

Autonomous Vessel Surveying

Bachelor Thesis



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Abstract

The following research project covers everything related to the new automated navigation techniques that have emerged in recent years.

Chapter 1 of the document contains aspects of a legislative nature, referring to the next regulations that must be covered by the next generation of ships. In it we find defined the classes of autonomous ships defined by the International Maritime Organization, IMO for its acronym in English. It is also complemented by European Commission guidelines.

Chapter 2 discusses in detail both the benefits and negative points of autonomous ships. It also adds information on relevant current projects on the subject. The collection includes both ship projects and some important ones related to the programming of the navigation and control systems themselves.

Chapter 3 specifies about digitized inspection processes, remotely done, and how they can benefit future ship inspections. It also explains how they have served today in the health situation experienced to achieve high quality standards. In this section you can find the new trends as well as the importance of their application in the naval field.

Finally, Chapter 4 expresses a series of applications for each of the types of ships defined by the IMO, and what functions they could develop for navigation in the coming generations. It also looks at how they can be connected to move forward or backward in degrees of autonomy.

Keywords: Maritime Inspections - Autonomous Ships, MASS - Legislation Autonomous Ships, Digitization Inspections - Digital Internal Audits, Legal Responsibilities - Autonomous Navigation,

Resumen

El siguiente proyecto de investigación recoge todo lo relacionado con las nuevas técnicas automatizadas de navegación emergidas en los últimos años.

En el Capítulo 1 del documento se pueden encontrar aspectos de carácter legislativo, referentes a las próximas regulaciones que deben cubrir la generación siguiente de barcos. En el mismo encontramos definidas las clases de barcos autónomos definidas por la Organización Marítima Internacional, IMO por sus siglas en inglés. Además, también se complementa con las directrices de la Comisión Europea.

En el Capítulo 2 se analiza detalladamente tanto los beneficios como puntos negativos de los barcos autónomos. Se añade también información sobre los proyectos actuales relevantes con respecto al tema. En la recopilación se encuentra tanto los proyectos de barcos como algunos importantes relacionados con la programación de los mismos sistemas de navegación y control.

En el Capítulo 3 se especifica sobre los procesos de inspección digitalizados, de forma remota y como pueden suponer un beneficio para las futuras inspecciones de barcos. También se explica cómo han servido en la actualidad en la situación sanitaria vivida para alcanzar altos estándares de calidad. En este apartado se puede encontrar cuáles son las nuevas tendencias, así como la importancia de su aplicación en el ámbito naval.

Por último, el Capítulo 4 expresa una serie de aplicaciones de cada uno de los tipos de barcos definidos por el IMO, y qué funciones podrían desarrollar de cara a la navegación en las próximas generaciones. Además, se analiza cómo pueden encontrarse conectadas entre ellas para avanzar o retroceder en grados de autonomía.

Palabras clave: Inspecciones Marítimas - Barcos autónomos, MASS - Legislación Barcos Autónomos, Digitalización Inspecciones - Auditorías Internas Digitales, Responsabilidades Legales - Navegación Autónoma,

Resum

El següent projecte d'investigació recull tot allò relacionat amb les noves tècniques automatitzades de navegació emergides en els darrers anys.

En el Capítol 1 del document s'hi poden trobar aspectes de caràcter legislatiu, referents a les pròximes regulacions que han de cobrir la generació següent de vaixells. En el mateix hi trobem definides les classes de vaixells autònoms definides per l'Organització Marítima Internacional, IMO per les seves sigles en anglès. A més a més també es complementa amb les directrius de la Comissió Europea.

En el Capítol 2 s'analitza detalladament tant els beneficis com punts negatius dels vaixells autònoms. S'hi afegeix també informació sobre els projectes actuals rellevants pel que fa al tema. En el recull s'hi troba tant els projectes de vaixells com alguns importants relacionats amb la programació dels mateixos sistemes de navegació y control.

Al Capítol 3 s'especifica sobre els processos d'inspecció digitalitzats, de forma remota i com poden suposar un benefici per les futures inspeccions de vaixells. També s'explica com han servit en l'actualitat en la situació sanitària viscuda per assolir alts estàndards de qualitat. En aquest apartat s'hi pot trobar quines són les noves tendències així com la importància de la seva aplicació en l'àmbit naval.

Per últim, el Capítol 4 expressa un seguit d'aplicacions de cada un dels tipus de vaixells definits per l'IMO, i quines funcions podrien desenvolupar de cara a la navegació en les pròximes generacions. A més a més s'analitza com poden trobar-se connectades entre elles per avançar o retrocedir en graus d'autonomia.

Paraules clau: Inspeccions Marítimes – Vaixells autònoms, MASS – Legislació Vaixells Autònoms, Digitalització Inspeccions – Auditories Internes Digitals, Responsabilitats Legals – Navegació Autònoma,



Preface

Since I was a kid, I was really interested in Technology. How the world changes continuously and how the technological field is constantly evolving have shown to me that we have to be continuously adapting to the upcoming technologies.

Robotics is one of the things that amazed me. When I was in 2nd year of secondary school, I've participated in a robotics tournament, and it was a great experience for me. Years later, the Automation of processes like Computerized Numerical Control also is for me an interesting field.

I always had a computer in my hands, which supposed to me a great understanding on how Technology never stops. On the last years, Technology made a change. The Computers are powerful enough to not collapse soon, so in this field Technology seems stagnant, but it is really evolving faster than ever. The Automation of big processes, and the autonomous vehicles that are appearing in all fields is awesome, and it is growing fast.

Vessels are not less important, and although it is difficult to apply the autonomous Technology, it becomes a before and after step.

Otherwise, law is for me another interesting field in my life that has matured during last years. The interest in legislative and regulations during my grade studies has become essential to me, to understand the world and to understand the reality and how everything is done. This for me supposes a part of my next steps in my life, how they will be done, and it applies to my vision now a much different one and upgraded from the one I had when I decided to study my university grade.

Although the topic was not in my plans from the first day, the idea that Dr. Jaime Rodrigo de Larrucea gave to me to do this project woke up my interest in the field and made me feel comfortable to do it. I have learned and discovered about a new Technology field in which I am really interested and amazed, and also compliments with the upgrade in regulations needed.

The young generations have to be open to the new world and be constantly growing, and have to be prepared to reinvent themselves and to become more efficient and intelligent in order to grow and help the world grow.

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CHAPTER 1. IMO REGULATION ON AUTONOMOUS VESSELS

New technologies are taking advantage really fast and autonomous transport methods gain popularity on different industries. This means that the interest from companies to develop new ways of transport are in the way to improve the actual environment.

The shipping industry is not excluded from this upgrade to more autonomous ways of navigation, that's why different types of autonomy are being put on the table to make the shipping industry safer and avoid human related problems.

1.1. Background

To ensure a safe environment, new regulations have to be provided in order to make this new field on the shipping industry be able to develop and continue growing with solid bases and fundamentals.

The International Maritime Organization (IMO) is currently trying to fit their regulations into this new field in the industry. To achieve this, the organization made a classification of the vessels depending on which level of automation they have. This means that the start points for this regulations is based in the way how those vessels are controlled.

The upcoming regulations that the shipping industry will have to set have to cover the most common and also the most unexpected scenario. These regulations need to cover safety issues that can happen on this ships, how the control of the vessel will be recovered in the worst scenarios, who will be legally issued in case of accident, etc. So, this suppose that each code and regulation nowadays have to be updated and adapted to fit the new requirements of the maritime industry.

1.2. The Idea Behind

The autonomous vessel idea existed for several decades. A naval architect from Danish Maritime Authority, Erik Tvedt, anticipated the future of navigation in several conferences through his ideas and theories about the automatization that was about to come.

On the last times, those ideas came to life in different ways in the maritime industry as digitalization, automation, and autonomous technologies. Each one, otherwise, has its characteristics and utilities and can't be confused.

Even though those technologies were existing before in the way of concepts or ideas and they are not new, the improvement of technologies made it possible to start implementing them in real-life case situations. The growth in the computer industry is an example. This results in more computerization power at less price.

Another important and essential improvement is connectivity, which in the last decade has become more reliable, faster, and stable. An important point here is that without proper connections the process of autonomous and automation becomes risky and can lead to dangerous situations. For example, applied to the maritime industry, it can lead to disasters not only in the navigation but also in the ship-to-port relationship or also in the crew on board in the case of manned vessels.

Finally, another technology-related important point here is the improvement on software and their implementation on new technologies. Software industries have evolved and they have more capabilities and tools than before which also reduces costs.

