personnel, potentially meaning less time off and less opportunities to rest. Other factors that can increase the effects of fatigue on mariners include night work, interrupted sleep, long shift hours, and rotating work hours. These conditions are all commonplace within the maritime industry.

Specific work-rest periods for watch standers are detailed in STCW regulations. According to this, the Officer in Charge of a Navigational Watch (OICNW) for seagoing voyages must receive at least 6 h of continuous rest. A period of rest is defined as a time when personnel are not on watch or on duty. OICNWs must also have a minimum of 10 h of rest within a 24 h period, which excludes drills and emergencies onboard. Within 7 consecutive days, an OICNW cannot receive less than 77 h of rest [40]. Even with these regulations in place, this does not guarantee that mariners are receiving enough rest time to counteract fatigue. According to a study completed in 2020, out of the 20 mariners from 16 different nationalities who were interviewed, all reported work/rest violations onboard their ship [41].

Fatigue continues to be a worldwide problem. A study conducted by the National Union of Marine, Aviation, and Shipping Transport Officers surveyed 563 seafarers and determined that half of those surveyed indicated that a typical work week was over 85 h. Two-thirds of participants agreed that extra manning was necessary to reduce fatigue felt as a result of excessive work hours [42]. A sample study of accident reports from the National Transportation Safety Board (NTSB) from 2001–2012 found that 20% of the 182 reports reviewed identified fatigue as a contributing factor, finding, or probable cause [43]. In a separate study, the UK's Department of Transportation concluded that roughly one third of all groundings occurring between 1994 and 2003 involved an Officer on watch alone on the bridge who was fatigued [44].

2.4.3. Mariner Experience and Situational Awareness

Knowledge, discipline, training, aptitude, and experience are all important factors in shaping a successful mariner [45]. Onboard, operational decision making is shaped by years of professional training and sea-going experience, which is hard to replicate. The specific movements of a vessel, understanding weather, knowing how to react in extreme situations, and personnel management skills are acquired and refined over time. The preservation and inclusion of this experience should be considered when moving ship operators shoreside.

Situational Awareness (SA) is the art of managing all available resources, particularly during a watch. It is necessary for the safe operation of a vessel according to the STCW [46]. A ship, being in a constant dynamic environment, must have crew that can accurately assess its ever-changing situation. Its crew is responsible for quick and diligent action to avoid potential dangers and preserve the safety of the ship and all personnel onboard. Loss of SA reduces vigilance and leads to breakdowns in communication, which can lead a vessel into a dangerous situation. This includes failure to observe or monitor critical data, failure to plan or to perceive the current situation accurately, and failure to project situations in the future [47]. Losing SA has proven to be a large contributor to maritime accidents [42].

With autonomous vessels, ship operators are removed from the immediate scenario and are located potentially hundreds or thousands of miles away from the vessel being

operated. How operators will maintain SA without physically being onboard must be addressed. In recent years there has been significant advances in automation technology within navigation systems, such as Electronic Chart Display and Information Systems (ECIDS) and Dynamic Positioning (DP), yet onboard crew is still needed to observe, monitor, and control these systems. To address SA, both the Rolls-Royce Autonomous Waterborne Applications (AAWA) initiatives project and the Lloyds Register concluded that a vessel with appropriate sensors could have SA that is as good as an onboard human mariner, but challenges with conveying this information exists [48].

2.4.4. Ship Regulation, Insurance, and Liability

The barriers of ship regulation, insurance, and liability could mean that it will be a long time before it is profitable to invest in autonomous ships [49]. According to research conducted by the DMA in 2017, there are seven categories where regulatory barriers exist with the implementation of autonomous shipping. They are: jurisdictional issues, COLREGs, the crew of the future, marine environmental protection, construction requirements, liability and insurance, and cybersecurity [10]. DMA research concluded that MASS should be regulated by the IMO, and additions to COLREGs and STCW have to be addressed to include MASS and Remote Control Operators (RCOs). They also concluded that MASS should be crewed appropriately to maintain the proper safety of the vessel, crew members should be adequately trained as current licensed mariners, passenger ships cannot be unmanned due to fire safety until changes to IMO's Safety of Life at Sea (SOLAS) are made, and cybersecurity has to be addressed by a vessel's safety management system [10].

From 2011 to 2016, the Allianz Global Corporate and Specialty Global Claims Review analyzed 15,000 liability claims from the marine sector that equated to 1.6 billion USD of losses [50]. These maritime incidents rank high as a cause of liability loss as each individual accident accrues costly expenses such as personnel liability, wreck removal, and pollution [51]. Many shipping insurers are skeptical of the practicality of removing crew from vessels, and there is some consensus that it may take more than just a few years for laws to change for unmanned vessels to operate without crew onboard [2]. Currently, the ship's Master is responsible for all actions related to their ship. If ships remove their onboard crew, ship liability will have to fall elsewhere, such as the ship's owner. MUNIN conducted an analysis of the liability and legal issues with regard to autonomous shipping. They determined that the current legal framework can be adapted, but significant issues exist with navigation and manning laws, liability, and ship design standards and construction. In any case, further research must be conducted [18].

