ΟΙΚΟΝΟΜΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

MSc in International, Shipping, Finance and Management

″Risks Associated with Unmanned Vessels″

by

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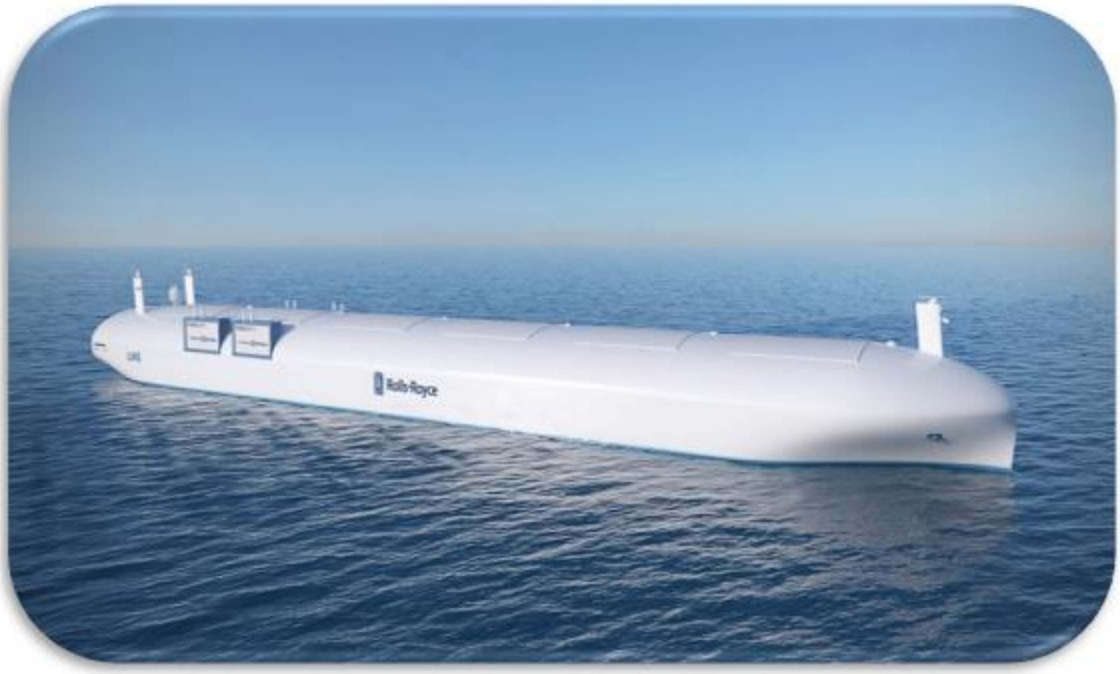
A Thesis submitted to the Secretariat of the MSc in International Shipping, Finance and Management of the Athens University of Economics and Business as partial fulfillment of the Requirements for the Master’s Degree



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CERTIFICATION OF THESIS PREPARATION

″We hereby declare that this particular thesis has been written by us, in order to obtain the Postgraduate Degree in International Shipping, Finance and Management, and has not been submitted to or approved by any other postgraduate or undergraduate program in Greece or abroad. This thesis presents my personal views on the subject. All the sources we have used for the preparation of this particular thesis are mentioned explicitly with references being made either to their authors, or to the URL's (if found on the internet).″

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1.Abstract

Unmanned transports are gaining acceptance from industry and public entities as research and innovations bring the possibility of driverless trucks and vessels closer to realization. This raises some legal and liability issues that needs to be resolved. Insurers also need to address the risks related to new technologies and the internet of things. New types of failure modes may be introduced, due to lack of knowledge and unforeseen interdependencies in the system design, operation complexity, and environmental challenges. Cyber-attacks, connectivity, interactions between components and between technical systems and humans, and autonomy assisted accidents are among the challenges. To become insurable, the use of autonomous systems must rely on proper industry standards, certification and classification regimes. Verification of safe performance will be crucial.

An unmanned vessel can be both remote controlled or fully automated, and it has been suggested that the first crewless vessel will be in service by the end of the decade. Most likely, there will be a number of variations and a stepwise progress, including the use of automated technologies with a reduced number of crew on board and for certain manoeuvres.

The development is driven by industry and government-run projects such as the Advanced Autonomous Waterborne Applications (AAWA) project backed by the Finnish Government with key players such as Rolls-Royce and FinnFerries. EU-sponsored research project MUNIN (Maritime Unmanned Navigation through Intelligence in Networks) was completed in August 2015, Norway announced in March 2016 the world's first designated test area for autonomous vessels, and a UK-sponsored project – the Machine Executable Collision Regulations for Marine Autonomous Systems – is looking into regulations and matching navigation algorithms for unmanned ships. In addition, there are a myriad of research and commercial projects. For unmanned vessels to become a reality, the regulatory framework must be in place. Requirements concerning the person having command of a vessel, sufficient manning, training and proper lookout must be considered in international conventions (SOLAS, STCW, COLREG). In February 2017, several Flag States proposed that the IMO Maritime Safety Committee (MSC) undertake a regulatory scoping exercise to determine the extent of the need to amend the regulatory framework to enable the safe, secure and environmental operation of maritime autonomous surface ships within the existing IMO instruments. The Comité Maritime International (CMI) is also looking into this issue through an International Working Group.

2.Introduction

International shipping transports almost ninety per cent of word trade, so the safety of vessels is critical to the global economy. Mankind existence and evolution is linked with the sea for thousands of years. Large investments lead to development of the the ships, equipment and navigation skills. ″Advances in sensor technology, data analytics and bandwidth to shore are fundamentally changing the way shipping works. And as operations are digitized, they become more automated, ″ says Dr Pierre C. Sames, Director of Group Technology & Research at DNV GL. For both safety and economic reasons, the technology improvement tent to minimize the onboard crew and the unmanned vessels is no longer an idea but the today’s reality. Many new risks and legal issues are risen with this new order of things and have to be solved in order for the unmanned vessels to be prevailing.

The idea of development of autonomous shipping:

According to AGCS[1] Global Claims Review: Liability in Focus: human error accounts on about 75% of the value of almost 15,000 marine liability insurance claims analyzed over five years, equivalent to over $1.6 billion. Unmanned vessels could improve maritime safety and revolutionize movement of cargo. It is forecast that a remotely-operated local vessel could be in operation by 2020. Safety considerations will be crucial to the development of autonomous shipping with concern about the potential for collision between manned and unmanned vessels and challenges around regulation and liability issues. A critical element will be whether there will be enough backup if things do not evolve as it should.

Technology is driving safety improvements, but overreliance is a concern: Safety-enhancing technology is already finding its way into shipping. Information from voyage data recorders is already used in accident investigation but important safety lessons could also be learned by analyzing information from everyday operations.

The cyber threat at sea is a matter of concern as it grows very fast:

The risk of a cyber-attack is very common nowadays. Ship-owners are often unwilling to share information but the number of incidents that have resulted in loss of critical data, financial loss or IT problems is increasing. To date, most attacks have been aimed at breaching corporate security, rather than taking control of the vessel but there are concerns that a major cyber-attack

[1]Allianz Global Corporate & Specialty

of this nature could occur in future. Cyber security should not be neglected at a time when crew, training and maintenance budgets are already under pressure. Standard practices, such as crew education and identifying measures to backup and restore systems, should be implemented to reduce cyber risk.

The technology behind autonomous vessels is developing rapidly, including technology that could allow ships to be controlled remotely or allowed to operate autonomously. Rolls-Royce for example, which is working on autonomous technology in the maritime sector, expects a remotely operated local vessel being in operation by 2020 and a remotely-operated autonomous vessel in international waters by 2025. Fully autonomous unmanned oceangoing ships could be around by 2035. The potential uses of automation is also going well beyond the vessels themselves and stretch the entire length of the cargo movement chain.

However, autonomous shipping is likely to be phased in over time. There are many legal and regulatory issues that need to be resolved.

Safety considerations are considered crucial to the development of autonomous shipping industry. For example, only large vessels routinely have tracking devices today, raising questions about the potential for collisions between an automated ship and smaller vessels.

Fully automated shipping may be possible from a technical view, but on a global scale it may not happen given the navigational challenges of entering ports and congested routes, as well as the challenges of operating in storm and general during rough weather conditions. It could be that automated, or ships controlled from the shore, will operate on local coastal routes.
It is not yet convinced that the technology is there to navigate difficult conditions, like the Suez Canal or the English Channel. Autonomous technology has the potential to improve safety but a critical element will be whether there will be sufficient backup when things go wrong.

To conclude the introduction area it would be significant to mention that autonomous shipping will be a reality within the next five years, but it will certainly take longer for the regulatory framework to reach the same quality or standards.

3.Literature review

In our thesis we were introduced to the idea of the unmanned vessels and the risks associated with the autonomous shipping. We have studied the technological achievements and the running projects in the internet. Our main source of information were related articles where a contradistinction whether the future ships will be more profitable or riskier was presented.

According to Allianz Global Corporate & Specialty Safety and Shipping Review 2017 a large percent accidents are related to human error so autonomous shipping will vastly reduce these numbers.

In the Norwegian Forum for Autonomous Ships all projects related to unmanned vessels are presented and we see that technology for autonomous shipping exists.

The main conclusion of the MUNIN (2015) research is that unmanned and autonomous ships can and will be applied where they will be both safer and more cost-effective.

A series of guidance notices from The Shipowners Club (2017) have provided their perspective on the subject and they support that technology for an unmanned vessel to be able to operate exists but there is a long way yet for the technology to reach the demanded standards and be embraced by legislation which is correct, since it is very challenging to be able to move to a new reality.

″In reality, no proposals on unmanned ships have been made in IMO yet″ (*Arnsdorf, 2014).* Amended law framework will be one of the most difficult achievements in order to establish maritime law for unmanned vessels.

″Autonomous ships make the open seas safer″ (Toor A.2015), legislation is the main barrier to the introduction of unmanned ships. Since ships can navigate all over the world through the oceans, international regulations are essential to keep the playing field level. ″ However, the biggest challenge, which is legislation, has not or has only roughly been addressed on a global level.

″IMO has not started to consider unmanned ships because they have not received any proposal from member States or industries″ (Arnsdorf, 2014). As we can understand it all depends from a homogeneous agreement between the States in order to proceed on the achievement and to the application of this idea.

″It can be an enormous task for IMO to review and revise all related regulations owing to fast development of technologies″ (Corbett, 2015). It is true that the rapid development of the technology does not help the IMO to establish the proper regulations as the circumstances change very fast.

″There was a surprisingly high level of support for starting the work on the regulation of autonomous ships, even from countries expected to be negative as they are major suppliers of seafarers, ″ (Lasse Karlsen, 2017). The approach of people that are the future of this method was and is uncertain, but it seems that it becomes more and more a broaden idea with both negative and positive results.

″Rolls-Royce is a revolutionary remotely controlled and autonomous ships and believes such a remote controlled ship will be in commercial use by the end of the decade and a common sight on the high seas by 2030, ″ (Asbjorn Skaro, 2017). A lot of tests and application have to take place in order to be sure if the total unmanned autonomous vessels will have that commercial use that is referred by Asbjorn.