A problem found here is that nobody thought before that vessels will evolve the necessary to become unmanned at some point and, as a consequence, it was not planned to be included in the existing regulations nor codes. After all the improvements on the existing industry, it is a matter of time that those regulations become clearer and more specific to any type of vessel.

1.3. Automation and Autonomy

The common understanding of autonomous vessels is that they are navigating without crew onboard and without any control. Otherwise, the reality is that this is partially true. They can vary from different types of automation since being automated on simple decisions, simple task or automated course steering, to high levels of automation where crew is not onboard and the vessel is remotely controlled or in another step, fully autonomous most part of the time.

The idea behind that is to build vessels with the ability to evolve from different grades of automatization. For example, a commercial ship vessels that covers a route could be evolving from one grade of automation to another in the different stages of its route. This means, one possibility could be to leave port handled by crew and once in open waters, be remotely controlled or inclusively evolve to an autonomous navigation.

To regulate this it is important to make clear the different kinds of automation that exist and how they combine between them.

1.4. IMO strategic plan

The IMO intention for the future is to “*Integrate new and advancing technologies in the regulatory framework*”¹. This means they plan to upgrade and adapt in a constant way each new advance on technology providing a stable framework for ensure that those new technologies are safe and will not cause any major problems.

They focus on different points, not just safety and security, but also the pollution and the impact that can have for the environment, impact on personnel and people on board.

The strategic plan, which has been established to be done in the years between 2018 and 2023, is an answer to the petitions of different institutions. This has the objective to merge the current navigation with the autonomous navigation and find the way to integrate this new field safely, securely and environmentally respectful way.

1.5. IMO MASS Vessel Types

The IMO established a distinction between the types of MASS (Maritime Autonomous Surface Ships) vessels in order to facilitate the regulations. First there are two types of autonomous vessels:

- **Remotely controlled:** Are the vessels manually mannered from land by operators. They are operated from the “Shore Centers”. Those buildings have the necessary equipment to remotely control the vessel and have the communications that are needed. In them have to work experienced masters with knowledge to take decisions and act according to the regulations.
- **Autonomous:** Vessels that function by themselves. They have been provided with the technology that ensures the correct “watchkeeping” for the systems, with visual and sound recognizing systems and sensors that make able the vessel to analyze and understand the environment and take the necessary decisions. This supposes that the equipment, the algorithms and programs are tested before to comply with the established rules, but also can be upgraded to accomplish further rules.

With those concepts in mind, the IMO established four degrees of autonomy in order to fit each possible type of vessel and navigation. Those combine the two concepts stated before and the grade of maneuvering that they have. The degrees of autonomy established by the IMO are found

¹ See: *Autonomous shipping*. International Maritime Organization Home Page[online]. [no date] [viewed 15 April 2021]. Available from: <https://www.imo.org/en/MediaCentre/HotTopics/Pages/Autonomous-shipping.aspx>

in the MSC.1/Circ.1638². These categories are defined as:

- *Degree one: Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.*
- *Degree two: Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.*
- *Degree three: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.*
- *Degree four: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.*

This means that, depending on the degree of autonomy of each MASS vessel, the regulations are specially established and studied in order to cover each of those types of vessels. The scoping exercise that the IMO did established in the MSC.1/Circ.1638 that they need to “analyse and determine the most appropriate way of addressing MASS operations, taking into account, inter alia, human element, technology and operational factors”. As they introduce in the same document, they need to identify:

The application of IMO instruments, as currently drafted, is divided in the following categories:

- A. *applied to MASS and prevented MASS operations; or*

² See: *Outcome of the regulatory scoping exercise for the use of maritime autonomous surface ships (MASS)*[online]. no. MSC.1/Circ.1638 of 3 June 2021 [viewed 6 June 2021]. Available from: [https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/MS.1-Circ.1638%20-%20Outcome%20of%20The%20Regulatory%20Scoping%20ExerciseFor%20The%20Use%20of%20Maritime%20Autonomous%20Surface%20Ships...%20\(Secretariat\).pdf](https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/MS.1-Circ.1638%20-%20Outcome%20of%20The%20Regulatory%20Scoping%20ExerciseFor%20The%20Use%20of%20Maritime%20Autonomous%20Surface%20Ships...%20(Secretariat).pdf)

- B. applied to MASS and did not prevent MASS operations and required no actions; or*
- C. applied to MASS and did not prevent MASS operations but might need to be amended or clarified, and/or might contain gaps; or*
- D. had no application to MASS operations.*

The most appropriate way(s) of addressing MASS operations are categorized with the following four options:

- I. equivalences as provided for by the instruments or developing interpretations; and/or*
- II. amending existing instruments; and/or*
- III. developing a new instrument; or*
- IV. none of the above as a result of the analysis.*

Their intentions were to finish this scope exercise at 2020 after four sessions of the MSC (Maritime Safety Committee). Otherwise, there was no intentions or plans in amending any regulations.

Actually, in the MSC.1/Circ.1638, the IMO established a set of priorities in regulations and amendings based in the results of the scope exercise and the set of priorities established.

1.6. European Commission

The European Commission decided to focus a part of their attention on the MASS field. They are aware of how the new processes and the digitalization and automatization of them are present and will be stronger in the next years. The fast rise of the MASS adoption needs a fast actuation in order to create and applicate new legislation that covers this and ensures that adoption will be done in the right path.

Currently, in the EU (European Union), the VTMIS Directive (Vessel Traffic Monitoring & Information Systems) legislation includes some fields applicable to autonomous vessels. Also, the VTMIS has tools that make viable monitoring and communication, which is one of the important and needed tools in the MASS adoption.

In order to perform upgraded legislation that can be applied and will be functional, they had to test to find where will be dangerous troubles and conflicts in safety, security, and navigation rules. It is important to consider that MASS transit has to coexist with conventional navigation without affecting or interfering between both and without affecting safe navigation.

Those tests and investigations started in Summer 2018 at the hands of the European Union in order to study the future of navigation including the MASS in conjunction with conventional shipping in the sea routes but also in ports. This led to a draft of “EU Operational Guidelines on trials of Maritime Autonomous Surface Ships (MASS)”.

1.6.1. EU Operational Guidelines on trials of Maritime Autonomous Surface Ships (MASS)

The “EU Operational Guidelines on trials of Maritime Autonomous Surface Ships (MASS)” is the first version of guidelines proposed by the European Union after tests and trials were made in order to learn and observe how the new technologies in the MASS field are going to affect the current navigation.

On the first draft, the intention was to protect safety and security in three environments: sea, marine, and coastal.

In order to ensure a nice coverage of these fields, the European Commission and the European Union member states maritime authorities had to work together in conjunction with a group of MASS experts and industry stakeholders. Also, the European Maritime Safety Agency had to support all those entities mentioned before in order to give a strong overview of the topic to work about.

It is important to mention that the “EU Operational Guidelines on trials of Maritime Autonomous Surface Ships (MASS)”, as mention before, were just a draft about the upcoming versions that will cover more deeply the MASS rules and regulations. Because of this new technological field in the maritime industry, this first approach to the regulation and the final adoption will be followed by

constant modifications and improvements at the same time that new trials are performed. Those test in conjunction with several types of research and studies from EU entities will make possible to find answers to doubts now about the upcoming regulations and the improvements that need to be done.

On November 30th, 2020, the 2nd International Ship Autonomy and Sustainability Summit took place. The MASS expert commission from the European Union in strong collaboration with the other entities found that the regulations, in order to make the MASS navigation safe and sustainable while ensuring an effective development, need to accomplish the following principles as stated by the European Commission in their online report³:

- *Start using the EU Operational Guidelines for trials and tests of MASS and exchange within and between EU Member States; and to identify needs for the further development as new challenges arise.*
- *Present and Make the EU Operational Guidelines publicly available by appropriate means.*
- *Bring the EU Operational Guidelines to the attention of the International Maritime Organization (IMO) and other appropriate stakeholder fora as well as to international like-minded partners.*
- *Work towards including the EU Operational Guidelines in regional agreements/plans.*
- *Support the use of the Union Maritime Information and Exchange System providing Integrated Maritime Services and its further development for the safe management, monitoring, communication and control of autonomous ships and shipping.*
- *Continue working in the context of the MASS expert group, inter alia, on:*

³ See: *Maritime autonomous ships and shipping - mobility and transport - european commission*. Mobility and Transport - European Commission[online]. [no date] [viewed 15 April 2021]. Available from: https://ec.europa.eu/transport/modes/maritime/mass_en

1. *The continuous improvement of the EU Operational Guidelines, in all its aspects, including uptake from relevant R&D projects and studies, to address the challenges and achieve alignment of standards and common understanding for trials and operations of Maritime Autonomous Surface Ships, including in ports;*
2. *Gathering and exchanging experience and developing practical procedures on the operational use of the EU Operational Guidelines, including table top exercises, building on the work by the European Maritime Safety Agency (EMSA) and liaising with other fora, both civil and military;*
3. *Developing, in due course, with the support of EMSA, appropriate training on the EU Operational Guidelines including on information sharing, communication and use of the Union Maritime Information and Exchange System;*
4. *Improving the risk assessment methodology, based on e.g. state-of-the-art research;*
5. *Further exploring needs, requirements and standards for seamless and integrated information and communication flows between autonomous ships/remote control centers and with national/regional vessel traffic services, as well as between authorities and operators.*

1.7. Regulations

In order to get full coverage on all the fields that surround the maritime industry, not only IMO and EU regulations are needed, but also new COLREG (International Rules for Preventing Collisions at Sea), SOLAS (Safety of Life at Sea), and MARPOL (International Convention for the Prevention of Pollution from Ships) to include new standards that can work in confluence with the old ones and give to the maritime industry a new framework in which to focus.