3. Materials and Methods

The qualitative methodologies of a multiple choice survey using a rating scale and individual semi structured interviews were used for this research. Competent, small-scale surveys can make valuable and substantive contributions to qualitative research [52]. This type of survey proved useful in the research conducted by MUNIN, where a group of maritime stakeholders were successfully surveyed on key aspects and impacts associated with autonomous ships [53]. Semi structured interviews include a prepared list of questions and topics to be discussed. They work well when interviewing managerial-type people and allow the researcher to be in control of the interview while being flexible enough to follow new leads as the interview is conducted [54]. The reliability and validity of the persons interviewed were considered as part of the research strategy.

A 20 question fully anonymous survey, answered by 42 personnel actively employed in the maritime industry, was conducted between February-April 2019. To avoid the possible subjectivity of responses given by current sailing Licensed Deck Officers, responses were divided and analyzed based on participants' employment being 'Licensed Deck Officer' or 'Other'. The 'Other' category includes those employed by government/regulatory institutions, shipping companies in shoreside positions, information science/research positions, or those who are academics/students. Survey questions are organized into

four categories: Employment, Training, Safety, and Feasibility. Of the 20 questions, 19 are multiple choice, followed by one open-ended short-answer question. Using a rating scale methodology, multiple choice answers are assigned to numbers as follows:

1. Strongly Disagree
2. Disagree
3. Neither Disagree/Agree
4. Agree
5. Strongly Agree

The mean and median for each question's answers are used as the final result of each question, and a Likert Bar Graph scaling approach presents the overall responses for each question on a sliding scale from −100 to 100 with the axis at zero.

Seven key maritime personnel were interviewed individually using 10 semi-structured open-ended questions. The personnel interviewed included a Senior Project Officer from EMSA, a Vice President of a respected International Flag Registry, a Researcher and expert in European Inland Navigation and Innovation, a Professor of Maritime Economics and Managing Director of an International Maritime Association, an Assistant Professor and Vice Chair of a Maritime Professional Education Facility, and 2 Actively sailing Licensed Deck Officers with Management-level licenses. A Theoretical Thematic Analysis is used to analyze participants' answers and determine overarching themes from the interview questions and from the survey's open-ended question. This six-step method is as follows: familiarize self with data, generate initial codes, search for themes, review themes, define themes, and write-up results [55]. This is a top-down approach to analyzing data as data isdriven by the research question and objectives [56]. Data is analyzed using the qualitative analysis software program ATLAS.ti, where lines of data are assigned to defined codes. After data analysis is complete, codes and subcodes are refined, data are reviewed, and overarching themes emerge. Survey answers are linked to interview data outcomes to achieve overall results.

4. Results

The results of the survey are presented in the following section. Survey responses are presented by the four categories of the survey questions, these being Employment, Training, Safety, and Feasibility. To remain objective, the results of the survey questions are analyzed based on the participant's employment either as a 'Licensed Deck Officer' or 'Other', as displayed in Figure 1. The results are similar, with the largest differences being found in questions 4, 5, 9, and 13. These results are discussed in their respective categories.