A review of the applicability of SOLAS Chapter V regulations has been performed and problems related to unmanned shipping are determined and discussed. Finally, some potential solutions and approaches to overcome those problems are introduced. However, it is expected that further studies and technical development is needed to realize unmanned ships. It is obvious even if unmanned ships will not come a reality that a lot of the technical solutions can and will be applied to today’s manned ships and may contribute to maritime safety and efficiency.

4.Presentation of the subject

Unmanned vessels are the next generation vessels with no crew members onboard which will be commanded from a shore operating center, where shore masters and engineers will be monitoring and controlling their navigation and performance through detectors, sensors, high-resolution cameras and high advanced satellite communication systems.

Automated vessels are able to provide a technological revolution in the shipping industry focusing on increasing the vessels' efficiency and in fact to offer higher benefits.

More specifically, the biggest part of vessels' operating cost is the crew wages along with all their living expenses p.ex. stores, provisions. According to OpCost report of Moore Stephens, the crew expenses are more than 50 percent of the vessel's total daily OpEx. This cost is about 2,500 dollars per day for the handysize bulkers which results in a saving of about 1 million dollars per year. The saving will be much higher in the case of tanker vessels or larger bulkers, where the crew expenses are also increased. Indicatively, the crew costs for handysize product tanker are estimated at about 4,000 dollars per day resulting in an annual saving of approximately 1.5 million dollars only from crew expenses.

The revenue of Cargo ships depends on the quantity of cargo they can load. In case that no crew will leave onboard, the accommodation installations of the vessels will be much smaller, and this will allow more spaces to be utilized for loading cargo which in fact will increase the vessel's profitability. As an example, the increase of vessel's deadweight by 10 percent will increase her revenue for about 40,000 dollars per month (as estimated on a handysize vessel performing one Indonesian-India trip per month) which is almost 0.50 million dollars higher revenue during the period of one year.

According to Rolls-Royce research[2], autonomous vessels will be up to 5 percent lighter in case the accommodation and therefore they will use about 15 percent fewer fuels which subsequently will also lower the vessel's voyage expenses.

[2] May 26th, 2017 09:22 GMT by Adam Corbett

The lower operating and voyage costs of the vessels along with the higher revenues can boost the companies' profitability. However, to have a clearer picture of the project's return, investment cost (capital expenses) of such automated ships should be taken into consideration and compared with the existing vessels.

Challenges are evolving around the regulatory framework, safety in navigation and liability, insurance cover, cyber security.

For the time being, the legislation which will regulate the autonomous ships are quite unclear. The main concerns refer to the manning and safety regulations as well as the constructions standards. According to IMO[3] International regulations, all vessels should be manned with a minimum number of crew members to be seaworthy. This principal should materially change so as to include vessels with specific characteristics which will be allowed to sail with less or no crew onboard. Same should also happen with the vessel's safety, where minimum standards of vessels' and equipment condition should apply. Since the autonomous vessels will be sailing in the same seas with standard manned ships, the legislation of navigation and collision liability might need a holistic review. The standards of construction and maintenance which is also followed by the Classification Societies should be materially amended and thus the Class societies may need staff with new expertise in the autonomous technologies and new designs. In the United Kingdom, the Maritime Autonomous Systems Regulatory Working Group is also working on the regulatory framework of the autonomous ships so as to ensure that the International Convention on Safety of Life at Sea can adopt these technological developments.

This is probably the main concern of those people who remain cautious for the autonomous ships. A vessel sailing in the open sea faces many risks which are related to the weather conditions, other obstacles which can be met around her or under her keel or even risks coming from third parties such as pirates. Therefore, such an autonomous ship should be very intelligent so as to be able to control any potential risk by herself or the help of the shore master so as to control all current risks and mitigate any new risks which may be related to the use of the automated vessels. But is this should be possible to happen in every part of the world and for any risk. The levels of liability should be expressly cleared so as all market players to be fully aware of the levels of liability of the shore master or the shipowner/ ship manager.

[3] International Maritime Organization

The existing insurance covers (Hull and Machinery, P&I Cover, War risks, Piracy risks, Cargo Insurance) should remain in place. However, the premiums might change depending on the levels of actual risks involved in the navigation of those vessels. Furthermore, the insured risks should materially change especially in P&I or Piracy Risks insurance. Initially, since the risks involved will be theoretical, the covers and premiums might be indicative. It will require a few years in order for the insurance covers and premiums to be finalized while the risk for an uninsured risk, during the first years of vessels' existence, remains despite the tests, which will be affected until the vessels' introduction in real market conditions.

A new risk which may arise with the use of remote navigation is the cyber security. A flow in the computer systems may give unauthorized access to hackers who will be able to take control of the ships. This way, a new type of piracy may be developed. Therefore, the systems should be developed in such a way that they will exclude unauthorized access but also give the shore master overriding authority over any unauthorized instruction. Furthermore, a new insurance cover may be required which will cover such type of risks.

So, a lot of analysis and concern is required in order the unmanned shipping can be fully implemented.

5.Researches and Projects regarding the new technologies

Ship design is a straightforward activity. Depending upon the role of the vessel, the design requirements, stakeholders and regulations underpinning its construction can be vast and complex. Adding automation into the mix presents its own set of design challenges and opportunities, and will require significant cooperation between ship owners, ship builders, classification societies, underwriters and P&I Clubs.

SHIP SYSTEMS

Humans are capable of the complex decision making and logic required to keep machinery in peak order and to keep the entire ship safe and navigable. Replacing crew presence inside the ship with technology would be difficult, but not impossible. There would be a need for greater redundancy to account for machinery failures; with no crew an equipment failure could not be fixed instantly. Whilst systems supporting crew welfare might shrink or be removed altogether, other systems could grow due to this increased need for redundancy. Ship operators might also start to demand higher levels of reliability from their equipment suppliers, to ensure continued vessel operation.

Propulsion architecture could also change to reduce the risk of total failure. Slow-speed diesel engines might be replaced with fully electric multi-engine architectures, ensuring continuity in case of failure. Whole systems could be duplicated to allow for a simple switch-over, negating problems until the ship arrives in port for repairs. Modularity may become a key requirement, enabling a ‘plug-and-play’ approach, so faulty equipment can be removed and quickly replaced in port.

In addition to the duplication of familiar systems, new systems would be introduced or expand. Communications to shore-based installations and satellites would be a greater priority, and the bandwidth required for achieving automation would grow. There would be a need to check the automated platform; the operating performance, location and condition of the ship will need remote monitoring, and commands will need to be delivered and acknowledged. The computational equipment needed on board would expand significantly to meet the complex demands of automation and remote communication.

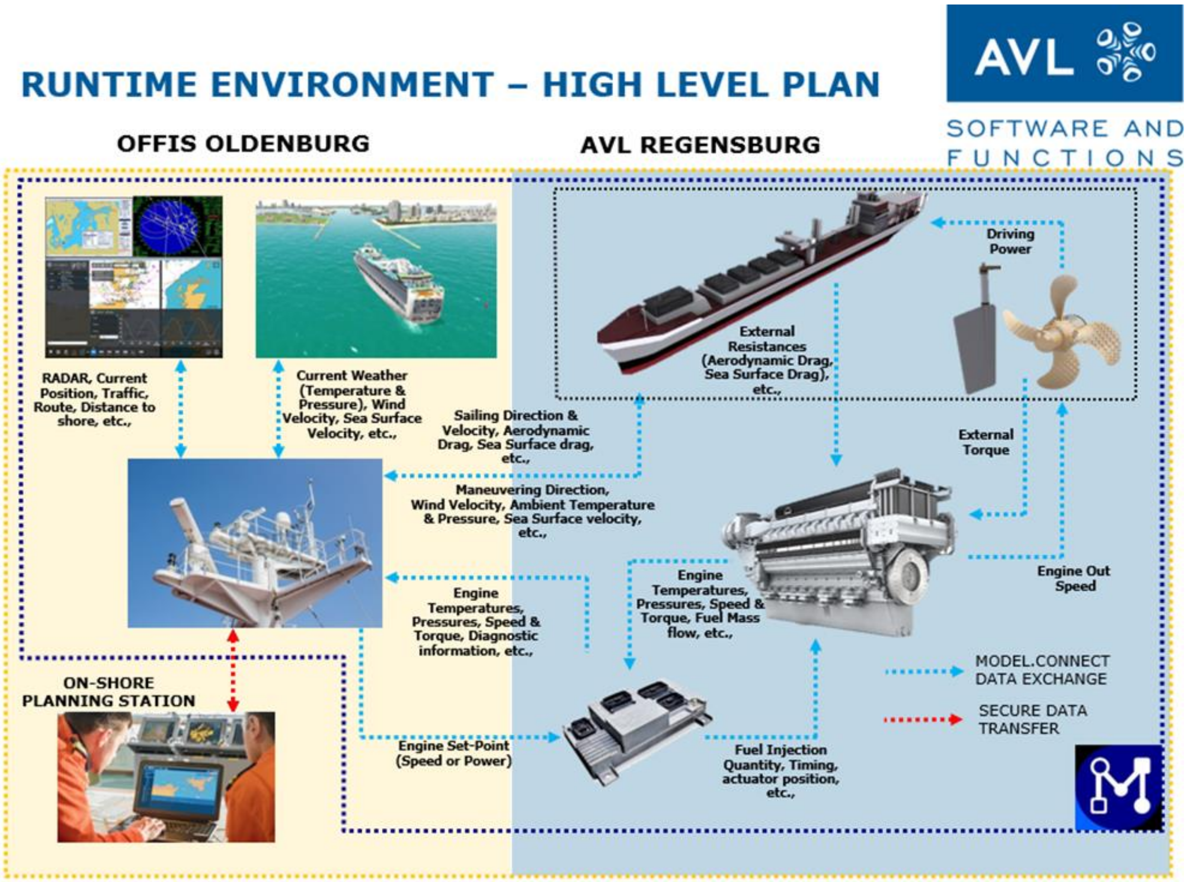
The significant growth ship control systems are experiencing is leading to the increase of initial capital costs for procurement. Ship owners and operators would place more emphasis on minimizing through-life costs, to offset the increase in the capital costs of purchase. The testing and commissioning of systems (especially automated safety-critical systems) could add a considerable burden to the commissioning and trials phases of ship design and construction. Ultimately, the need for more complex systems from the outset could push the cost burden to earlier in the ship's life cycle, and this would need to be balanced by lower operating costs.

ENABLE *3 Shore based bridge concept

This demonstrator will explore new, advanced simulation and testing opportunities in the maritime industry through close dialogue and cooperation with partners from the automotive industry in Europe. Methods, processes, references and virtual test benches utilized in the automotive industry are to be adapted to the maritime sector, and the results will be demonstrated and evaluated. Focus will be on knowledge transfer from especially the automotive industry: Early, systematic simulation, testing and validation. This also means looking at the possibility of new types of approval procedures for navigation systems based on scenario simulation adapted from the automotive industry.