To achieve efficiency while both navigational worlds, the traditional and the autonomous, work together without any kind of interference, it is important that regulations take place. The problem is that without knowledge about the things that need to be regulated, no new regulations can be done.

In order to fit new regulations in this upcoming industry but without making conflicts with traditional navigation a new mindset has to be set.

1.7.1. COLREGS

An example of this is the International Regulations for Preventing Collisions at Sea (COLREGS) which state that ships have to be controlled by human beings capable to make the navigation according to seamanlike assessment on specific situations. This means that an autonomous vessel without crew will not be able to make seamanlike decisions in special and critical situations. This creates a conflict between the current navigation and the upgrades needed for the autonomous one.

In the case of a remotely controlled vessels the situation is different as the vessel will be controlled by a human being and will fulfill the rule stated before. Also, the regulation doesn't specify from where the vessel is controlled.

The problem is that an autonomous vessel is programmed by algorithms and not by "seamanlike" assessments. This could cause problems where vessels navigate between manned and non-autonomous vessels and the reactions that algorithms produced could not be suitable to the current navigation happening in the immediate environment around the vessel. The way it reacts could lead to an accident or difficulties which may cause a non-safe situation for other vessels and the vessel itself.

One alternative situation here found by experts is to write the code with new regulations that include the pre-programmed decisions that algorithms do instead of the current seamanlike assessment way to make decisions. This makes challenging to instruct existing navigators to a new way of making decisions. It is needed to establish international guidelines which makes clear the decisions that will be able authorized to make an autonomous vessel and the decisions that will have to be performed by humans.

Another conflict is that Captains of current vessels need years of study, training and examinations plus a lot of experience in order to be able to be the captain of a big ship. All this is needed in order to verify that a person is able to be a captain and has full knowledge and capabilities to perform

this job. Instead, an autonomous vessel core computer will be programmed but a way to verify this is needed to avoid having system fails and mistakes that can make navigation unsafe.

We can focus in some actual rules that could be updated in order to include the autonomous vessels in COLREGS. First of all, would be right to mention the Rule 3 because it provides a definition that will give the general background to mention the other rules.

The following rules from COLREGS⁴ are interesting for a revision and amending in order to fit the upcoming generations of vessels.

Rule 3, “General Definitions”:

(a). The word “vessel” includes every description of water craft, including non-displacement craft, WIG craft and seaplanes, used or capable of being used as a means of transportation on water. (IMO, 1972)

As it is obvious, autonomous vessels are not included nor excluded, which could be understood as they still be considered as a “vessel”

Once the autonomous vessels may be considered accepted in the code by default, a detailed view of other rules may be provided.

Rule 2, “Responsibilities”:

(a). Nothing in these Rules shall exonerate any vessel, or the owner, master or crew thereof, from the consequences of any neglect to comply with these Rules or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case. (IMO, 1972)

This rule must be updated to include the absence of Captain and are onboard (in the case of unmanned vessels) on Autonomous ships.

⁴ See: INTERNATIONAL MARITIME ORGANIZATION. *COLREGS - international regulations for preventing collisions at sea*. London: I.M.O, 1972. 978-92-801-0097-6.

A need to move the responsibility from onboard crew (in manned vessels) to personnel on shore, like personnel on Control Centre, where remotely they control the vessel in determinate circumstances, puts another study point: “ordinary practice of seamen”. This makes mandatory that personnel in Control Centre or land-based stations will need to have proper seamanship experience and formation.

Rule 5, “Look-out”:

Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision. (IMO, 1972)

In order to adapt the Rule 5 to the new technologies, would be really interesting to focus on ways that make possible to replicate the sight and hear in an automated way. For example, the use of high-tech cameras that can analyze the environment in any kind of conditions and send the information to a processor would be an alternative to the sight system. The use of highly sensitive microphones and sensors would be needed to replicate the hear system.

We can consider that these alternatives would be accepted because the statement “... as well as by all available means appropriate in the prevailing circumstances and conditions...” (IMO, 1972) which consider that the use of different technologies and systems that helps a safety navigation and replicates the human senses would be allowed.

The problem relies in the statement “so as to make a full appraisal of the situation and of the risk of collision” (IMO, 1972) which implies that in order to avoid accidents and collisions, judgment and reactions based on experience and seamanlike are needed.

Rule 6, “Safe speed”:

. Every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions. (IMO, 1972)

The definition of safe speed provides an open consideration related with the decision of a human being, based on the experience and the consideration and knowledge of the master about its ship.

In the situation of a collision happening, although existing the Rule 6 and an experienced master who determined a safe speed, the speed at which it was navigating would be categorized as unsafe because it didn't avoid the collision.

The Rule 5 and Rule 6 are linked because both provide the need of an experienced master that can determine a safe navigation situation. This is not suitable with an autonomous vessel which cannot provide experienced-based decisions.

In order to make this possible, a new appointment on this rule would have to consider autonomous vessels in categories that can provide different physical data and speeds in conjunction with a security margin that makes possible stop the vessel in order to avoid collision.

Rule 7, "Risk of Collision":

(a). Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist. (IMO, 1972)

The Rule 7, in conjunction with the Rule 6 and Rule 5 provides a problem at the time to consider by a human being when the risk of collision exists or not.

Otherwise, an on-shore station could provide this risk of collision and take the control of the ship in a remotely way to avoid any collision and act in the proper way.

It would be correct to take a further look at the statement:

(b). Proper use shall be made of radar equipment if fitted and operational, including long-range scanning to obtain early warning of risk of collision and radar plotting or equivalent systematic observation of detected objects. (IMO, 1972)

Which implies the importance of a constant have audio and visual information and use it in order to determine the presence of risk.

Rule 8, “Action to avoid collision”:

(a). Any action to avoid collision shall be taken in accordance with the Rules of this Part and shall, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship. (IMO, 1972)

This rule, like many others seen, provide some power to good seamanship in order to determine the most adequate action to avoid a collision.

In this kind of situations, could be considered the option to transfer the control of the vessel to personnel on shore that has proper training and experience. This will ensure that the action took has the necessary seamanship in order to avoid the accident and collision.

Rule 17, “Action by stand-on vessel”.

(a)

(ii). The latter vessel may however take action to avoid collision by her manoeuvre alone, as soon as it becomes apparent to her that the vessel required to keep out of the way is not taking appropriate action in compliance with these Rules. (IMO, 1972)

In the Rule 17, (a) (ii) a dilemma is found. It relies on the necessity to take action when the vessel which is supposed to take action doesn't do. This relies on the necessity that a human onboard with the knowledge determines that the vessel is not respecting their obligations and, in order to avoid the collision, thinks it is needed to take action first.

In the autonomous vessel situation, it would be needed to have a system which permits not only to spot a situation when the other ship is not complying with their navigational obligations, but also to communicate fast and efficiently with the center onshore to coordinate the maneuvering.

Rule 19, “Conduct of vessels in restricted visibility”

(e). Except where it has been determined that a risk of collision does not exist, every vessel which hears apparently forward of her beam the fog signal of another vessel, or which cannot avoid a close-quarters situation with another vessel forward of her beam, shall reduce her speed to the minimum at which she can be kept on her course. She shall if necessary take all her way off and in

any event navigate with extreme caution until danger of collision is over. (IMO, 1972)

In the Rule 19, the statement “...every vessel which hears apparently forward of her beam the fog signal of another vessel...”, the implication of the word “hears” means that a human being onboard is needed like seen in other rules.