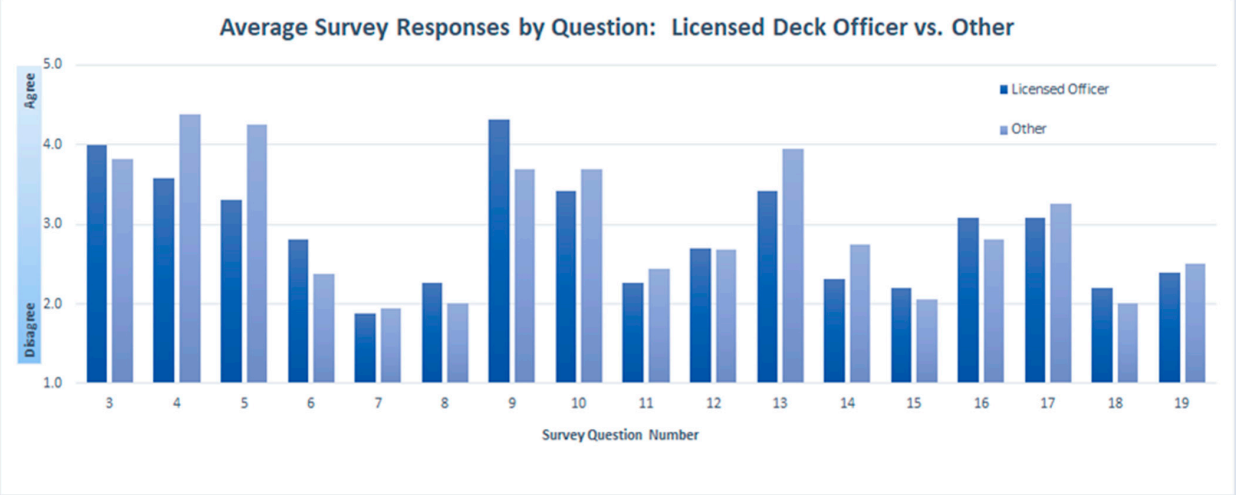

Figure 1. Comparing 'Licensed Deck Officer' survey responses vs. 'Other' survey responses.

The Employment category consists of the first three survey questions. The responses show that 26 of the 42 surveyed participants, or 62%, are sailing Licensed Officers. Of all participants, 47.6% believe that unlimited tonnage/deep sea going vessels will be the maritime sector first impacted by autonomous shipping, and 50% agree that there will be less job opportunities for Licensed Deck Officers in the future.

In this category of Training, questions 4–9 from the survey are displayed in Table 1.

Table 1. Training Category survey questions and response results.

Question Number	Training Category Survey Questions	Mean & Median Answer
4	The skill sets required for Licensed Deck Officers will significantly change in the future due to autonomous shipping	**AGREE**
5	Licensed Deck Officer training will change significantly in the next 10 years by the onset of autonomous shipping	**AGREE**
6	Current sailing Licensed Deck Officers are adequately prepared for industry changes due to autonomous shipping	**NEITHER DISAGREE/AGREE**
7	Current Shipping Companies, Unions, and Merchant Mariner educational facilities are adequately prepared for industry changes regarding autonomous shipping	**DISAGREE**
8	Current midshipmen/cadets training are adequately prepared for industry changes regarding autonomous shipping	**DISAGREE**
9	Shore side control centers that will remotely control vessels will require operators who possess the experience and credentials similar to current Licensed Deck Officers	**AGREE**

The majority of participants, 32 people, agree (33.3% strongly agree and 42.9% agree) that due to autonomous shipping, the skillset of the Licensed Deck Officer will significantly change; and 26 people agree (23.8% strongly agree and 38.1% agree) that Maritime Education and Training (MET) will significantly change within the next decade. Survey participants who are not employed as Licensed Deck Officers agree to these results more strongly than participants employed as Licensed Deck Officers. Participants strongly disagree (9.5%) or disagree (38.1%) that current sailing License Deck Officers are adequately prepared for industry changes; 38 participants do not believe that shipping companies, unions, and MET facilities are adequately prepared for changes in the industry regarding ship automation (21.4% strongly disagree and 69% disagree that they are prepared); 32 participants (16.7% strongly disagree and 59.5% disagree) that current cadets are adequately prepared for industry changes due to autonomous shipping; and 33 participants agree (47.6% strongly agree and 31% agree) that RCCs will require operators who possess experience and credentials similar to those of current License Deck Officers. A Likert Bar Graph representing results from the Training Category is found below, in Figure 2.