Shore Based Bridge/Navigation Centre incl. Secure Data Exchange

On board a vessel planning, and actual navigation is normally done in an ECDIS system (Electronic Chart Display and Information System), frequently in combination with a planning station. By 2018 ECDIS becomes a mandatory navigation system on board most merchant vessels according to International Maritime Organization (IMO). To increase safety of navigation, ECDIS and future highly automated navigation systems need frequent updates with shore-side information. The safe and secure transfer of this information today is a major concern for ship owners and a prerequisite for further automation of navigation such as for future autonomous vessels. The impact of this ENABLE-S3 use case will be to speed up the development of advanced virtual and physical testing, simulation, and type approval approaches for highly automated navigation systems to reduce time to market for European e-Navigation (short: e-NAV) providers, thereby increasing competitiveness of European maritime industry. A shore based bridge will be developed, simulated and tested , which moves planning, monitoring and safety-critical navigation functions from vessel to shore by introducing a shore based e-NAV station receiving sensor data such as ship radar, GPS, AIS (automatic identification system), VDR (voyage data recorder), etc.



AUTOSEA - Sensor Fusion and collision avoidance for advanced ships

The AUTOSEA project is focusing on automated situation awareness using sensor fusion to reduce the risk of collisions between ships and vehicles when an increased level of autonomy is introduced. To improve detection capabilities also on small objects and better cover the close-range sector, the AUTOSEA project will, in addition to conventional maritime radar, include sensor types not normally used for such purposes in the maritime sector, like camera, infrared and LIDAR.

For the technology to be successful, it will be necessary to resolve conflicts between sensors, and to interpret and support decisions in situations of ambiguity. An increased degree of autonomy on oceangoing vehicles also needs to comply with maritime anti-collision regulations (Convention on the International Regulations for Preventing Collisions at Sea - COLREGs).

The project is divided into four areas: sensor fusion, collision avoidance, system architecture and experiments. Sensor fusion involves detection and tracking of moving objects during navigation and maneuvering using imaging sensors, while collision avoidance will investigate both proactive and reactive methods. System architecture will consider reliability, handling of erroneous data and adaptation of strategies from the automotive and aerospace industries. Experiments will be used to validate and demonstrate COLREGs-compliant navigation and control and assessing detection capabilities using different sensors.

Project partners

The Norwegian University of Science and Technology (NTNU) is Norway's primary institution for educating the future's researchers, scientists and engineers. NTNU's research is cutting edge, and many of the technological and cultural innovations that allow Norway to extract oil from the North Sea, grow healthy salmon in fish farms, or interpret the country's 9.000 years of human history have been developed there.

DNV GL is the world's leading classification society and a recognized advisor for the maritime industry. They enhance safety, quality, energy efficiency and environmental performance of the global shipping industry – across all vessel types and offshore structures. They invest heavily in research and development to find solutions, together with the industry, that address strategic, operational or regulatory challenges.

Maritime Robotics provides products and systems solutions for Unmanned Vehicle Systems for maritime data acquisition. With its main office in Trondheim, Norway, the company is now internationally promoting and delivering 3 product groups of unmanned vehicle systems: Unmanned Surface Vehicle (USV), Moored Balloon System (MBS) and Unmanned Aircraft System (UAS). The main markets are within applications for environmental monitoring, geophysical data acquisition and defense/security.

Kongsberg Maritime is a global marine technology company providing innovative and reliable technology solutions for all marine industry sectors including merchant, offshore, subsea and naval. Headquartered in Kongsberg, Norway, the company has manufacturing, sales and service facilities in 20 countries. Kongsberg Maritime is part of Kongsberg Gruppen (KONGSBERG), an international, knowledge-based group that celebrated 200 years in business during 2014.

AAWA - The Advanced Autonomous Waterborne Applications

The AAWA project was started by Rolls Royce to develop specifications and possible designs for the next generation completely or partially autonomous ships. Finding the optimum way to combine the different sensors technology in a range of operating and climatic conditions will be the subject of a series of tests at sea. The need is to develop a set of electronic senses allowing the vessel to navigate safely and avoid collisions. The Rolls-Royce led, Advanced Autonomous Waterborne Applications Initiative (AAWA) project is exploring technologies such as sensor fusion, control algorithms and communication and connectivity to support this development.

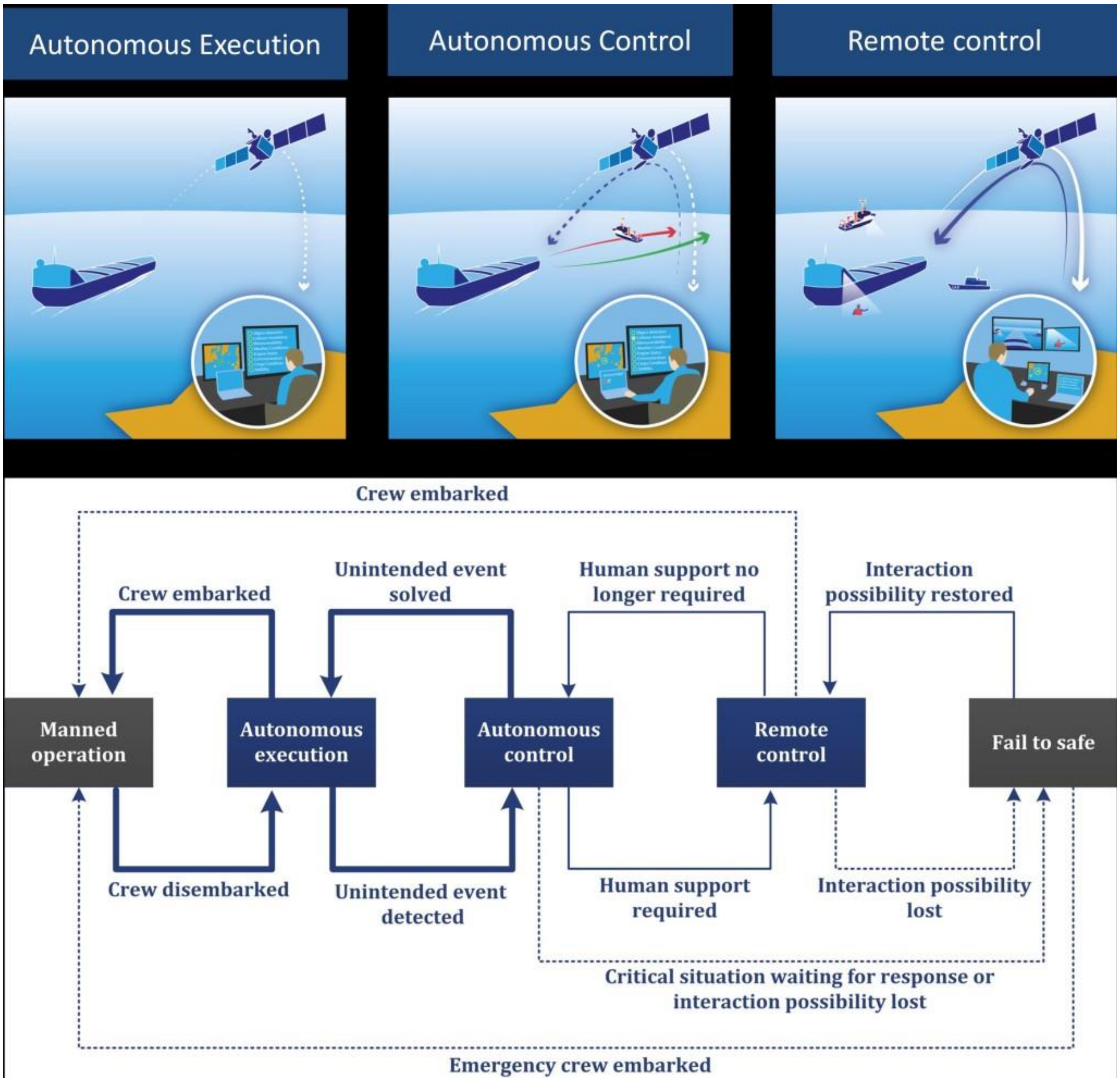
The project has explored the contribution different sensor technologies make in providing a vessel or its remote operators with an accurate perspective on the vessel's surroundings. Looking at different types of radars, high definition visual cameras, thermal imaging and LIDAR, the project has concluded fusing multiple sensor inputs provides the best results.
Navigation and collision avoidance will be particularly important for remote and autonomous ships, allowing them to decide what action to take in the light of sensory information received. The development of control algorithms will be a gradual and iterative process and subject to extensive testing and simulation in addition it requires an interpretation of maritime rules and regulations.

Autonomous vessels will still need human input from land, making connectivity between the ship and the crew crucial. The project is exploring how to combine existing communication technologies in an optimum way for autonomous ship control.

MUNIN - Concept study for unmanned bulk ship

MUNIN was an EU project that ran from summer 2012 to summer 2015. It is a concept study for a completely unmanned Handymax bulk carrier. The project came right at the start of the great interest that autonomous ship later created and has published a number of articles and open reports. MARINTEK (now SINTEF Ocean) was technical coordinator of MUNIN.

The use case investigated in MUNIN is a dry bulk carrier operated in intercontinental trade. This type of trade bears a high attractiveness for the MUNIN concept, as additional cargo requirements are low, the attractiveness for slow steaming is high and dry bulk carriers normally transport cargo from point to point resulting in a long, uninterrupted deep-sea voyage compared to e.g. container vessels. This is an important characteristic, as MUNIN only envisages autonomous operation of an unmanned vessel during deep-sea-voyage, but not in congested waters or during the approach. Those tasks will still be executed by a crew on board, though the deep-sea/voyage-length ratio is an important economic factor for the operational efficiency.



Some of the areas where the research and development conducted in the MUNIN project may find an application are described in the following.

Better obstacle detection can reduce accidents by providing decision support for the officer of the watch. Anti-collision radars (ARPA) and Automatic Identification Systems (AIS) are standard on modern ships today and contribute significantly towards the reduction of maritime collision incidents. To improve technological anti-collision means in the future new sensor systems based on, e.g., infrared, low light cameras or laser range finders as well as small object radar detection bring along substantial potential. The technical systems by themselves are sufficiently advanced for a maritime deployment. The challenge is their integration into legacy systems as well as the combination of complementary data form different sources to improve the overall performance. Since an autonomous ship has to rely solely on its sensors to detect objects in its vicinity, the design of such surveillance sensor system takes in a prominent role within MUNIN. Likewise, the insights gained in this area will bring along the potential to improve or augment today's bridge equipment and accordingly enhance the support it offers the officer of the watch.

Furthermore, improved small object detection also is a valuable capability during Search and Rescue operations. Especially in extreme weather conditions with limited sight and heavy sea, highly advanced sensor systems developed for autonomous ships can considerably enhance the ability of today's ships to detect e.g. a lifeboat in its vicinity.