Rule 20, “Application”

The use of navigational shapes and lights is an important part of the current navigational process. In the case of an autonomous vessel, without crew onboard, new ways to monitor those signals will be needed.

1.7.2. MARPOL

The International Convention for the Prevention of Pollution from Ships, 1973, also known as MARPOL, is not excluded from setting a new regulation.

The MARPOL, amended in 1978, is the code that sets all the standards to prevent pollution from ships by oil, chemicals, garbage...

The actual MARPOL regulation includes a set of actuation plans and directives in order to protect the environment in case of an accident. This means that at least, the first actuation, have to be made by the crew on board. In the next generation autonomous vessels, those that will be unmanned won't be able to perform the necessary actuations that the crew onboard would be supposed to do.

This requires that upcoming regulations specify procedures that have to be applied in this kind of situations, where there is no crew onboard and thereby, nobody can do the first actuations manually.

Autonomous vessels have a set of positive points reducing maritime pollution.

- On vessels without crew onboard the production of garbage, human waste and grey waters will be non-existent, which makes them cleaner with the environment.
- The pollution from oils, harmful substances or chemicals made by humans on board will be non-existent. Any spill will be registered by the systems and will need a petition - approval process in order to release any kind of substance to the sea. This reduces any illegal action made by crew without being properly registered.

On the opposite side, risk of pollution produced without any intention, like pollution coming from the result of accidents, weather, capsizing, fires and explosions, ... will persist and will put in the focus another problem: fast actuation.

Those situations that require immediate and efficient action in order to avoid further damage to the environment will be an object of study. The need of immediate action and how it is performed in autonomous vessels is something that has to be studied in detail.

1.7.3. SAR Convention

The International Convention on Maritime Search and Rescue (SAR) was adopted in 1979 and had the mission to develop the search and rescue plans in order to protect life at sea and ensure fast and efficient actuations.

The SAR organization coordinates rescue at sea and co-operates with other SAR organizations in order to make the best actuation possible each time.

Before SAR operations, going back in time shows that the obligation of ships to rescue and assist vessels in distress existed either in tradition and other conventions like SOLAS.

The last resolution adopted, the MSC-167(78), made between SAR and Guidelines on the Treatment of Persons Rescued at Sea on the May 20th, 2004, only included on it manned vessels. There aren't references for Autonomous vessels.

In the case of an accident happening, the obligation of a vessels to assist and rescue members on board of a distressed vessel supposes a conflict. A vessel that is obligated to rescue members of another vessel will need to receive survivors on-board of their vessel if it's possible and perform other actions in the rescue operations.

If the vessels that has to rescue is an unmannered Autonomous vessel, the most probably event is that the Autonomous vessel will not be able to perform and provide any required action to assist the vessel on distress and its crew.

Another problem will be how it performs with the environment. In the case of castaways at sea, the autonomous vessel will most probably not see any signals of them to be rescued. Also in the situation of a man overboard scenario, the probabilities to miss finding it will be high.

1.8. Legal Responsibilities

One of the biggest problems found in the autonomous vessel and remotely controlled vessels is who becomes legally liable.

In traditional vessels, the legal responsible is the Master of the vessel. This means that he is liable for every legal affair that could happen.

The upcoming generations of vessels, whether it is a remotely controlled vessel or fully autonomous, removes the captain figure. This makes a new problem because in case of accident nobody is liable for this.

1.8.1. Public Law

One of the obligations that the flag state has in relation with the vessels is found in the Art. 94.4.4.b from the United Nations Convention on the Law of the Sea (UNCLOS). It says that the flag state from a vessel has to ensure that each ship has to be *“in charge of a captain and duly qualified officers, in particular with regard to their seafaring experience, navigation, communications and naval machinery and that the competence and number of the crew are appropriate for the type, size, ship's machinery and equipment”*. This means that autonomous vessels and their flag states will not be compliant on this obligation.

Another affair are all the duties and obligations that the public law imposes to the captains and other crew members. For example, the MARPOL and SOLAS obligations that, in case of fail, makes liable to the captain of the vessel.

This makes evident that all those laws, regulations and codes will find that this liable person is missing in the vessel. In order to fulfill those flaws and missing liable persons, the International Maritime Public Law will have to be reformulated and modified in order to fit this new generation of vessels. They have to include new annexes or additions to existing regulations, but also to specify to avoid multiple interpretations.

In order to find a liable person, International Federation of Shipmasters' Associations (IFSMAs) proposed to the International Maritime Organization (IMO) that autonomous vessels could be at the orders and controlled by an experienced captain, with the right training and understanding to assess the environment and take the right decisions like regulations make mandatory.

To ensure this is necessary that a new update in the Standards of Training, Certification, and Watchkeeping (STCW) that have to include training for remote operators.

1.8.2. Private Law

All this new technology and as a consequence all these new laws in the public law also affect the private law. This is because the private law includes a lot of legal figures, like the captain. It also includes several definitions that can make troubles and have several interpretations. For example, the term “operator” is used to refer to the “shipowner” but in Spanish can have two different interpretations. This can be misunderstood when referring to the new term “Remote Operator”, “Land Operator”, “Shore Operator” or any similar name that includes the word “Operator” and refers to the shore captains in central stations.

Once the figure of the master appears in the regulations becomes one of the most difficult parts. The missing of the captain and crew on board makes that a lot of regulations become obsolete and lose the full sense. For example, in The Hague-Visby Rules the nautical fault⁵ in conjunction with negligence clauses in the charter contracts will be difficultly applicable as there is no negligence of nobody on board. It also can affect a lot of international treaties that will lose their utility and finally they will not exist.

In relation with this, the new subject mentioned before as a “Remote Operator” and other similar combinations has to take the position of the captain and its crew in the security tasks and functions remotely.

The idea behind is to be at any given time monitoring by the land captain or any other liable figure that is decided to exist. The land crew is not necessarily different from the ship one. It can have a captain that is the liable person, and other crew members that do the watchkeeping. The IFSMA suggested a captain form for the autonomous vessels, and this could have experience on board in order to ensure the seamanship needed and the experience to take decisions. This also ensures that the vessel, although is fully autonomous (but also applicable to remotely controlled vessels) it is controlled and monitored by a captain, complying then with the UNCLOS Art.94.

This new figure is not included now in the actual regulations. The thing is that it can be easily accommodated to fit in them, and the “operator” will be also protected by clauses like The Himalaya clause found in The Hague-Visby Rules, and others with similar intention.

The positive point is that the liable person, responsible of the shore center and the crew, will be finally regulated by state laws in the different fields. There are also other conventions and treaties that make the direct responsible the ship owner. For example, the Civil Liability of the Ship or Cargo Owner for Damage Suffered as a Result of a Pollution Damage, adopted by the IMO in 1969 after the Torrey Canyon accident, makes responsible the ship owner of the vessel in some specified and

⁵ The nautical fault supposes an accepted cause of responsibility exemption by the The Hague-Visby Rules. It is defined as *“any action or omission that generates negligence or fault of the Captain, crew or other dependents of the carrier, or the pilot in the navigation and technical handling of the ship”*.

clear cases. This makes necessary that the shore operator figure needs to be clear and internationally valid and unified, as it can become different responsible figures depending on the interpretation. So, to avoid misunderstandings, it needs to be defined in a international way.

Note here that the impact of this new shore operator figure can make an impact in other treaties and conventions and can finally create its own liability.

1.8.3. The Master

Finally, the problem found with the master is that, several charterparties and documentation makes the captain (master) figure to be needed.

For example, although parties can accord any contractual agreement referred to the technical field like the inexistent crew on board, there are several conventions and regulations that can make compulsory to have crew on board. This means that any agreement will not invalidate their obligations and finally this clause will not be accepted.

Also, the signature of the captain in bill of ladings and other documentation will suppose a problem. Once the vessel is not supposed to have a captain on board, and also the responsible person can be in a control center far from the loading/unloading port, makes a need for new regulations that can make a new person of trust to sign any documents with the same safety than the captain in the traditional vessels.

CHAPTER 2. AUTONOMOUS VESSEL INDUSTRY

Maritime autonomous surface ships, MASS, are going to be one of the improvements that will make the shipping industry evolve into a safer and more efficient ones. The autonomous and remote navigation could provide a lot of benefits to the industry. Some of them can change the whole industry and others will improve in safety and make the shipping industry cleaner and respectful with the environment. Otherwise, the industry will face new problems and challenges that will need to be solved to make possible this change and upgrade.