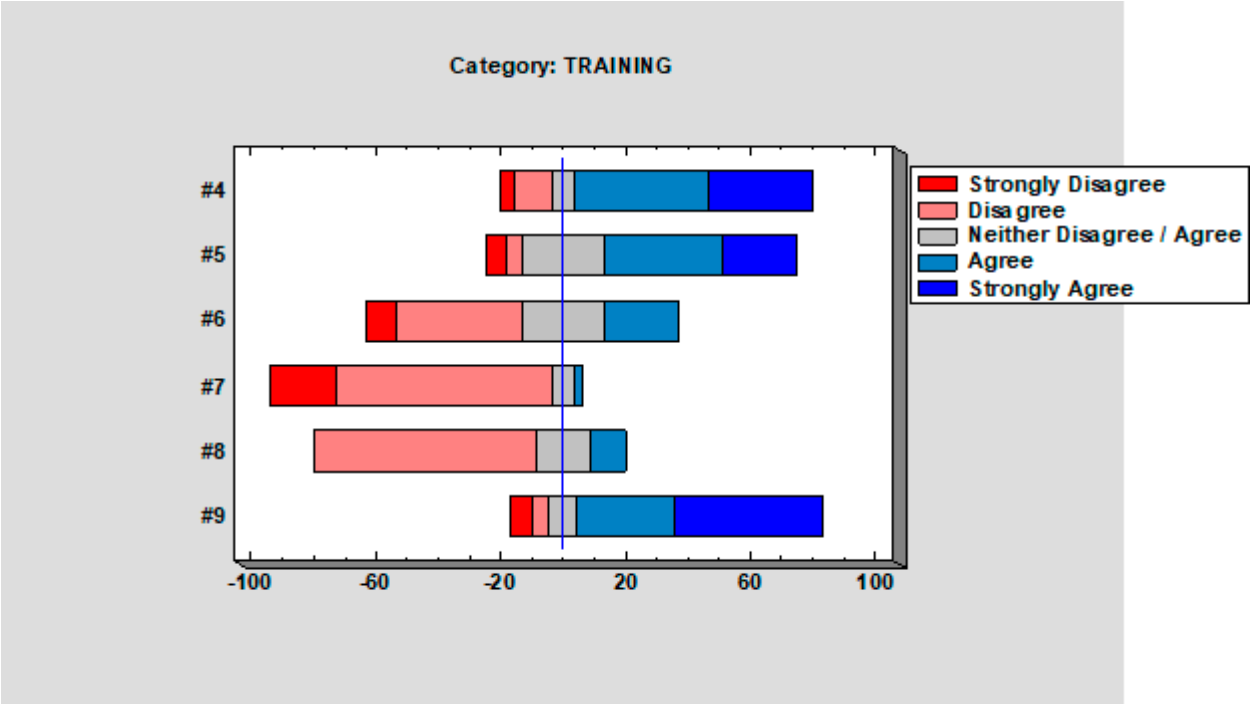

Figure 2. Likert Bar Graph representing scaled Training Category question responses.

Safety survey questions 10–15 are found below, in Table 2.

Table 2. Safety Category survey questions and response results.

Question Number	Safety Category Survey Questions	Mean & Median Answer
10	Reducing Licensed Deck Officers onboard vessels with a proportional increase of automation will increase sensor over-reliance and increase information overflow for the Deck Officers	**AGREE**
11	Reducing Licensed Deck Officers onboard vessels with a proportional increase of automation will reduce the percentage of navigational accidents	**DISAGREE**
12	Reducing Licensed Deck Officers onboard with a proportional increase of automation will reduce human fatigue	**NEITHER DISAGREE/AGREE**
13	Reducing the amount of Licensed Deck Officers onboard with a proportional increase of automation will increase Deck Officer complacency	**AGREE**
14	Reducing the amount of Licensed Deck Officers onboard with a proportional increase of automation will decrease the daily duties and demands of the Deck Officer	**DISAGREE**
15	Reducing the amount of Licensed Deck Officers onboard with a proportional increase of automation is safe	**DISAGREE**

The results of the safety section conclude that the majority, 24 participants, believe that an increase in vessel automation will increase Licensed Deck Officers' over-reliance on sensors and could cause information overflow (23.8% strongly agree and 33.3% agree).

The 'Other' survey participants agree more strongly that complacency will increase. It is also determined that the majority, 25 participants, disagree that an increase in shipboard automation will reduce the amount of navigational accidents (26.2% strongly disagree and 33.3% disagree). Participants were neutral about automation affecting the amount of fatigue felt by Officers. The majority, 25 participants, disagree that an increase of automation will decrease their daily duties (11.9% strongly disagree and 47.6% disagree). The majority of the 30 participants also disagree that reducing onboard crew while increasing shipboard automation is safe (26.2% strongly disagree and 46.2% disagree). A Likert Bar Graph representing results from the Safety Category is found below, in Figure 3.