Besides a mere detection of possible threats of collision, highly advanced navigation systems will increasingly be capable to evaluate the current traffic situation and recommend suitable solutions to avoid upcoming dangers or even induce an action to avoid a collision in the last moment, a functionality that can be found in cars already today. Such capabilities are indispensable for an autonomous ship and accordingly will be studied in the MUNIN project. The identified solutions can also be adapted for manned ships where they would support the officer of the watch.

NTNU AMOS - Centre of Excellence Research

NTNU AMOS is a center of excellence which is led by the NTNU in Trondheim. AMOS stands for "Centre for Autonomous Marine Operations and Systems". AMOS covers all forms of autonomy, on land, in the air, at sea and under the sea.

NTNU AMOS will contribute with fundamental and interdisciplinary knowledge in marine hydrodynamics, ocean constructions and control theory. The research results will be used to develop intelligent ships and ocean structures, autonomous unmanned vehicles (under water, on the surface and in air) and robots for high-precision and safety-critical operations in extreme environments. This is necessary to meet challenges related to environmental and climate, safe maritime transport, mapping and surveillance of large ocean and coastal regions, offshore renewable energy, fisheries and aquaculture as well as deep-sea and Arctic oil and gas exploration.

Test area Grenland

In May 2017, the port authorities in the Grenland area applied for test-area status. This area has much more traffic than Trondheim and will be useful to test more developed concepts in heavy traffic environments. The area also includes an VTS which will further add to the usefulness as a test-area. There is also significant maritime industry and research going on in the area and they will get test facilities much closer to home.

Test area Trondheimsfjorden

Through an agreement between national authorities and the industry and research organizations in the Trondheim region, a partnership has been established to develop Trondheimsfjorden into a test area for autonomous vessels. The agreement was signed aboard the research vessel Gunnerus 30th September 2016. The purpose of the agreement is to facilitate the testing of fully or partly unmanned vessels and to exchange experience and data to facilitate the development and use of such vehicles.

Milli-Ampere: Autonomous passenger ferry

Milli-Ampere is a small autonomous and unmanned passenger ferry that is intended for use in the port area of Trondheim. It is an on-demand ferry that is proposed as an alternative to a bridge that would otherwise hinder boat traffic in the area. NTNU is leading the development work.

Yara Birkeland

The vessel Yara Birkeland will be the world's first fully electric and autonomous container ship, with zero emissions. Yara will reduce diesel-powered truck haulage by 40,000 journeys a year. Birkeland will initially operate as a manned vessel, moving to remote Yara operation in 2019 and expected to be capable of performing fully autonomous operations from 2020. The new zero-emission vessel will be a game-changer for global maritime transport contributing to meet the UN sustainability goals.

ASTAT - Autonomous Ship Transport at Trondheimsfjorden

ASTAT will examine possibilities for operating small and battery powered unmanned ship in the Trondheimsfjord area. This will mainly be as replacement for today's truck transport. The project will develop a high-level design of the vessel and supporting equipment ashore. The design will in principle cover both bulk and break-bulk transports. Kick-off was in May 2017 and the project will run for two years.

Signing MoU between Smart Ship Coalition and NFAS

At October 21st 2017, the governor of Michigan, Rick Snyder, and the general manager of NFAS, Ornulf Jan Rodseth, signed a Memorandum of Understanding (MoU) for exchange of information and non-competitive cooperation on smart ship technology and autonomous ships. This is part of an international network of organizations working on unmanned ship technology that is under establishment. The "Smart Ship Coalition" covers organizations in the Great Lakes region both in USA and Canada.

6.Capital cost, gains and losses

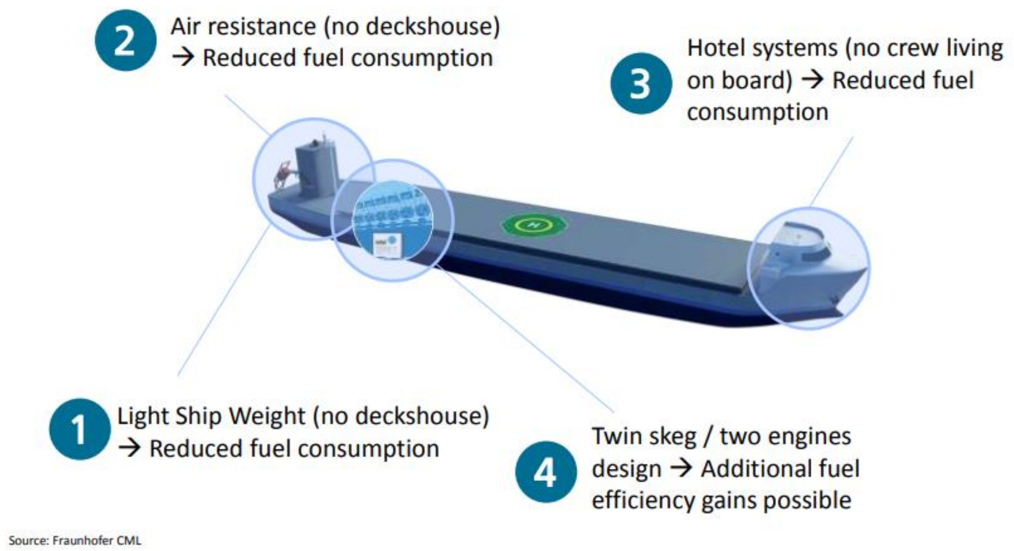
Autonomous ships can provide the advantage of reducing/eliminating the expense of salaries and benefits for crew members.

1) Efficiencies of Ships Without a Crew

Once the need for having crew on board is eliminated, the entire vessel can be radically redesigned to improve efficiency. For example, systems once needed to make the vessel livable for the humans can be removed entirely, simplifying the design.

The deckhouse that currently sits above the deck of ships, holding the crew and allowing them to steer the vessel, would no longer be required. This could open up more space for cargo, possibly making loading easier, or allow for a more aerodynamic profile.

When automation becomes viable, the industry isn't planning to just make the same cargo ships they currently do minus crew. They are planning on making a whole new class of vessels re-envisioned from the ground up.



It seems likely that crew reduction will occur before total crew replacement. Until robots become dexterous enough to fix engines or complete other routine onboard tasks, humans may need to be in the loop – even if just in the case of emergencies. Given the robotics applications for learning complex physical tasks (including surgery, factory assembly, and more), we might expect robotics crews to go along with autonomous vessels in the next decade ahead.

2) Reduced Human Error and Risk

Autonomy also holds the promise of reducing human error and therefore bringing down costs related to accidents and insurance. According to Allianz Global Corporate & Specialty, between 75% and 96% of all accidents in the shipping sector can be attributed to human error. These incidents rank as the top cause of liability loss.

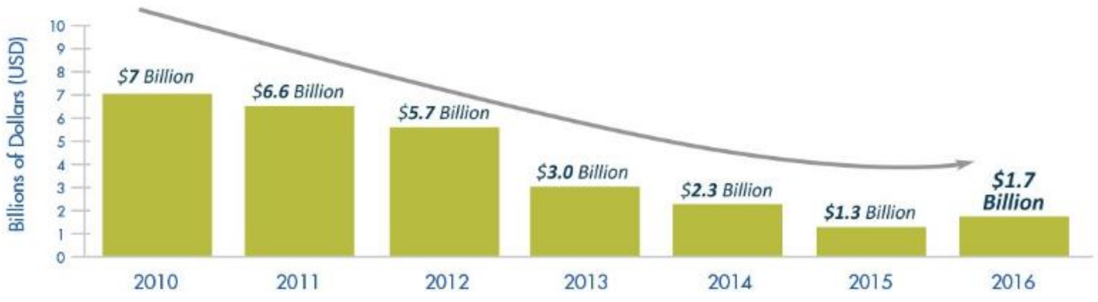
The Costa Concordia disaster is perhaps the most famous example of how much damage human error can cause when dealing with massive ocean-going vessels. On the other hand there are error possibilities in the machineries as well.

3) Reducing the Risks of Piracy

Kidnapping crew members for ransom money is a main driving force behind modern piracy. Without human crews to threaten or hold hostage, the issue of piracy along certain trade routes would also likely be reduced or mostly eliminated.

Cost of Somali Piracy

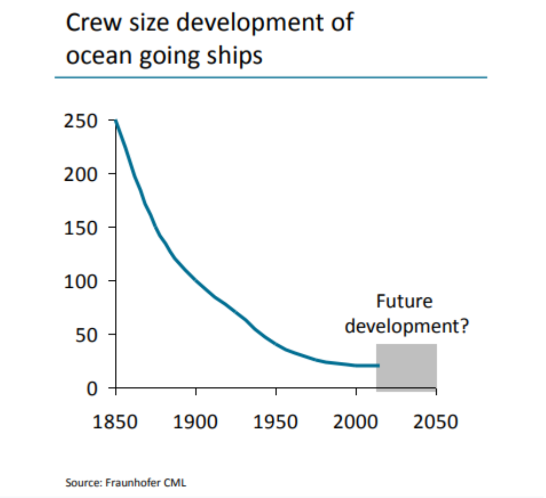
The economic cost of Somali piracy was $1.7 billion in 2016 and $7 billion in 2010. Pirate attacks in Sulu and Celebes Seas has result in some merchants choosing to change their routes which can mean longer delivery times.



The economic cost of Somali piracy, as reported by www.oceansbeyondpiracy.org

The economic benefits of autonomous vessels are centered around lower operational costs due to reduced fuel consumption and crew costs. Most of the reduced fuel consumption is due to the removal of the accommodation structure, which can result in a reduction of fuel due to the reduction in weight and air resistance. At the same time removal of the accommodation structure lowers construction costs and opens up for more cargo space and thus higher freight income.

As a result the full benefit of the autonomous technology is only likely to be obtained if a vessel is completely unmanned. If an autonomous vessel is manned, but with a reduced crew, much of the benefit is lost as the vessel will still incur certain crew costs and, more importantly, needs a costly, heavy and bulky accommodation structure.



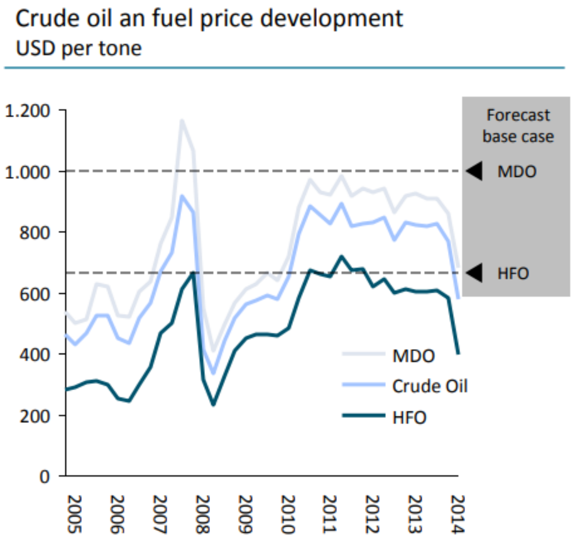
The cost reductions must in turn be balanced against higher capital expenditure when constructing autonomous ships. With no crew onboard there is much greater need for technical redundancy systems, such as twin screw rather than single screw propulsion, which drives up costs.