2.1. Potential Benefits

We will take a further look in the benefits that can provide the implementation of autonomous vessels in the maritime world.

2.1.1. Operational safety

Most of the maritime accidents are related to the human factor. It is known that humans tend to take bad decisions in stress situations. The insurance group Allianz, as it states in the “Safety Shipping Review 2020”⁶ document, says that:

“Extended periods on board vessels can result in mentally and physical fatigued crew, which is known to be one of the underlying causes of human error, estimated to be a contributing factor in 75% to 96% of marine incidents.”

This supposes that the majority of accidents at sea are made by fatigue associated mistakes. All these mistakes can lead to major problems, like hazardous spills, dangerous maneuvering, machinery related problems, ...

Another benefit of this increase in safety would be the number of casualties at sea. The Allianz report shows that in 2019 the number of casualties at sea was 2,688 and the number increased a

⁶ See: ALLIANZ GLOBAL CORPORATE & SPECIALTY. *Safety and shipping review 2020 report*[online]. Germany, 2020 [viewed 29 April 2021]. Available from: <https://www.agcs.allianz.com/content/dam/onemarketing/agcs/agcs/reports/AGCS-Safety-Shipping-Review-2020.pdf>

5% in 2020 with a total of 2,815. One key reason for this could be the COVID-19 crisis which led to higher levels of stress and mental fatigue for crews on board.

Those affairs could be reduced with the implementation of semiautonomous and fully autonomous vessels. In the case of semiautonomous vessels, thanks to autonomous tasks, the crew on board could have less fatigue and stress which could affect positively in the attention that they can put in their environment and make the job with an increased level of safety. In the fully autonomous vessels situation, the lack of crew on board will make that, personnel on land, will be in a more relaxed, focused and out of fatigue during the time they are in their job place. The change of crew more frequently and the different conditions that can provide a base on land in comparison with the vessel could make the control of the vessel easier in dangerous situations, more precise and reasoned decisions and then less human related bad decisions that are common in actual incidents.

2.1.2. Reduction of costs

Taking a further look on the costs of crew on board, the use of less crew or non-having crew on board will make a huge impact in the costs of maritime shipping industry.

Actually, the cost of seafarers has increased due to the actual situation. Since the COVID-19 crisis, crew change on vessels experienced difficulties. The impact of this is that seafarers on board had to serve longer time than the one expected and companies had to pay for the extra time at sea. The other side of this was that for each seafarer who stayed extra time at sea other crew members stayed at home waiting to start their contracts while losing money. Some companies decided to pay extra money to compensate those delays to their crew members at home.

Also, due to the change in procedures by the coronavirus crisis, seafarers need extra personal protective equipment to avoid the virus transmission, which leads in extended costs per individual for the company. It is important to mention that this is related to the cost of new sanitary and disinfection measures in order to increase the health safety and diminish the virus transmission.

Another added cost was the repatriation costs. During the worst months of the virus in 2019, airports were mainly out of activity and most flights were cancelled. This situation led to longer waiting time for crew to take a flight and return home, and also increased allocation times during those days for those persons in hotels. The prices in flights rose during this period due to scarcity on passenger flights. Finally, this exceptional situation added costs of quarantine in hotels for seafarers who were asked to do it by law.

Although this is an exceptional situation, personal protective equipment, sanitary measures, quarantines, COVID tests when joining and leaving the vessels, and all the new measures that will be normal in the upcoming years are going to be an extra price to pay for each seafarer at sea.

The benefits of autonomous and semiautonomous vessels in this field are clear. Semiautonomous vessels will have less crew on board and will reduce the total costs. Autonomous vessels which will have a base on land will reduce drastically their costs due personnel on land. This will be easier to change and rotate, without added costs like flights, hotels, quarantines and COVID tests. They will

also be cheaper to pay because in land insurances will cost less than insurances at sea for the crew members.

2.1.3. Energy efficiency and environmental impact:

Energy efficiency is highly related with environmental impact. The waste of energy, when this is produced by ways that have an environmental impact like the burning of fuels, makes contamination being higher than the necessary.

One of the benefits that can provide automated processes is the ability to increase efficiency and reduce the amount of energy wasted on each instant.

With the use of algorithms, mathematical formulas and technology, the interaction between vessel and the environment around it becomes an improvement in the navigation techniques. The use of sensors and navigation ways such as low steaming makes possible to adapt the navigation to the sea without the human influence.

The use of weather ship routing systems can be combined with slow steaming and automated vessels in order to find the most optimal route that can optimize the use of fuel and then reduce contamination produced by energy waste. This means that, optimization of consumption will be more precise using technology that separates the human factor and decisions.

Another positive thing is that the partial or total reduction of crew in the vessels will contribute to get a cleaner navigation. The reduction of human produced waste and sewage will be something positive for the environment. Also, the influence of humans in decisions is important. With autonomous or remotely controlled vessels it will be more difficult to contaminate in an irresponsible way.

2.1.4. Reduction of the Human Factor

One of the common problems in all navigation fields is the human factor. This can be described as all the actions that can affect in a positive or negative way the result of an action.

The biggest part of vessel related accidents, as mentioned before, is produced by human factor. There are several important cases in the maritime history where the human factor was the main problem, and without it, the accident would never happen.

One example of this is the "Costa Concordia". The human factor was decisive, as the established route was modified by the personal behavior of the captain, Francesco Schettino, who decided to deviate the route in order to accomplish personal affairs in front of the Giglio Island, the January 13th of 2012.

Another important case is the "M/S Estonia". This vessel is a nice example of the influence of human factor. The confluence of different situations made the disaster. We can find examples of human factor in several areas. For example, the vessel was in bad maintenance condition, which lead to a

breaking of the security seals in the embarking door. The seals were presenting several rust spots that weakened them. Also, the captain took bad decisions and started the emergency procedures late, including bad communications to initiate the distress procedure. Finally, the passengers never had an emergency training because of the short distance navigated, which led to a lot of casualties because they weren't able to know where they had to go in case of evacuation.

This kind of situations are common and affect in most of the most important cases. The influence of the human perception of reality, the stress in dangerous situations in conjunction with fear are decisive factors when an accident happens.

One of the benefits found in the autonomous vessels is the relief of the human factor to automated processes. The ideas on actual MASS vessels are pointing to give the control of the ship in danger situations to remote centers in land. This makes the decision-making process safer, as the decisions will be made out of stress and fear. Also, the process of activating danger procedures will be faster and clear, as sensors and algorithms will act immediately and without judgement.

The disconnection of human decisions to start a protocol is one of the most important facts that can make a bigger improvement in safety. Starting the procedures once the problem starts can give a lot of time of reaction to avoid further problems.

Another problem related with the human factor is pollution. It is well known that a lot of unauthorized spills at sea are not recorded and are made illegally. If there is no crew on board, any kind of discharge to sea will have to be executed by computers, which makes them difficult to hide and will be recorded by the system. This will avoid illegal practices made on board and will make more marine respectful the sea navigation.

2.1.5. Piracy

The last but not less important benefit is the reduction of piracy. Nowadays in some areas of the sea the interest of pirates in determinate products and ships is high, making the navigation there risky and dangerous. As Marine Digital⁷ article says, *"Pirates in 2020 are a manifestation of growing capitalism, lack of job opportunities as well as illiteracy"*. They also state that *"there is a 24% increase in piracy due to the current COVID-19 pandemic, which has shut down many businesses and job opportunities around the world"*.

⁷ See: *Evolution of piracy at sea: pirates in maritime 2020*. Marine Digital System - ML-based platform for maritime logistics[online]. [no date] [viewed 2 May 2021]. Available from: https://marine-digital.com/article_pirates

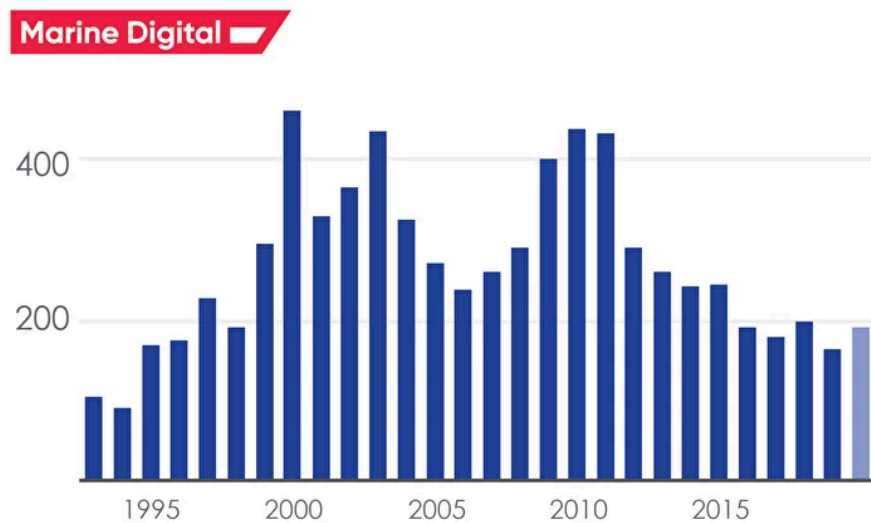


Figure 1. Evolution of piracy. Source: Marine Digital. 2020

In the image above we can see that during the 2000 to 2010 period, according to global crisis years, the number of yearly known piracy cases was over 400 in many years. The last 5 years the numbers were under 200 cases per year but the 2020 started rising another time.