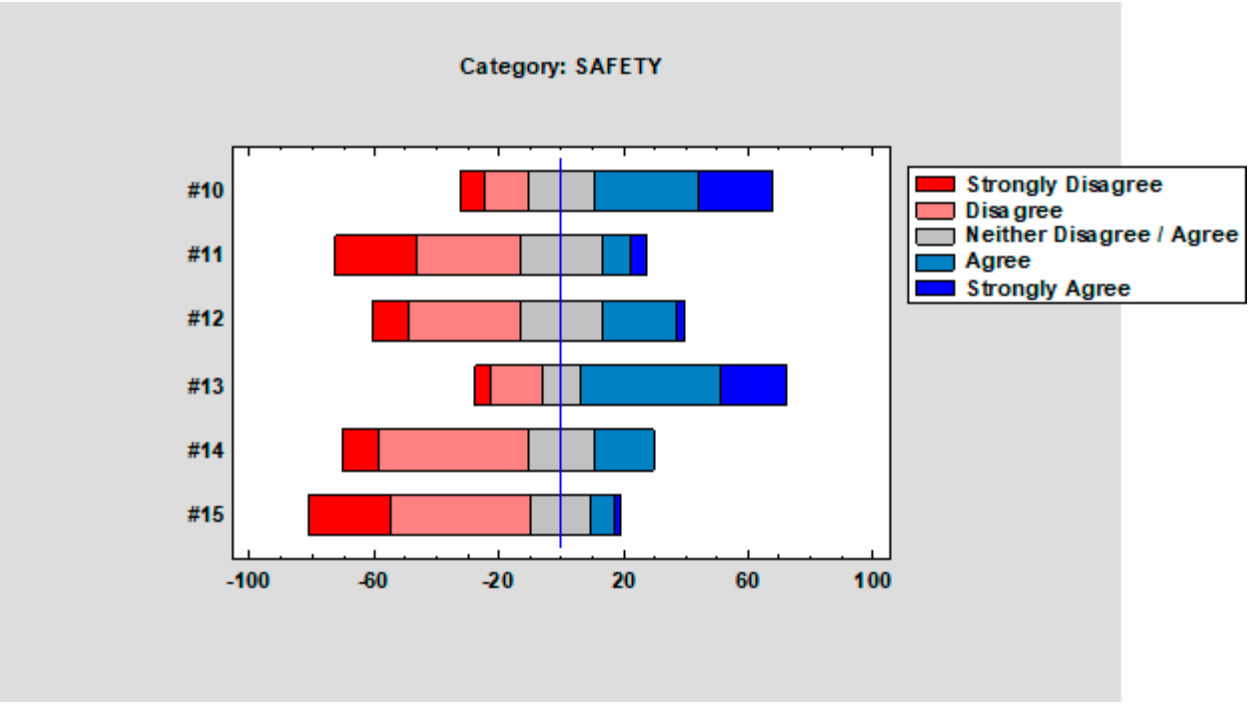

Figure 3. Likert Bar Graph representing scaled Safety Category question responses.

Survey questions for the Feasibility Category, numbers 16–19, are found below, in Table 3.

Table 3. Feasibility Category survey questions and response results.

Question Number	Feasibility Category Survey Questions	Mean & Median Answer
16	Reducing the amount of Licensed Deck Officers onboard with a proportional increase of automation is feasible	**NEITHER DISAGREE/AGREE**
17	Reducing the amount of Licensed Deck Officers onboard with a proportional increase of automation is economical	**NEITHER DISAGREE/AGREE**
18	Onboard situational awareness can be effectively replicated with advances in simulation	**DISAGREE**
19	In the future, vessels have a practical potential to be safely operational as fully autonomous	**DISAGREE**

Regarding the feasibility of autonomous shipping, survey participants are neutral when asked about the feasibility and economic advantages of shipboard automation. The

majority of participants, 32, disagree that SA can be accurately replicated shoreside (31.8% strongly disagree and 38.1% disagree). The majority of the participants, 28 people, also believe that it will not be safe to operate vessels in the future as fully autonomous (23.8% strongly disagree and 38.1% disagree). The Likert Bar Graph representing results from the Feasibility Category is found below, in Figure 4.