Moreover, reduced fuel consumption may not necessarily translate into lower costs for an autonomous vessel. The Heavy Fuel Oil (HFO) is widely used today because of its low price but it is dirty, greasy and maintenance intensive. Without humans to ensure the smooth operation of engines operating on such fuel, machinery breakdown is a likely outcome. Autonomous vessels must instead turn to higher-grade fuel such as Marine Diesel Oil (MDO) or Marine Gas Oil (MGO). Such fuel is considerably costlier than HFO and prices of MDO/MGO would have to decrease to justify an investment in an autonomous bulker in the current market.

- Impossible to predict how fuel prices develop in future
- Necessary to predict how fuel prices develop in future
- Approach based on forecast for crude oil prices (IEA World Energy Outlook)

	2020	2025	2030	2035
Crude Oil [USD/barrel]	119.5	121.9	123.6	125

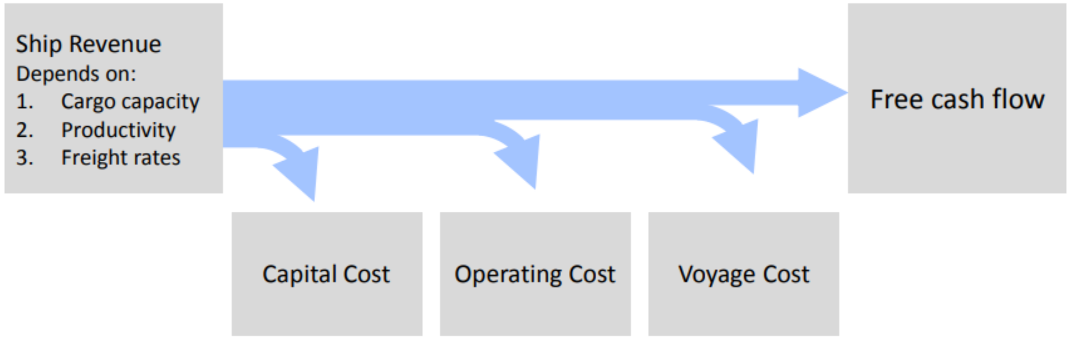
- Oil price is converted into fuel prices (HFO/MDO) based on past ratio



Source: IEA World Energy Outlook 2012, Fraunhofer CML

Interestingly, this may very well change with the new IMO emission rules scheduled to take effect from 2020. Fuel such as MDO or MGO emitting less sulphur will then become a much more viable alternative to HFO, which can only be used if expensive and space constraining scrubbers are installed instead.

Further to the above uncertainty surrounding investments into new technology a strong consideration should be added regarding the fact that the return on an investment into new vessels must be calculated for 25 years, the generally accepted life-span of a vessel. This is a powerful disincentive for investments into a new and untried technology such as autonomous vessels.



- If cost over lifetime of unmanned autonomous bulker is lower than cost of conventional bulker it will generate a higher free cash flow

Source: Stopford 2009

One important variable is the cost of insurance. As around 75% of marine casualties are caused by human error, there is good reason to think that marine accidents are likely to be reduced due to autonomous vessels, with lower insurance premiums to follow. However, at the same time mitigating the effect of incidents will be challenging without the presence of humans. This casts some doubt on the insurance consequences of unmanned vessels. Insurers cannot easily model a new concept as there is no available data and are therefore likely to err on the side of caution when underwriting the risk.

7.Risks

Autonomous shipping could face risk of disconnected regulation

Regulations for unmanned vessels could occur in a disorganised manner as the International Maritime Organization's Maritime Safety Committee could take some time to come up with specific measures, according to Helle Hammer, managing director of Cefor and chairwoman of the International Union of Marine Insurance Political Forum (IUMI).

The committee in June said *"it would carry out a regulatory exercise to gauge the necessity of amending the regulatory framework to ensure safe, secure and environmentally sustainable operations for Autonomous Ships. "*

The scope is to identify IMO regulations which exclude unmanned operations as currently drafted, would have no application to unmanned operations, do not preclude unmanned operations but may need to be amended. IUMI supported the IMO's proactive role to ensure a coordinated international approach to the operation of autonomous ships. However, the scoping exercise will not be completed till June 2020 and only then will the committee begin the process of amending current regulation or coming up with a separate code for the operation of unmanned vessels. This means that it will be years before the IMO even decides on any amendments, and the outcome is far from certain.

During the exercise, number of member states had supported opinions outlined by the International Transport Workers' Federation, which suggested a more all-encompassing approach to factor in the human element, technical and operational aspects of autonomous vessels.

There are concerns as Norwegian chemical company Yara International partnered Kongsberg Maritime to construct the world's first fully electric and autonomous containership Yara Birkeland, which is scheduled to start operations in the second half of 2018 to transport cargoes across three ports in southern Norway. The vessel will start off manned by a crew before transitioning to remote operations in 2019 and is scheduled to be able to be fully autonomous from 2020. Class societies and the Norwegian Maritime Directorate are working closely to find out a regulatory framework to operate the vessel. An enterprise established by the Norwegian

Ministry of Petroleum and Energy, Enova, at end-September disbursed a NKr133.6m ($16.8m) grant to Yara International to finance the development of the autonomous containership. Kongsberg Maritime is also collaborating with Automated Ships and Bourbon Offshore to fund a prototype offshore support vessel, Hrönn, which will follow a similar path to achieving fully autonomous operations.

It is likely that national rules for domestic trade will emerge while the IMO is still conducting its scoping exercise for international trade. Likely, this will not lead to a national reproduction of rules, but rather as input to a future international harmonization of the regulatory framework.

Awareness and Control of risks:
The goal of Situational Awareness and Control is to ensure that the unmanned vessels have sufficient information, construction and control of its position and systems, to enable them to be as safe as a manned counterpart operating in similar circumstances.

A Risk Assessment will be undertaken using an appropriate method, e.g. Failure Mode Effects Analysis (FMEA), so that to identify the risk levels associated with the unmanned vessels and its operation. Internal and External sensors may be used to monitor the state of the platform and the external environment. It is convenient to have the ability to interpret sensor data in terms of its immediate impact on the performance, and its direct or indirect effect on the safety of the monitoring automated ships (MASS), surrounding structures and vessels, humans and environment.

The control system will be designed and constructed to enable its operation
and operate in a predictable way with a level of integrity proportionate with operational and safety requirements. Also, to ensure the watertight and weathertight integrity, to meet buoyancy and stability requirements and minimize the risk fire and explosion.
Operators will be provided with adequate access and instructions for the safe operation and maintenance of the control system.

The main challenge is that Conventions do not correspond to unmanned ships. According to *Toor (2015),* there is a perception that regulatory challenges could create a bigger bottleneck than technical ones. International shipping works under international regulations. States implement regulations and ships need to comply with these regulations. However, these regulations were developed for conventional ships, not for unmanned ships. In other words, there is no regulation for unmanned ships yet. It may be interpreted that unmanned ships do not need to comply with existing regulations. There is no any clear definition that clarifies whether the definition of ship includes unmanned ships or not (AAWA, 2016). Certainly, this is a grey zone, but many thinks that the definition of ships includes unmanned ships. Furthermore, there is a minimum manning requirement in SOLAS. In this situation, unmanned ships are illegal to operate on an international voyage *(Arnsdorf, 2014; Toor, 2015).*

Looking into details of Conventions, according to AAWA (2016), SOLAS, COLREG[4], STCW[5] and liability regulations must be reviewed and amended. Firstly, SOLAS is the main Convention for maritime safety and corresponds a range of factors under its 14 chapters. However, it is difficult to apply this Convention to unmanned ships since equipment, design and operational procedures will be] different from the rest of the ships because no human operator will be on board. In order to make unmanned ships as safe as conventional ships, SOLAS must be reviewed and amended carefully.

Secondly, COLREG is another important Convention that regulates the operation of ships to avoid collision, addressing factors such as look-out (IMO). On unmanned ships, sensors will act as a substitute for humans to implement look-out. However, COLREG requires crew to be on board to implement look-out. It should be considered whether sensors can be replacement for humans or not *(AAWA, 2016*).

Thirdly, STCW is a Convention that regulates training, certification and watchkeeping standards for seafarers (IMO). This Convention applies to seafarers on board, not persons on shore (AAWA, 2016). Persons who oversee remote control and supervising ships from shore are not regulated in this Convention. In other words, no regulations apply to those persons. Since they have authority to control ships, there must be regulations to authorize them. A potential approach to solve this operational and administrative problem may start from Vessel Traffic Services (VTS) rules and regulations. This is an example of the type of scheme applicable to shore-based operators, such as Vessel Traffic Services (VTS).

[4] Convention on the International Regulations for Preventing Collisions at Sea

[5] International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978

IMO developed ″GUIDELINES FOR VESSEL TRAFFIC SERVICES (Resolution A.857(20)) ″ and IALA developed ″Standards for Training and Certification of VTS Personnel (IALA Recommendation V-103) ″. These guidelines provide model training courses for VTS operators and certification schemes to qualify VTS operators to ensure that they have enough knowledge to handle VTS *(IALA,2013; IMO, 1997*).

Lastly, the liability of unmanned ships needs to be more comprehensively discussed. When accidents may occur under the controlled of the systems, who will be liable? This must be highlighted before unmanned ships are put into service. Some car companies have stated that ″we are the suppliers of this technology and we are liable for everything the car is doing in autonomous mode. If you are not ready to make such a statement, you shouldn't try to develop an autonomous system″ (*AAWA, 2016*[6]).

But the important part is that legislation for cars may be different from ships and maritime legislation, so it is difficult and needs to be studied in detail to adopt this principle. Furthermore no proposals on unmanned ships have been made in IMO yet (*Arnsdorf, 2014)*. It might be supported then that no States are ready to accept unmanned ships or put a priority on unmanned ships, even though some classification societies have projects about unmanned ships. According to United Nations Convention on the Law of the Sea (*UNCLOS) (1982*), ships need to be registered under the flag of one State. Ships need to comply with the national regulations of that state in accordance with international regulations, but there are no international regulations. It is possible for flag states to develop their own national regulations; however, it might be difficult to navigate to another country with different regulations. Concluding, lack of international regulations is already causing a lack of national regulations. This means that no State can sail unmanned ships, except for domestic internal navigation purposes.

There are several risks related to operation, such as maintenance, cargo management, response to emergency situations, search and rescue (SAR), and workload.

First, to the replacement of the daily maintenance operations is one of the difficult tasks. Daily maintenance is an essential factor for maintaining ships in good condition *(Hapag-Lloyd,*

[6] Advanced Autonomous Waterborne Applications

2016). There are two benefits. One is that the docking period of a ship can be minimized, and another is that the risk of technical failure might be reduced. These benefits may be able to maximize profits because the operation of ships can be maximized. In addition, when it comes to selling ships, good condition is a key. However, unmanned vessels do not have crew on board to implement daily maintenance during voyages.