Autonomous vessels can suppose an improvement in the piracy field. One of the decisive factors here is that actual vessels need to have easy access to embark but also disembark in emergency situations. This means that there are several ways for a pirate to enter the vessel. In autonomous vessels there is a lack of accesses because there is less need to embark on them. This will make the vessel more secure to avoid pirates, who will have more difficulties to enter and will lose their interest in attacking those ships.

The most important improvement in this field are the crew-less vessels. One of the biggest interests in piracy are the crew. This makes easy for pirates to start negotiations for big quantities of money to release hostages. Without people on board, they can't make crew hostages and then they will have less interest into attacking vessels for profit.

2.2. Challenges and Problems

In the other side, there are some difficulties that the autonomous ship industry will have to face. The main problem is that most of them are security and safety related rather than logistic problems. This supposes that they require to be prioritized in order to improve the MASS vessels and ensure they are safe.

2.2.1. Reliability

Maintenance of the vessel is one of the most important and continuous works aboard. The most common works are lubricating critical moving parts, work shift checks, visual inspection on important parts, checking liquid levels and pressure conditions and more. Also, if something fails

while the vessel is navigating it needs to be repaired, whether is a permanent repair or temporal one, in order to avoid extending the problem to other parts and maintain the route.

The problem found in vessels without crew aboard is that they will not be monitored in each work shift as always and it will not be continuously maintained and repaired as it happens in vessels with crew aboard.

This means that their level of reliability can be decreased while the vessel is in navigation. This can make the port stays longer in order to check that everything is right before the next route and also those times can increase if any repair is needed. This last point is important because a lot of repairs are made between navigation or anchoring saving a lot of mooring time, and they will need to be done in port stays. This will increase the costs of shipping, but the thing is to know if in the long term they suppose a bigger increase in costs than the ones that suppose the crew on board or if they remain lower.

The use of newer machines that require less maintenance and the improvement on the building designs and techniques in the further generations of ships can suppose a reduction of the maintenance requirements of a vessel. This newer technology in conjunction with sophisticated sensor systems and algorithms can provide a safer environment for those ships. Also, the use of new materials that can last longer and can resist more to the marine environment are an upgrade to the existing ones and for example, the rust related problems that produces marine salt. Also, the use of more simple machines than the ones needed in vessels that have crew aboard, and also the missing of the personnel equipment structures makes the possibilities to avoid maintenance increase, so it will be only necessary to maintain the minimal machines to perform the activity of the vessel.

2.2.2. Cyberattacks

Like any technology related industry, one of the most dangerous problems are cyberattacks. They suppose a big risk of information leaks, the loss of control and also they become the 21st century piracy. The use of ransomware and viruses supposes a big problem for private information companies. Once they are stolen, the “hostage” is the information and it is used to blackmail the companies for big quantities of money in order to not being leaked to the public. Also, the stolen information can be sold to competition companies that can gain advantage thanks to it.

One of the biggest problems of cyberattacks in autonomous vessels is the loss of control. This can suppose a risk for other vessels and infrastructures like ports or coastal areas that can become interesting for cyber pirates in order to produce a big damage to persons. Also, they can find in this procedure the interest to kidnap the full vessel and ask to the company for high quantities of money to release the control of the vessel. Another

important problem is if they decide to change the route and guide the vessel to a place where they can steal the cargo contained in it.

2.2.3. Interaction with other vessels

After the implementation of autonomous vessels, the interaction with traditional vessels supposes a goal. The way how they will react to some high traffic situations is decisive.

One of the positive points that a crew have and an autonomous vessel misses is the ability to actively observe the environment and decide which is the correct path to follow. Autonomous vessels need to be developed and designed with a lot of attention in the observation systems and the program after them, so they have to be able to spot dangerous situations related with other vessels and take immediate actions to avoid a collision.

If those systems are well designed will present an inflection point in the way how those vessels perform and can flip the current situation and take advantage of the human factor. This means that, if the systems can be designed to react fast and precise, it can be more profitable for the navigation than the human criteria, which is highly influenced by thoughts and perceptions.

The problem is not only from autonomous vessels to traditional ones, but also exists an inverse relation. This means that how humans perceive the autonomous vessels route and its own decisions is important. It would be good to have great connectivity between vessels, a way to tell to ships around the autonomous vessel how it will move and which actions will perform. Also, a way to communicate and interact with other MASS vessels without crew aboard, in order to fit their responses in a safe way.

2.2.4. Responsibility

One of the biggest dilemmas in autonomous vessels are the liability and legal issues that can incur if an accident happens. Questions like “who will be responsible?” and “how anyone will be judged if nobody was moving the vessel?” are the most typical ones.

The challenge to define a legal figure after this is really hard. The way to judge an accident is definitely very extensive as there are a lot of parties involved in the design of the systems and data processors, algorithms and software.

Historically the legal issued is the captain in first place, as the vessel is under its control and it is responsible of any issues happening. In a vessel without crew there is no captain, and if the accident happens without the remote control being active is very difficult to define who is the responsible party.

This involves a new legislation and procedures to be developed in order to decide who is responsible of any accidents that involve an autonomous vessel. This regulation needs to provide a safe and strong policy that can involve the most of the situations in which a vessel could be involved,

and have to be international and strong in order to avoid misunderstanding or different interpretations.

2.2.5. Connectivity Issues

Another important thing to take into consideration is the connectivity. One of the most discussed ideas around those vessels is to be remote controlled in some situations to ensure a good decision-making process. This means that great connectivity is key to make this useful and safe.

There are several areas on earth that can incur to loss of the signal or that can be out of the range of a shore central. This means that if the vessel crosses one of those areas the control will be lost and it can incur to bigger problems. To make this evitable it is important to maximize the connectivity on those vessels via different methods and make them able to be controlled anywhere and anytime without the possibility to loss the signal.

Also, they have to be able to maintain connectivity when going through high security areas that can be provided of signal blocking systems or also improve their connectivity systems to avoid interferences, from the vessel or other dispositive around, that can make erratic working like adding lag to the orders that are sent from coastal centers.

2.2.6. Special Situations

The last important challenge that autonomous vessels can face are those situations where the human presence is needed.

Some situations require a fast actuation to avoid a bigger problem. Flooding or fire onboard are examples of accidents that can get worse if there are no fast actuations once it starts.

The problem of vessels without crew is that typical problems such as the ones mentioned before are difficult to solve once it grows. They need that trained people take the necessary actions the faster possible. Without crew aboard this fast actuation can be nearly impossible. The period time since the beginning of the fire, the preparation time for the rescue team and the action to solve the problem can be extensive compared to the times of reaction on board.

It is very decisive to have designed protocols and systems that increases the time of reaction and ensures that the needed actuations will be performed in a positive way and also it is important to provide a safe environment while the emergency crew arrives to the vessel.

2.3. Real Cases

Nowadays the MASS industry is evolving fast. After the legal basis were established as stated before with some regulations, there are some projects that are being developed with solid ideas but also some projects that are being tested and improved.

2.3.1. MV Yara Birkeland

One of the most interesting projects is the MV Yara Birkeland, a feeder vessel specially designed to cover the Yara International necessities. This ship is the first world's electric autonomous vessel. It has a cost of 25 million dollars and the scheduled time for start operating fully autonomously was in the beginnings of 2020.

Characteristics

The Yara Birkeland, owned by Yara International, was ordered in 2017 and was a partnership between Yara and Kongsberg. It is an autonomous vessel, with capacity for 120 TEU and a it has 3200 dead weight tonnage. Its dimensions are 260 ft (80m) length, 49 ft (15m) beam, 39 ft (12m) depth and a draught of 16 ft (5m).