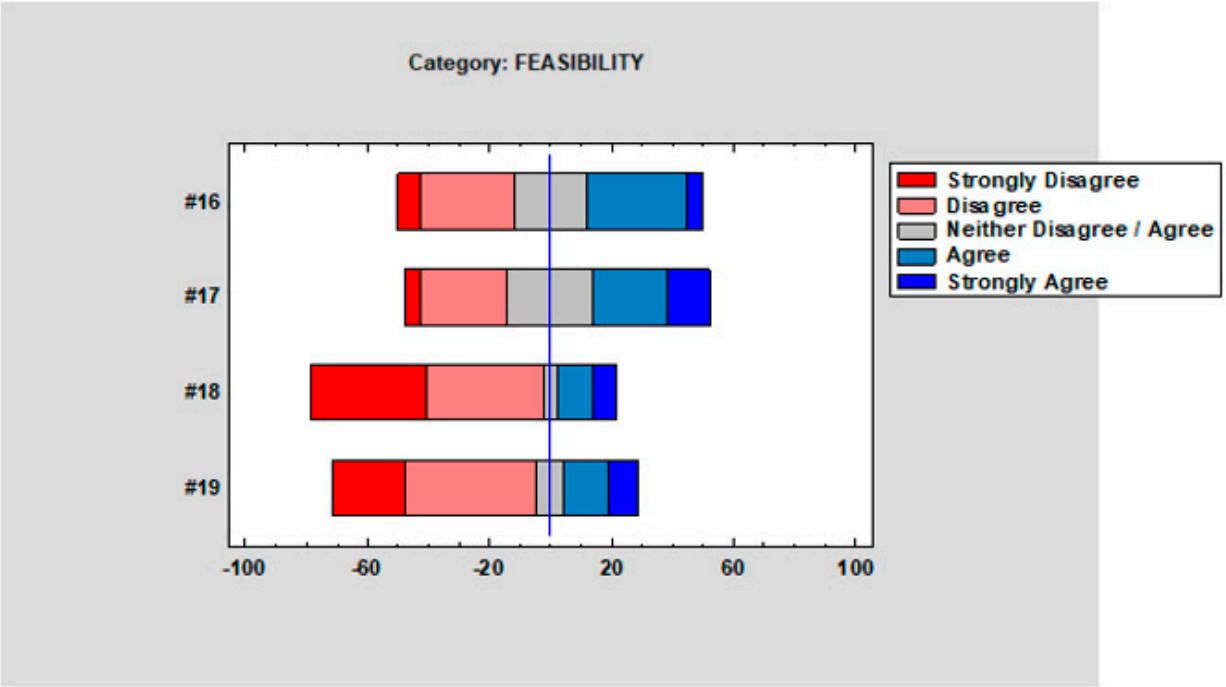

Figure 4. Likert Bar Graph representing scaled Feasibility Category question responses.

5. Discussion

From the survey, the results conclude that 76% of participants believe that with the onset of autonomous shipping, Licensed Deck Officer skillsets will significantly change; 62% of participants believe the MET will also significantly change in the next decade; and almost half of the participants believe that those currently sailing are not adequately prepared for changes in the industry. Just over 90% believe that shipping companies, unions, and MET facilities are not adequately prepared for changes that will be brought on by autonomous shipping, and 76% do not think that cadets are well prepared for these changes. Of the participants, 79% agree that RCCs will require operators who possess experience and credentials similar to that of current License Deck Officers; 57% believe that an increase in vessel automation will increase Licensed Deck Officers' over-reliance on sensors and could cause information overflow; while almost 60% disagree that an increase in shipboard automation will reduce the number of navigational accidents or decrease their daily duties. Additionally, 71% disagree that reducing onboard crew while increasing shipboard automation is safe, and 76% disagree that SA can be accurately replicated shoreside. Two-thirds of participants believe that it will not be safe to operate vessels in the future as fully autonomous (level 4).

Using a Theoretical Thematic Analysis and qualitative analysis software program, ATLAS.ti, the semi-structured interviews were analyzed. The overarching themes of the effects of the implementation of autonomous shipping on the Licensed Deck Officer that emerged are as follows: Barriers, Purpose, the Unknown, External Factors, and Adaptability. These are detailed in Figure 5, followed by their associated codes and subcodes, which overlap into more than one theme.

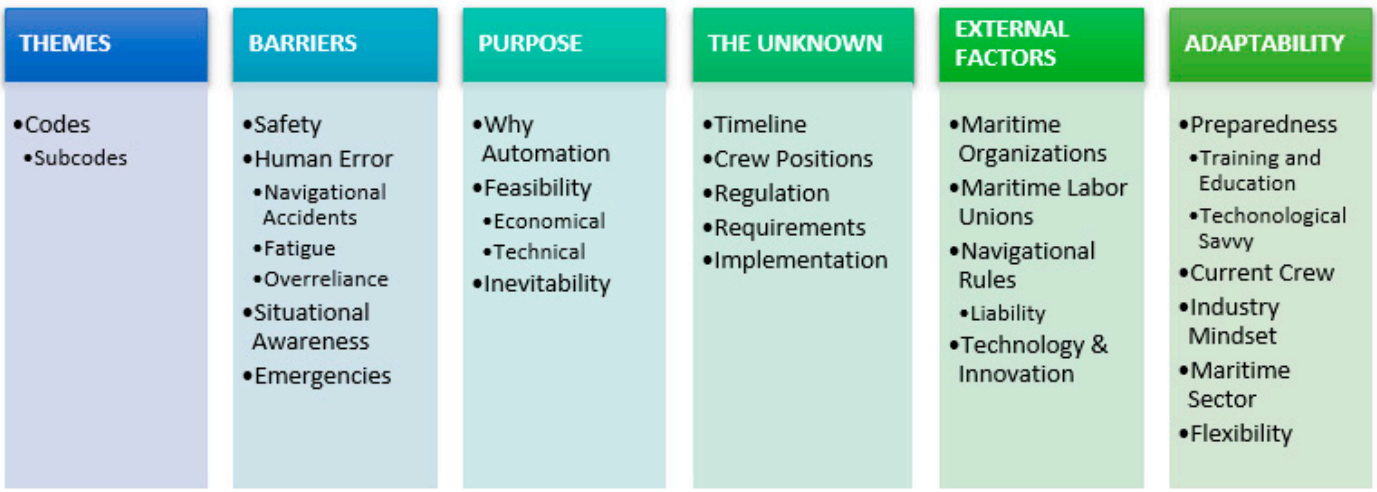

Figure 5. Thematic Analysis themes, codes, and subcodes.