Secondly, responsibility for cargo management is another crucial problem. Normally, the chief officer oversees cargo management on conventional ships. The management of the loading and unloading of cargo is an essential job for the chief officer. However, in unmanned ships, there is nobody who can implement cargo management on board. So, it is necessary to find another person who can be in charge of cargo management or a completely new solution needs to be established. A possible solution on that may be the port operators or designated person, but they need to be trained and procedures must be developed (*AAWA, 2016)*.

Thirdly, response to emergency situations should be considered. It takes time to respond to emergency situations from shore (*Hapag-Lloyd*, *2016).* It is possible to install additional equipment for these situations, but it may augment the price of ships and reduce the benefits of unmanned ships. Also, there is no clear instruction to determine how much additional equipment might be enough or what additional equipment might be needed.

Fourthly, Search and rescue (SAR) needs to be discussed strictly. Under SOLAS Chapter V, ships are required to engage in SAR when they receive a distress call. Unmanned ships cannot provide rescue operations, although they could possibly to assist in search operations. If there are only unmanned ships, this is not going to be a problem. However, there might be manned and unmanned ships together. The SAR procedure of unmanned vessels should be discussed and developed in accordance with their ability. Unmanned ships may provide some life-saving appearance and could be brought to the emergency scene.

Finally, limitation of work load of operators on shore should be identified. As mentioned before, there is no regulation for operators on shore. It might be possible to apply the labor laws of land to them. However, there is no information as to how many ships an operator could handle at once. For instance, in Unmanned Aircraft System (UAS), some mistakes have already taken place when the operator changeover. These mistakes may cause accidents (AAWA, 2016). Work load should be limited in order to avoid accidents and operators should have some frames to be able to respond to any situation. In addition, to prevent this kind of mistakes, certification of operators might be helpful.

Analysis of challenges

The combination of surveys and PSC[7] is an effective way to maintain the safety of ships. Certainty, this would apply to unmanned ships. However, since unmanned vessels are a new concept in maritime industry, there could be some impacts on these schemes. The big challenge is that, according to present state of the art, unmanned ships will consist of ships and remote-control centers. Currently, there is no scheme to check this kind of facility. The main challenge is how to implement flag State surveys to unmanned ships, especially if they are connected to a remote-control center. In addition, determining the interval of surveys is another challenge because remote control rooms may supervise several ships at the same time. Furthermore, since no crew is on board, it is impossible to carry out PSC as it is an essential item to be examined analytical. These three challenges, flag State survey, interval of surveys and PSC shall be further analyzed and examined in the frame of unmanned vessels, in order to be a reality.

[7] Port State Control

8.Questions regarding law material

A Regulatory framework and the Classification regime

The development of unmanned vessels has continued at a very significant pace over the recent years with more vessels entering operation. They come in a variety of sizes and have a very diverse set of operational capabilities which all place their own unique demands on those who own and operate them and the remainder of the Maritime Community. This Code of Practice (″Code″) has been prepared by the UK Maritime Autonomous Systems Working Group (MASRWG) and has been published by Maritime UK through the Society of Maritime Industries. It has been reviewed by the UK Maritime and Coastguard Agency (MCA) and the Agency will need to conduct several regulatory scrutiny processes before it will be able to publish this style of document. This will depend to some extent on the progress made within the IMO Scoping Exercise. For the interim period, this Industry Code of Practice ask to provide practical guidance for the design, construction and safe operation of autonomous and semi-autonomous vessels under 24 meters while the more detailed regulatory framework for development.

This Code will be updated as required when guidance from the IMO Regulatory Scoping Exercise is published, and as the MCA develops policies to meet the needs of forthcoming technological and regulatory developments. The primary aim in developing the Code has been to set initial standards and best practices for those who design, build, manufacture, own, operate and control of autonomous vessels of less than 24 meters in length. But it will establish some principles and guidance which will be applicable for those operating larger ships. It should be read in connection with ″An Industry Code of Conduct″ for Maritime Autonomous Systems (Surface) which was published by the UK Marine Industries Alliance in March 2016. The Code also deals with the equally important subject of remote manning and of the training and qualifications that needs for those operating unmanned vessels.

Another query is the intent to ensure a degree of equivalence with the provisions of the current IMO instruments (COLREGS, SOLAS, MARPOL, and STCW) and to provide links to related documentation (e.g. ISPS, IMDG, ISM, Fire Safety Code and the Load Line Convention). The Code also aligns with other relevant documents, for example the Lloyds Register Unmanned Marine Systems Code and the SARUMS Best Practice Guide for Unmanned Maritime Systems.

It is believed that Maritime Administrations may be able to use the Code as a basis for their instructions to their Recognized Organizations (RO), or other flag State authorized bodies, to facilitate due regulatory compliance. The potential for authorization of RO has been influenced by the requirement to have a local capability for the efficient handling of the needs of owners and operators of some classes of MASS. Authorized RO are generally permitted to charge for undertaking Code of Practice examination and certification processes as a provision of their authorization.

The International Maritime Organization (IMO) from its scope, is in line with the proposal and will start mapping how existing international regulation can be applied to autonomous ships and maritime technologies. Submitted by Denmark, Estonia, Finland, Japan, the Netherlands, Norway, South Korea, United Kingdom and the US, the proposal gave rise to a prolonged debate, which showed that many safety and legal issues still remain to be solved as regards autonomous shipping. According to plan, this issue will be discussed at the next meeting of the Maritime Safety Committee (MSC 99), and then a plan will be drawn up for further consideration of the matter.

"Despite some concern, it was generally agreed that the IMO needs to start its work now. There was also general agreement that the IMO must take into consideration how developments will affect the seafarers, " the Danish Maritime Authority said.

"There was a surprisingly high level of support for starting the work on the regulation of autonomous ships, even from countries expected to be negative as they are major suppliers of seafarers," Lasse Karlsen, Technical Director in Norwegian Maritime Authority, added.

MacGregor and Rolls-Royce have signed a memorandum of understanding (MoU) to collaborate on research and development aimed at exploring the implications in autonomy for cargo ship navigation and cargo systems onboard containerships.

The collaboration between MacGregor, a provider of engineering solutions and services for the offshore and marine industries, and company Rolls-Royce is expected to lay the groundwork for the development of autonomous containerships.

An unmanned vessel can be both remote controlled or fully automated, and it has been suggested that the first vessel without crew will be in service by the end of the decade. Most probably, there will be several variations, including the use of automated technologies with a reduced number of crew on board and for certain maneuvers. The development is driven by industry and government-run projects such as the Advanced Autonomous Waterborne Applications (AAWA) project backed by the Finnish Government with key players such as Rolls-Royce and Finn Ferries. EU-sponsored research project MUNIN (Maritime Unmanned Navigation through Intelligence in Networks) was completed in August 2015, Norway announced in March 2016 the world's first designated test area for autonomous vessels, and a UK-sponsored project – the Machine Executable Collision Regulations for Marine Autonomous Systems – is looking into regulations and matching navigation algorithms for unmanned ships. For unmanned vessels to become a reality, the regulatory framework must be in place. Requirements concerning the person having command of a vessel, enough manning, training and proper lookout must be considered in international conventions (SOLAS, STCW, COLREG).

In February 2017, several Flag States proposed that the IMO Maritime Safety Committee (MSC) undertake a regulatory exercise to determine the extent of the need to amend the regulatory framework to enable the safe, secure and environmental operation of maritime autonomous surface ships within the existing IMO instruments. The Committee Maritime International (CMI) is also looking into this issue through an International Working Group.

"Rolls-Royce is a revolutionary remotely controlled and autonomous ships and believes such a remote controlled ship will be in commercial use by the end of the decade and a common sight on the high seas by 2030, " Asbjorn Skaro, Rolls-Royce, Director Digital and Systems, said.

"In the segments where we (MacGregor) operate, we see a lot of unnecessary waste in the forms of inefficiency, damage to cargo, and continuously dangerous working conditions. Our aim is to minimize this waste from the value network," Pasi Lehtonen, Senior Vice President, Strategy, Business Development and Marketing, MacGregor, explained.

According to MacGregor, in the new epoch known as the fourth industrial revolution, the increasing amount of data will offer great opportunities for offshore and marine industries with access to real-time information.

Connectivity will enable remote diagnostics and control autonomous vessel operations. The development of new solutions and services, which will be a mix of hardware and software, will be based on the approach of identifying where unnecessary industry waste is taking place. Earlier this month, Rolls-Royce received approval for a research grant by Tekes (the Finnish Funding Agency for Innovation), supporting its aim to make remote and autonomous shipping a reality. The company said that the funding would enable it to further invest in a research and development center in Turku, Finland.

Furthermore, there are several regulatory consideration of international maritime laws including requirements of setting up minimum crew at least on the ships in the wake of operating unmanned ships and vessels(GE Reports, 2014). MUNIN is busy on the legal bit of unmanned vessels examining declaring the unmanned ship as flag state "territory" and updating the International Convention for the Safety of Life at Sea SOLAS[8] and COLREGS[9].

Maritime law that is currently implemented does not take unmanned shipping into account. There are various rules that contradict with the idea of focusing entirely on unmanned shipping operations. The intensity of the challenge to adjust itself with the current laws may differ from one rule to another. As it is considered that the vehicles that a researcher is referring to is

[8] International Maritime Organization, 1974
[9] International Maritime Organization, 1972

defined as ‘ships’ according to the broad range of international and national regulations, the intended situation is quite clear. The maritime law framework is less likely to be amended, but it could experience various changes over the period of time, as new entrants, new risks and new laws would be implemented for the operational work in unmanned shipping. The liability rules that are currently implemented should be further analyzed and supplemented with certain laws taken into consideration in order to cope up with the traditional maritime law and regulations.

Flag State Survey

Flag State surveys are the basic concept to maintain the safety of the ship. There is no doubt that surveys are required for unmanned ships as well. However, there is a big difference between manned ships and unmanned ships. That is, unmanned ships have remote control centers. Remote control centers are a new concept not only for IMO but also for the shipping industry. In order to consider the procedure for carrying out surveys on unmanned ships, two factors should be discussed, the relationship between unmanned ships and remote control centers, and surveyors.

A remote-control center can be considered as part of unmanned vessel. For vessels surveys will be implemented as usual and certificates will be issued but the remote-control centers, would be a different chapter. Is it required for remote control centers to take a survey at the time a new ship is introduced under its control? The answer is complicated as, the reason it is yes is that the remote-control center should show the capability to handle newly introduced ships. On the other hand, the reason for no is that it is possible to clarify the capacity of a remote-control center and what kind of systems should be on board to connect to the remote-control center at its initial survey. If a new certificate for remote control centers can specify the system on board which can be connected to the remote-control center, it can be easier to identify which ships or systems on board can be controlled by which remote control center.