The ship is electrically propelled. It has electric motors that uses two azimuth pods and two tunnel thrusters. It can provide a speed of 6 knots with a maximum speed of 12 knots. The Yara Birkeland is provided with batteries rated between 7 and 9 MWh.



Figure 2. MV Yara Birkeland. Source: Kongsberg

The project

The goal of this project was to design a vessel that can be fully autonomous and have zero emissions. It was intended to cover the routes Herøya–Brevik and Herøya–Larvik, in the Norwegian coast. Since the date those routes were done in trucks. The planned route unites both routes in one. The total length of the voyage is about 31 nautical miles.

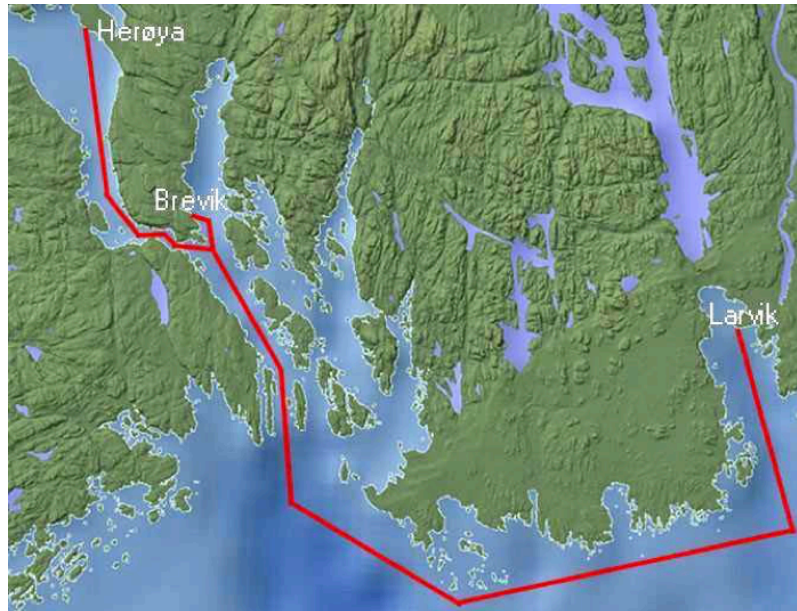


Figure 3. Yara Birkeland Route. Source: Change-Climate.com

Yara International is a chemical industry company from Norway. Their main activity is to convert the energy, minerals and nitrogen from the air into agricultural products and industrial solution. They mainly produce fertilizers, but they also produce product to avoid air pollution, improve better water quality and eliminate unpleasant odors.

Their intentions to develop this project were to reduce the pollution from diesel engines of the trucks used to transport their products from the base in Herøya to the ports in Brevik and Larvik. Their estimation is to reduce the truck haulage for about 40,000 journeys a year.

The President and CEO of Yara International, Svein Tore Holsether, said that they were willing to reduce not only the quantities of NOx and CO2 emissions, but also the dust and noise produced by trucks in conjunction with an improvement of the safety on the local roads.

They also are trying to meet the sustainability goals from the UN. Svein Tore Holsether said that *“As a leading global fertilizer company with a mission to feed the world and protect the planet, investing in this zero emission vessel to transport our crop nutrition solutions fits our strategy well. We are*

*proud to work with KONGSBERG to realize the world's first autonomous, all-electric vessel to enter commercial operation*⁸.

Also, Svein Tore Holsether explains in the same report how it can provide a good environment impact the use of an electric ship to move their cargo *“Every day, more than 100 diesel truck journeys are needed to transport products from Yara’s Porsgrunn plant to ports in Brevik and Larvik where we ship products to customers around the world. With this new autonomous battery-driven container vessel we move transport from road to sea and thereby reduce noise and dust emissions, improve the safety of local roads, and reduce NOx and CO2 emissions,”*

Design

To achieve the goal, Yara International partnered with KONGSBERG, a Norwegian company that produces high technology systems and solutions for different industries like merchant marine, aerospace, offshore oil and gas industries, ...

In this project, KONGSBERG was responsible of all the development and design of the required technologies, including the sensors and integration required for the remote and the autonomous operation. They also provided the electric batteries and propulsion systems.

In the same report, the President and CEO from KONGSBERG, Geir Håøy said that *“By moving container transport from land to sea, Yara Birkeland is the start of a major contribution to fulfilling national and international environmental impact goals. The new concept is also a giant step forward towards increased seaborne transportation in general,”*.

The hull of the vessel was made in Romania, by Vard Braila Shipyard. It was put into the water in February 2020 and was expected to arrive to Vard Brevik Shipyard in Norway in May. After the arrival it was KONGSBERG who followed with the installation of all the systems.

Another interesting fact in the ship is that it hasn’t any ballast tanks. Otherwise, it uses the batteries as a permanent ballast. This supposes a positive thing for the Yara Birkeland, as not using ballast water means a cleaner ocean environment.

The certification process is intended to be performed by Det Norske Veritas (DNV) to ensure that everything complies with safety and security regulations.

⁸ See: YARA. *The first zero emission, autonomous ship*. Yara None[online]. [no date] [viewed 9 June 2021]. Available from: <https://www.yara.com/knowledge-grows/game-changer-for-the-environment/>

The loading and unloading process

In order to improve the automation systems in the Yara Birkeland, the company Yara International partnered with Kalmar, a company from Cargotec. The agreement was intended with the intention to build a fully automatized and digitalized container handling terminal at Yara's Porsgrunn facility in Norway. This supposes for the Yara Birkeland to be fully autonomous and be managed in the most efficient way possible, reducing costs and emissions. The delivery of the project was established to be during the second quarter of 2020.

Kalmar will provide the required technology to not only make the loading and unloading work, but also to make possible the transportation from the fertilizer production factory to the quay. The benefits from the Kalmar technologies are that they are fully electrical and fast charging. This supposes that all the process since the leaving from the factory to the ports has been removed the pollutant process with trucks to a zero-emission process fully autonomous.

The equipment that Kalmar will provide consists one automated rail mounted gantry crane, three fast charging automated straddle carrier, one fast charging stations and all the automation systems and safety systems needed to ensure the correct working of the infrastructure.

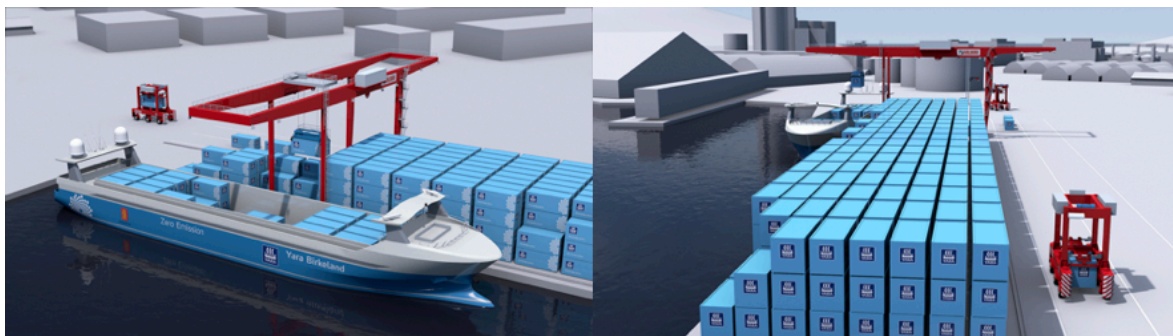


Figure 4. Yara Birkeland Automated station. Source: KALMAR

The straddle carriers provided by Kalmar will have to drive along the public roads in the factory vicinities in Porsgrunn, being in direct contact with the normal road traffic. To achieve this, Kalmar and Yara industries had to work hand by hand with the local authorities in order to ensure safety of vehicles and passenger in all situations.

The project in the actuality

The COVID-19 pandemic supposed a problem for the project. In May 2020, the pandemic changed the whole world and industries. Confinements made lots of workers to be at home and the whole world entered in a long pause.

The project during this stage had been stopped. Yara International decided to pause the project. At the same time, after the hull was launched to the sea in Romania, in February 2020, it was navigating and supposed to arrive to the Yara International facilities the same month the project

was paused. It is important to note that the project was expected to be ready to test in 2019, and it has been late for over a year.

The first steps once the vessel was delivered were planned to test its capabilities with crew on board, and remotely controlled. The first navigation of the vessel was in December 2020, when the vessel made an inauguration trip between Brevik and Horten. The trip lasted 7h.