5.1. Barriers

The most commonly occurring theme from the interview data is barriers to the maritime industry regarding reading and/or removing crew onboard ships. The codes and subcodes within this theme are as follows: safety, human error (navigational accidents, fatigue, and system overreliance), SA, and emergencies.

According to one interviewee's response when asked about autonomous shipping and how it will affect the merchant mariner, "it is still too early to go into details. There may be positive impacts but also problems not yet envisaged. The more automation a vessel has, the less experienced people become when dealing with day-to-day problems." Another interviewee determined that it is difficult to remove human error from the equation, as any accident has some form of human error contribution. Human error moves somewhere else within the chain. At the same time, different emerging risks are expected to increase that can eventually cause accidents. According to a different interviewee, when it comes to extreme weather, which is out of human control, there will not be the risk of loss of life as no personnel would be onboard, but there is the risk of overestimating the capabilities of the equipment.

The interview responses are in-line with the survey responses. Many are concerned that overall safety can be compromised by reducing/removing crew from vessels and that automating certain tasks of a ship's Officer's daily routine does not necessarily relieve him/her of certain burdens.

5.2. Purpose

The codes and subcodes in the theme Purpose are why automation, feasibility (economical and technical), and inevitability. From the perspective of the majority of Licensed Deck Officers interviewed, there are doubts that full automation is feasible or necessary, but the majority believe that semi-autonomous shipping will likely occur. Noted by one leader in MET, "automation will never be able to account for all the variables of the sea and shipping. To get more automation, you will not save money, you will need to hire a proportional amount of IT technicians to manage the computers and sensors. This means manpower costs are similar but now you have the added cost of equipment." Another response is that it may save crew costs for the shipping company, but it will not have a positive effect on the seafarer. There were also multiple comments stating that it may not be economical to change the current fleet into an autonomous one, and that it would be better to construct future ships with automation design in mind.

Other important topics from the interviews and open-ended survey question include: technological advancements in the industry are welcome; this technology will certainly

affect our industry in the future; and autonomous shipping is an evolution of current practices, not a revolution in the industry. Hence, it is accepted that automation in shipping will occur but not without further development of technology and practices. From an interview with a leader in MET, it was stated that autonomous shipping is inevitable, but it is in its infancy. "I don't know when and I don't know the details, but it is going to happen. The best thing we can do now is to prepare ourselves with research, training, and testing, testing, testing." Another expert noted "vessels will be more automated, some technologies will be developed, and money will be spent particularly from the side of manufacturers. It will be, nevertheless, difficult to reach autonomy, if that means vessels without crew, operating worldwide by 2030 or 2040."

Multiple responses stated that there are too many safety issues that need onboard human interaction to be able to fully remove crew. There is also an acknowledgement that current developments and projects in this field that have not yet been implemented on a wide enough scale to determine the impact on the merchant mariner. Overall, the interviewees' responses aligned with those of the surveys, and the responses are split when it comes to the economic and technical feasibility of shipping.

5.3. The Unknown

The Unknown codes and subcodes include: timeline, crew positions, regulation, requirements, and implementation. The majority of interviewees feel at this time that the question of autonomous ships cannot be accurately or fully answered due these unknowns. It was agreed by most that regulations and requirements have to be settled first.

Most respondents answered that it is too early to identify the amount of crew and the specific roles that will be needed because the crew has not been replaced yet, and not enough research has been conducted or published. According to one expert from a well-respected maritime organization, "there might be issues that emerge from automation that have not yet been considered. For example, some people are concerned about how to fight a fire or situations where the vessel becomes disabled without anyone being able to check or manage the problems on site. However, there is certainly room for improvement when it comes to reducing accidents and automation may assist towards that direction if properly implemented." These opinions generally fall in line with the survey results regarding the Safety category.

It is generally accepted that vessels will initially become semi-autonomous with reduced crews onboard, but the timeline of this transition is unknown. This also affects what the actual crew positions will be, but the majority of people interviewed believe that Licensed Deck Officers will be utilized in RCCs. According to an EMSA employee, "it is most likely that operators will work in control centers ashore. It is important to define the standards of competence needed for such positions first."