Interval of Surveys

Ships take safety surveys annually. The introduction of unmanned vessels may not change this basic principle as the requirements for safety are unchanged. Even though there is no crew on board, the same level of safety should be ensured as on conventional ships. If the same requirements related to safety apply to unmanned ships, the idea will be convenient. Evaluating the reliability of the system that the survey interval depends is a significant factor to think about. Test operation might be crucial in order to collect data for evaluation. However, this kind of surveys that are carried out by airlines, are certified to implement surveys by States in accordance with approved service manuals and States implement on-site inspection of airlines to verify the status of implementation (Civil Aviation Bureau MLIT, n.d.). In order to maintain the original procedure of implementing surveys annually, in order to avoid the burden on flag states, back-up systems might be a potential approach. Certainly, this will increase cost. To conclude, sufficient data collection is an urgent matter to consider when determining the appropriate interval of surveys of remote-control centers.

Reference to SOLAS Chapter V:

According to Toor (2015), legislation is the main barrier to the introduction of unmanned ships. Since ships can navigate all over the world through the oceans, international regulations are essential to keep the playing field level. However, IMO has not started to consider unmanned ships because they have not received any proposal from member States or industries (Arnsdorf, 2014). It can be an enormous task for IMO to review and revise all related regulations owing to fast development of technologies (Corbett, 2015). Taking this into account, the applicability of SOLAS Chapter V, which requires ships to have navigational equipment for safety of navigation, to unmanned ships will be discussed and possible bottlenecks will be identified. SOLAS has 14 Chapters, and Chapter V is ″SAFETY OF NAVIGATION″. In Chapter V, there are 37 regulations and one appendix, as well regulations were categorized into three aspects, requirements for States (Reg.3-15, 17,18), requirements for ships (Reg.14, 16, 17, 19-30) and requirements for masters and officers (Reg. 23, 24, 26, 28,31-35).

From the point of view of ships, requirements for ships and for masters and officers are important. The application of some regulations depend on ship type, size, construction date and navigation area. For instance, regulation 30 is only applicable to passenger ships. In the same way that regulation 22 only applies to ships (>55m) constructed on or after 1 July 1998. When it comes to a dry bulk carrier which is operating in international trade, almost all requirements (Reg.14, 16, 17, 19-29, 31-35) are applicable. Presently, a bulk carrier needs to be equipped with all navigational systems and equipment, the long-range identification and tracking information, VDR and pilot transfer arrangements. That ship must carry International Code of Signals and Volume III of the IAMSAR Manual and keep minimum safe manning documents. It should be designed in accordance with Regulation 22, Navigation bridge visibility. The master and officers on board are required to implement these requirements, as necessary.

If a dry bulk carrier is an unmanned ship, the question is which regulations might be affected. There are three main areas which will be affected, the obligation of masters, officers and crew, minimum manning requirement and pilot services. As the name ″unmanned″ suggests, there is no crew on board, the implementation of the current obligation of masters and officers becomes a big concern. Taking this into account, these regulations need to be reviewed and amended, and the definition of master, officer and crew might be re-identified. So far, it seems to be the shore-control operator who is responsible, but he is rather equivalent to watch officer, not necessarily to the captain. In addition, minimum manning requirement is another big issue. When a flag State is satisfied with the number and qualifications of crew, it will issue a minimum safe manning document. It is true that the decisions are left to flag States. So, it might be possible to be approved without crew on board but shall be defined in relation to manning of remote control centers. However, it may safely be said that this requirement was developed based on manned ships because there was no unmanned ship yet in the shipping trade, nor has it been discussed. This issue is closely related to the issue of definitions of master, officer and crew because if the definition of officer includes remote controller, the minimum manning requirement can be complied with, without a person on board (AAWA, 2016).

Moreover, pilot services might become an issue. In this aspect, ships are required to equip Pilot transfer arrangements under Regulation 23. The application itself is not an issue because a ship can be equipped regardless of whether a crew is on board or not. However, the application of these arrangements is an important concern. This regulation would probably need to be extended to not only pilot but also crew transfer arrangements, as MUNIN’s concept suggests that there might be a crew from/to pilot embarkation station.

9.Verification of safety

The objective of this chapter is to provide guidance on the requirements for Safety Management systems for MASS operations to meet the provisions of the IMO codes. The objectives of this Code are to ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, to the marine environment and to property. This can be successfully implemented using a Safety Management System (SMS) as part of the management and operation of MASS. The regulations and rules, not addressed by this Code of Practice, which apply to all MASS include, but are not limited to:

The IMO Instruments - Local navigation rules - National health and safety regulations - The Code of Safe Working Practices for Merchant Seamen - All relevant national shipping or guidance notices.

The Operator should pay due adherence to the many statutes, legislations, rules, regulations and codes of practice that apply to seafaring. Although the autonomous nature of the MASS operation may seem to negate some requirements, it is the unmanned aspect that should demand increased awareness. Any procedures produced should pay attention to this, especially those systems and equipment procedures that are required to avoid collision. The Operator should formulate and document procedures to ensure that safe working practices are carried out in the operation of the MASS. These may be in the form of checklists, which can be followed by all personnel irrespective of their location. Simple procedures should be developed for the operation of the MASS.

These should include, but not be limited to:
-Testing of equipment, including propulsion and steering gear, prior to commencing a passage
-Navigation and handling of the MASS - Maintenance routines - Bunkering operations - Watertight/weathertight integrity -Conduct of passengers and crew if utilized on board.

Due to the autonomous nature of vessel operation the following areas should be considered on top of traditional vessel operating procedures:
- Anti-Collision, unmanned vessels and the ability to detect and avoid collision;
- Cyber Security, anti-hacking and vessel hijacking for remote operated vessels;

- Anti-Piracy, close protection, remote control

SOLAS Reg 14,[10] considerations pertaining to evidence of minimum manning level requirements.

SOLAS Reg 33, Distress situations and how the Operator meets its obligations and responsibilities to other mariners in distress.

SOLAS Reg III/17-1, How the MASS could possible assist in the removing persons from the water.

All ships are to be provided with plans and procedures for recovery of persons from the water. The plans and procedures[11] are to identify the equipment intended to be used for recovery purposes and measures to be taken to minimize the risk to shipboard personnel involved in recovery operations.

Port State Control

Since there is no crew on board, implementation of PSC may become much more difficult. The principal of PSC is to verify whether ships flying foreign flags comply with regulations or not. The scope of PSC is not only the structure and equipment of ships but also operational matters, such as Certificates of seafarers and record book. However, there is no crew to accept PSC officers on board and all records may be kept in remote control centers. In addition, remote control centers would not move once they are established.

The procedure for PSC for ships will probably not change significantly. The design of ships might be changed as accommodation will no longer be required, but the basic structure of ships and navigation equipment may remain the same. However, the most fundamental change is that there will be nobody to accept PSC officers on board. If PSC officers cannot get on board, PSC will no longer work in the traditional manner. This fact may potentially increase substandard ships. In order not to do so, a designated person from the shipping company should be there when the ship is in port. Nevertheless, PSC is not routine work and there is no announcement that a PSC inspection will be implemented. This is not a realistic idea because it would increase cost and reduce the benefits of unmanned ships. In this case, the responsibility of the flag States becomes more significant than for conventional ships.

[10] Analysis at Annex

[11] do not need to be approved by the Administration

Unfortunately, PSC for remote control centers is impossible. PSC is done by port States where ships currently exist, but remote control centers are limited to one place and there is no need to move, although in the future there might be an option to have mobile control centers.

However, remote control centers have significant functions for the operation of unmanned ships. If PSC inspection is impossible for remote control centers, the reliability and compliance of regulations of remote control centers fully relies on flag States. In this case, the responsibility of flag States become greater than for conventional ships.

The reason for the development of PSC cannot be forgotten. If there are only flag State surveys, substandard ships may increase and substandard remote-control centers may be created. These situations will increase the risk rate of accidents. To solve the challenge of PSC, audit by third parties or IMO may be a good solution instead of PSC.

Not every member State of IMO will have unmanned ships as their flag ships in the near future, and it would take time to review all countries that have unmanned ships under IMSAS. In this regard, it seems to be a better idea to develop an expert group[12] to verify and check the condition of ships and remote-control centers.

Requirement of minimum manning

Minimum manning is a significant factor for safety of navigation. Before ships start navigation, they need to propose the plan of manning and receive the minimum safe manning document that will be issued by flag States.

A proposal for the minimum safe manning of a ship submitted by a company to the Administration should be evaluated by the Administration to ensure that:

- The proposed ship's complement contains the number and capacities of personnel to fulfil the tasks required for the safe operation of the ship, for its security, for protection of the marine environment

[12] The expert group would consist of specialists in computer systems and telecommunication technologies and PSC officers.

- As well the master, officers and other members of ship are not required to work more hours than is safe in relation to the performance of their duties and the safety of the ship and that the requirements for work and rest hours, in accordance with applicable national regulations.

In applying such principles, Administrations should consider existing IMO, ILO, ITU and WHO instruments in force which deal with:

- watchkeeping;
- hours of work or rest;
- safety management;
- certification of seafarers;
- training of seafarers;
- occupational safety, health and hygiene;
- crew accommodation and food;
- security
- radiocommunications (IMO, 2011, pp.9-10).

However, the decision to approve a proposal for the minimum safe manning of a ship is left to flag States. In ships that are unmanned, there is no person on board and remote controllers on shore are possible alternatives to masters, officers and crew. It is doubtful though, whether ships can receive minimum safe manning documents or not.

The requirement of minimum manning has to be reviewed and revised in accordance with the solution that is adopted from the two suggested solutions for definitions of master, officer and crew. If the definitions of these include remote controller, this requirement may not have to be revised because the principle of manning may expand, and the minimum safe manning document will be issued to unmanned ships. On the other hand, if a new definition of remote controller is established, the requirement must be revised, depending on cases of manned ships and unmanned ships. Flag States need to make sure that the requirements are relatively equal to both ships. In addition, if unmanned ships are operated in fully autonomous mode, not remotely controlled, who is going to be an alternative for remote controllers who engage in minimum manning? This is also big concern to be solved. One possible idea is to assign someone to be responsible for a ship. This requirement is for safety of navigation by requiring persons on board. If ships can operate fully in autonomous mode, it means that those ships are as safe as manned ships. On the other hand, this may bring another concern which is how to evaluate whether or not unmanned ships are as safe as manned ships.

Controller certified as a pilot

This idea is that remote controllers are trained to be pilots to provide pilotage service themselves. Since the remote-control center is immobile, it is almost impossible to get pilots to foreign ports. The benefits are that they can manage themselves and they know how to use the systems. Firstly, pilots need to have local knowledge and experience as seafarers. Currently, pilots are typically specified to one port.

Secondly, there is doubt as to whether foreign States would allow this activity or not. If pilotage service is provided by States, it is going to be a challenge for them to work as pilots of these countries. There is no information as to whether the systems are standardized or not. If not, they need to prepare for all possible systems. It may be costly as well high-speed telecommunication system have to be established, which may raise cyber risks.

10.Observations along with questionnaire

Questions regarding risks associated with unmanned vessels:

1. Do you believe that unmanned vessels will be the future of maritime economy?

A. Yes B. No C. Maybe with cooperation with manned vessels.

2. What do you think will be the impact on any crew that are involved in such autonomous systems and how autonomous systems will face with areas, like entry into port, congested waters, etc.?