5.4. External Factors

The theme of External Factors includes the codes of maritime organizations, Maritime labor unions, navigational rules (liability), and technology and innovation. One specific issue is how autonomous ships will interact with each other, as COLREGs do not currently address this, and who is liable once an accident occurs. One interviewee from a respected International Flag Registry noted that nothing will be done regarding the flag state until COLREGs and specific manning requirements are established. It may take many years for regulation to change and take effect, and maritime organizations and rule makers have to pave the path for other organizations to follow.

It was stated by three interviewees that the Maritime Labor Unions will work with the idea of autonomous shipping and that they are not afraid or threatened by it. This reinforces the idea that the future of shipping is ever evolving, and seafarers will have to evolve with it.

There was also a recurring code of technology and innovation. A concern was that most autonomous shipping projects are on their own trajectories. As mentioned by a

leader in MET, different technologies are being developed at different paces with different outcomes and goals.

5.5. Adaptability

The theme of Adaptability contains the codes and subcodes of preparedness (training and education, technological savvy), current crew, industry mindset, maritime sector, and flexibility. It is generally accepted that onboard positions will be reduced, but the experience, education, and training that Licensed Deck Officers possess will be needed for shoreside positions. Newer skills, such as proficiency in data analysis, will be required in a world with more technologically advanced vessels. This may be attractive to some mariners but may also raise licensing concerns for others. "Jobs of merchant mariners are not going away, they are going to change. Looking at steam, there were sailors before steam, they harnessed the wind. Then when diesel came, sailors were still there, they changed. History repeats itself." Training will have to include more technical skills. Multiple experts who were interviewed agreed that qualified maritime personnel with strong backgrounds in IT and programming will be needed. Most interviewees had a positive outlook compared with the survey responses regarding jobs being available in RCCs for Licensed Deck Officers, agreeing that there will be enough opportunities in the future as long as they are willing to adapt.

From the survey open-ended question, an echoing theme is that the maritime industry is slow to change and that automation will be an incremental process and will take time to be fully adapted. A mental shift within the industry will have to occur. It was also stated that it will take at least 10 years for delegations from IMO to adjust regulation. This is in-line with most of the interview responses.

The responses as to which maritime sector will adapt to autonomous shipping first varies from the interview versus the survey answers. Two interviewees were certain that it would be inland shipping, one determined that it would be the ferry industry, two determined deep sea, and two decided on short sea shipping. The survey resulted in almost 50% of participants choosing deep sea shipping.

5.6. Limitations

The qualitative method of using semi-structured interviews with open-ended questions, as used in this research, allows for the opportunity for the interviewee to bring up subject-related issues that they deem pertinent [57]. As it is important to investigate the potential risks and benefits of autonomous shipping from the perspective of the Licensed Deck Officer, this research using semi-structured interviews and surveys is limited by its sample size. It would benefit this research to expand and include a larger sample size of Licensed Deck Officers and maritime and autonomous industry SMEs.

6. Conclusions

Recent years have seen a surge in research and development in autonomous shipping technology. Various maritime organizations, private companies, governments, and academic institutions are paving the way to reduce and potentially remove crew from merchant ships. The two main driving forces behind these developments are reduction of maritime accidents and cost savings. There is currently no one answer how or when autonomous shipping will be implemented.

The purpose of this research was to investigate the potential risks and benefits that the implementation of autonomous shipping may have on the Licensed Deck Officer, focusing on using their perspective as the ship operator. A qualitative approach was used for this research, using literature review, survey questions, and open-ended interviews of SMEs. A Theoretical Thematic Analysis was used to analyze the data to conclude overarching themes, and these results were linked with survey results.

Based on the performed research, it can be concluded that the maritime sector will be impacted by autonomous shipping, but many barriers and unknowns exist with its

implementation. Changes in regulation must be addressed first. Reducing crew and increasing automation have potentially negative effects on the Licensed Deck Officer, as 57% of survey participants believe that an increase in vessel automation will increase over-reliance on sensors, and 76% disagree that SA can be accurately replicated shoreside. Vessels are not currently seen as having the practical potential to be safely operational, as 71% of participants disagree that reducing onboard crew while increasing shipboard automation is safe, and two-thirds state that it will not be safe to operate vessels at level 4 in the future. Additionally, 76% of survey participants believe that less traditional Licensed Deck Officer positions may exist in the future, and their skillsets will need to change, but many believe that the mariner will adapt and new jobs requiring their experience will emerge.

As autonomous shipping technology develops, promoted use of interinstitutional platforms to draw upon the expertise of SME to include Licensed Deck Officers is recommended as 90% believe that shipping companies, unions and MET facilities are not adequately prepared for changes in the industry. It is also recommended that further research should be conducted in the field of MET as 62% of survey participants believe that MET will appreciably change within the next decade. New skills and STCW competencies may be required, but discussions regarding the operator skills necessary to meet these future requirements are currently limited [58].

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