A. Worst B. Better C. Maybe the same

3. Should all legal aspects concerning IMO – ISM – MLC comply with unmanned shipping or are there still problems to be faced with?

A. There are a lot of research that still must be considered to reply

B. Still problems to face

C. Write your own opinion:

4. Do you estimate that risks involved in an unmanned vessel be higher than those concerning a non-unmanned vessel?

A. Yes B. No C. Maybe

5. Do you believe that unmanned vessels will have a positive contribution to the maritime industry?

A. Yes B. No C. Maybe

6. Will unmanned vessels be cost efficient?

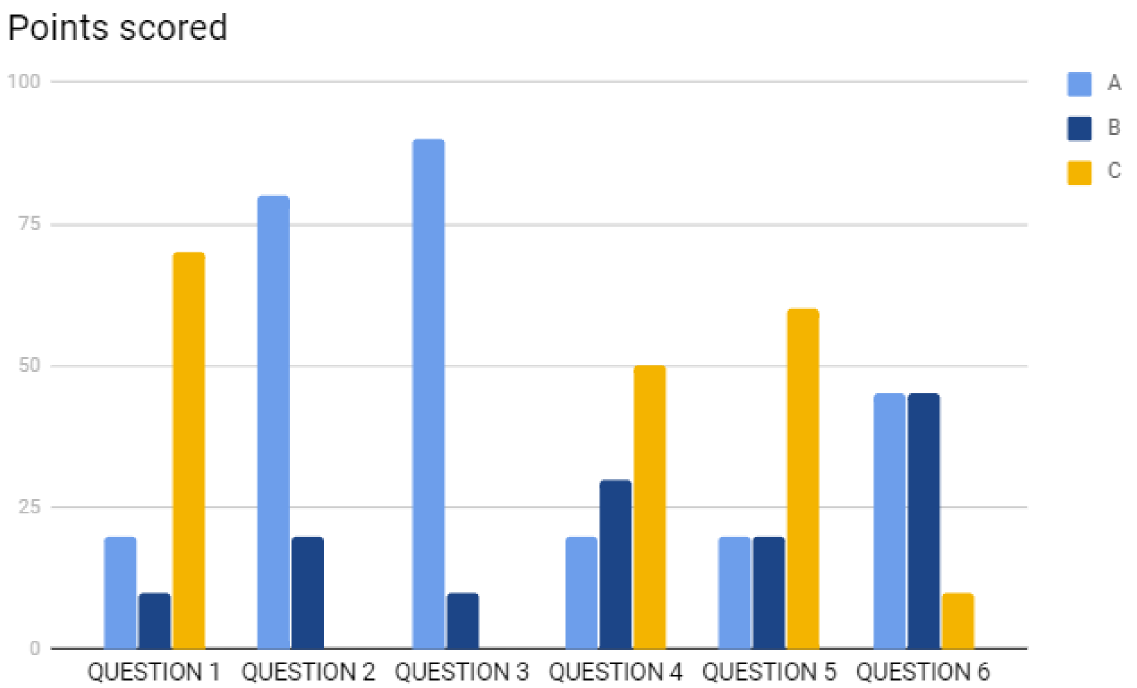
A. Yes B. No C. Maybe the same efficiency

The questionnaire was submitted to shipping companies, flag states and to classification societies, but the reaction was not the same from all the organizations, as some of the above organizations did not reply the questionnaire.

The following table and charts show the results after the investigation:

The first column shows those who answered the A as reply, the second column those who answered the B and the last one those who chose the C as their reply.

QUESTION 1	20	10	70		
QUESTION 2	80	20	0		
QUESTION 3	90	10	0		
QUESTION 4	20	30	50		
QUESTION 5	20	20	60		
QUESTION 6	45	45	10		



As we can understand from the chart regarding the first question, 70 per cent of the respondents chose the last response, so the future of maritime economy may be the cooperation of manned and unmanned vessels. The preferable choice regarding the second question is that the impact on any crew that are involved in such autonomous systems and how autonomous systems will face with areas will be worst. To continue with the third question is that a lot of research is required that all legal aspects concerning IMO – ISM – MLC could be able to comply with unmanned shipping. Regarding the fourth question the risks that estimated for unmanned vessels could be the same as the manned vessels. Also, at fifth question the reply was neutral as unmanned vessels may have a positive contribution to the maritime industry. Finally, the people involved in the questionnaire support that unmanned vessels can be cost efficient or maybe not.

The result of that research is that the unmanned vessels have yet an ambiguous point of view. Not even for those who are working in the shipping industry, is the future of the unmanned vessels clear. The big part of the responses is more neutral or more a combination between manned and unmanned vessels. It seems that in the future the shipping industry may have huge technological changes but it's almost sure that despite the enormous technological progress manned vessel will exist in the future as much as today.

The new trend of the shipping industry is the development of unmanned ships. There are several motivations, such as response to the increase of demand in the shipping trade, improving ship safety by reducing human factors which are main causes of accidents and efficient operation of hydrographic surveys. This concept sounds futuristic, but it is strongly believed that it is coming soon. For example, according to Corbett (2015), the first unmanned coastal ship will be introduced by 2025. In order to make it possible, several projects have been or are being carried out by interested countries, companies and research institutions.

11.Conclusions - Recommendations

Generally speaking, it is said that basic technologies already exist to make unmanned ships a reality. However, integration of sensor technologies is still under development. This is an essential factor for unmanned ships, as the ships cannot navigate without proper and enough SA, which will be provided by sensor technologies. It seems that unmanned remote-control ships can be introduced faster than unmanned autonomous ships. It is a good idea to have remote control ships first. On open seas, it is rare to see other ships. So, it is possible to test autonomous systems on open seas by using remote control ships and data can be collected to improve response capability to extreme conditions and verify the reliability in practical use. Land tests cannot reveal all the problems and challenges, such as durability in practical use. Real situational tests might help to develop technologies and can identify other challenges to be addressed.

It might be very difficult to introduce fully autonomous ships because manned ships will still exist. If fully autonomous ships want to operate in areas where at the same time manned ships operate, they must have same thought process as masters and crews and must be able to imagine what a master of another ship intends to do. The transfer of knowledge, skill and experience of seafarers to autonomous systems is essential to put fully autonomous ships into practical use. This is a big challenge, but appropriate research can help.

IMO should start the process of reviewing all relevant regulations to enable unmanned ships to navigate and identify the challenges related to regulations accordingly. Otherwise, when technologies are ready, legislation may not be ready. From the review of SOLAS Chapter V, it may be concluded that it takes time to review all regulations and there are many issues to be addressed. It is essential to identify all challenges first and decide how to address them later. Also, if it is possible, a review of each regulation should be implemented at the same time to discuss the issues. Also, it is very important for IMO that States assert their opinions so that IMO can develop better and appropriate regulations. IMO needs to amend regulations whenever appropriate. From time to time, regulations may require amendment in accordance with new situations and IMO needs to keep regulations up to date. For the side of the States, should try to keep their national legislation up to date and improve their capacity to implement new regulations.

New challenges may arise to be addressed. This trend may last for quite a long time because it may take time until unmanned ships face all situations. For fully autonomous unmanned ships, feedback from remote control operations might be or even has been collected and analyzed, especially focused on how to operate fully autonomous unmanned ships with manned ships being a big concern. The possibility is up to technology, but operational ideas can help as well.

12.Annex

SOLAS Reg 14

1 *Contracting Governments undertake, each for its national ships, to maintain, or, if it is necessary, to adopt, measures for ensuring that, from the point of view of safety of life at sea, all ships shall be sufficiently and efficiently manned.*

2 *Every ship to which chapter I applies shall be provided with an appropriate minimum safe manning document or equivalent issued by the Administration as evidence of the minimum safe manning considered necessary to comply with the provisions of paragraph 1.*

3 *On all ships, to ensure effective crew performance in safety matters, a working language shall be established and recorded in the ship's log-book. The company, as defined in regulation IX/1, or the master, as appropriate, shall determine the appropriate working language. Each seafarer shall be required to understand and, where appropriate, give orders and instructions and to report back in that language. If the working language is not an official language of the State whose flag the ship is entitled to fly, all plans and lists required to be posted shall include a translation into the working language.*

4 *On ships to which chapter I applies, English shall be used on the bridge as the working language for bridge-to-bridge and bridge-to-shore safety communications as well as for communications on board between the pilot and bridge watchkeeping personnel, unless those directly involved in the communication speak a common language other than English.*

SOLAS Reg 33

1. *The master of a ship at sea which is able to be able to provide assistance on receiving information from any source that persons are in distress at sea, is bound to proceed with all speed to their assistance, if possible informing them or the search and rescue service that the ship is doing so. This obligation to provide assistance applies regardless of the nationality or status of such persons or the circumstances in which they are found. If the ship receiving the distress alert is unable or, in the special circumstances of the case, considers it unreasonable or unnecessary to proceed to their assistance, the master must enter in the log-book the reason for failing to proceed to the assistance of the persons in distress, taking into account the recommendation of the Organization, to inform the appropriate search and rescue service accordingly.*

1. *Contracting Governments shall coordinate and cooperate to ensure that masters of ships providing assistance by embarking persons in distress at sea are released from their obligations with minimum further deviation from the ships' intended voyage, provided that releasing the master of the ship from the obligations under the current regulation does not further endanger the safety of life at sea. The Contracting Government responsible for the search and rescue region in which such assistance is rendered shall exercise primary responsibility for ensuring such coordination and co-operation occurs, so that survivors assisted are disembarked from the assisting ship and delivered to a place of safety, taking into account the particular circumstances of the case and guidelines developed by the Organization. In these cases the relevant Contracting Governments shall arrange for such disembarkation to be effected as soon as reasonably practicable.*

2. *The master of a ship in distress or the search and rescue service concerned, after consultation, so far as may be possible, with the masters of ships which answer the distress alert, has the right to requisition one or more of those ships as the master of the ship in distress or the search and rescue service considers best able to render assistance, and it shall be the duty of the master or masters of the ship or ships requisitioned to comply with the requisition by continuing to proceed with all speed to the assistance of persons in distress.*

3. *Masters of ships shall be released from the obligation imposed by paragraph 1 on learning that their ships have not been requisitioned and that one or more other ships have been requisitioned and are complying with the requisition. This decision shall, if possible be communicated to the other requisitioned ships and to the search and rescue service.*

4. *The master of a ship shall be released from the obligation imposed by paragraph 1 and, if his ship has been requisitioned, from the obligation imposed by paragraph 2 on being informed by the persons in distress or by the search and rescue service or by the master of another ship which has reached such persons that assistance is no longer necessary.*

5. *The provisions of this regulation do not prejudice the Convention for the Unification of Certain Rules of Law Relating to Assistance and Salvage at Sea, signed at Brussels on 23 September 1910, particularly the obligation to render assistance imposed by article 11 of that Convention.*

6. *Masters of ships who have embarked persons in distress at sea shall treat them with humanity, within the capabilities and limitations of the ship.*

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