Nowadays the vessel is located at Horten Port, where it is under testing of the autonomous systems. The launch is expected to be at the end of 2021, with a loading between 40% and 60%. The first two years it is expected to navigate with a little crew on board. As it is planned to allocate the crew during this time but the vessel is not planned to operate with people in it, actually it is being adapted to allocate this persons. This is achieved with a modular bridge and allocation space that, once the vessel becomes fully autonomous, this module will be detached and removed from the vessel. It was planned to be fully autonomous in 2020, but the high level of complexity that this project has, made the project to be delivered late.

2.3.2. The ReVolt

Another interesting project is The ReVolt, an autonomous short sea shipping vessel idea developed by Det Norske Veritas (DNV), in 2014. The intentions of the company to develop this project are to design a faster and safer vessel than those powered by diesel. This vessel wants to serve as an inspiration for the upcoming generations of shipbuilder and wants to provide a solution for the increasing need of maritime transport to avoid the road transport.



Figure 5. ReVolt. Source: DNV

Characteristics

The ReVolt has similar characteristics with the Yara Birkeland. The length of the vessel is 60 meters, a 14,5 meters beam, 13,8 meters of depth and a draught of 5,02 meters fully charged. It has a capacity of 100 TEU. It has a total deadweight of 1250 DWT.

The vessel design provides the ship with two azimuth pods and one retractable bow thruster. It has a 3000 kWh battery that sets the cruising range in 100 nm at a speed of 6 kn.

As it has no intention to allow crew on board, the vessel has not a superstructure for people allocation. The design of the vessel is special compared with the common vessels. It has raised hull side and the container stacking is made entirely in the interior of the vessel.



Figure 6. Revolt interior design. Source: gcaptain.com

This particular design of the ship allocation is possible thanks to not being provided of crew allocation superstructures and additional machinery. This design reduces the wind friction with the elevated structures, reducing also the energy consumption and increasing the cruising range. This means better optimization of the available energy. Another positive thing of this design is the increased safety to avoid stowaways or pirates to enter the ship illegally.

The less use of machinery decreases the need of maintenance and the main idea is to make this vessel capable of reducing the costs and the necessity of crew on board to maintain the vessel.

Another common thing with the Yara Birkeland is the missing of ballast tanks with the permanent ballast made by batteries. Also, to make the ship simpler, the rotating machines (the electric motors on azimuth pods and bow thruster) are located out of the ship, so it can be changed easily than if they are located in the interior of the ship.

Mooring

Since the vessel sails at lower speeds than conventional vessels, it supposes a longer navigation time. In order to fit the vessel in the current navigation market, it needs to be optimized the time in other jobs, like the mooring time and the loading and unloading times.

The mooring idea behind this vessel is to use grip arms and vacuum to make the mooring easy and faster. This allows the vessel to operate autonomously without the need of human assistance for

this job. This is crucial, as traditional mooring with winches and ropes is slower and high depending of the human assistance and also needs high levels of regular maintenance.

The port time is also included in the design. DNV shows in its informative data sheet that the estimated port time is about 4 hours, and also the ship needs to be charged in each port stay.

Loading and Unloading

Thanks to the design of the ship using interior stacking using guides, the stevedores needed is less than a normal vessel of the same characteristics. The reason is because the guides make easier to stack the containers and they don't need to be manually lashed as they are in the exact position without danger of moving. Finally, the cargo is secured in the interior with holds that makes the compartment fully sealed.

To ensure fast times of the load and discharge job, it would be needed to have dedicated terminals that have easy access for trucks and all the necessary equipment to make the mooring and the load and unload tasks fast and efficient. This would compensate the lower speed and make it a great alternative to traditional diesel-powered vessels. Also, those specifically designed facilities need to include charging stations so in every port stay it can re-charge the batteries.

Costs and Savings

In order to make the vessel idea good for sailing and using it in real life scenarios, the important thing to look are costs. The positive point in this field is to consider the low crew needed or inclusive the no need of crew operating in the vessel. This reduces all the crew related costs, like salaries, infrastructures and auxiliary machinery. Also, all this space will get an optimization as it is released to hold payload space which produces profits instead of costs.

The negative point is found in battery packs. This supposes a big consuming cost as the price per kWh is estimated in 1,000 US dollars, which supposes a total of 3,000,000 US dollars to replace the whole pack. The problem with batteries is performance degradation, which will reduce the cruising range overtime. Depending on the use of the vessel, the charging frequency and the charging conditions it is exposed it can increase the degradation. Also, the environmental conditions could affect to the battery total life. This means that it is not possible to make a precise estimation of the battery costs that can face in the years it is expected to last the vessel. The estimation in the moment of the project design was about 30 years, with at least 2 changes of batteries. Also, it is expected to see a decrease in the battery costs at the same time that battery technology advances, which could lower the costs a lot.

The positive fact is that The ReVolt will be producing profits since the first day of operation thanks to the low need of maintenance, the operation costs like not needing crew and not needing diesel to be operative. This makes an average of 1 million US dollar saving each year compared to a diesel-powered vessel of the same characteristics. At the end of the lifespan, it is expected to save 34 million US dollar in operation costs, but could increase as technology advances and becomes cheaper.

The present and future of the project.

The project was a vision for the future and not a short time vision project. This means that the idea from DNV was developed in order to open a new greener and more efficient shipping industry.

Their vision was to build this vessel once the technologies involved were matured. The technologies at the moment of designing the vessel could allowed to build the project and operate the vessel without problem. Otherwise, DNV states that their intention was to motivate and serve as an inspiration for shippers, equipment manufactures and shipowners to develop the necessary technologies and improve their vision for a safer and cleaner shipping industry in the upcoming future.

2.3.3. MUNIN

The MUNIN (Maritime Unmanned Navigation through Intelligence in Networks) is a research project in collaboration with the European Commission. The intention of this project is to develop and verify a new concept for the autonomous vessel industry. Nowadays, the actual definition is that autonomous vessels are primarily guided by the automated on-board systems but controlled by a remote operator in a shore control station.



Figure 7. MUNIN Coastal Station Design. Source: MUNIN

Background

In the actuality, maritime transport within the European Union (EU) needs a redistribution. The increasing volume in transport, the pollution produced by road transport and the increasing traffic is being an important focus point for the EU. The Short Sea Shipping within the EU territory and neighbor countries has been studied as a solution for those problems. The use of ships instead of trucks supposes a big alleviation for the European roads, and they can be used only in the first and

last legs of the transport, from factories and warehouses to ports and from ports to the buyer or receiver of them.

The EU has been developing a project called “The Motorways of Sea” which pretends to remove the main inland transport with maritime transport. The benefits that expose this project are the following:

- Reducing the air pollution: most of the road transport will be done in the sea by ships, which supposes an improvement as the cargo transported by thousands of trucks can be moved by just one vehicle.
- Noise reduction: by the same reason, the less traffic supposes a reduction in the noise produced by trucks.
- Cheaper transport: as the intention of The Motorways of Sea is to incentive the maritime transport, the idea behind is to create regular lines in the stablished routes. This supposes a reduction in the costs and taxes, which is a great improvement related with the road transport.

Also, the new navigation techniques, such slow steaming, means that the reduction in speed needs to be compensated with more vessels and more vessels need to be supplied with more seafarers. The lack of seafarers supposes a big barrier to achieve the needs and the autonomous vessels technology makes an important improvement against this problem.

The project

The project brings to the autonomous shipping industry the capabilities and the potential needed to improve the European Union ideas and face the challenges that they have in front in order to accomplish their goals. The MUNIN project can provide the tools needed to overcome the limitations and make available the tools and development needed for the shipyards and shipbuilders to make safe autonomous vessels.

The MUNIN’s results will provide a safety environment, with efficiency and sustainability advantages for the current vessels without the need to become autonomous.

In the long term, the autonomous vessels are the focus on the project. For them to operate is necessary that some of the current tasks on board are redesigned. The project has the intention to develop programs and applications that help in the optimization in tasks such as navigation and maneuvering. It also is intended to investigate watch keeping techniques and use it for the navigations and maneuvering.

For this to happen, they have to develop all the necessary communication architecture that gives the programs and applications to communicate and work together.

Finally, the MUNIN project includes in their guidelines the organizational and legal aspects of the unmanned shipping.

Interaction with land centers

As stated before, the project is intended to assist the autonomous vessels future to make it defined and establish a legal base for them to operate.

MUNIN proposed a concept, in order to make the navigation safe, where the vessel operates autonomously with the use of new technologies and systems on board. In order to ensure safety, the operations will be constantly controlled by the operator in the Shore Control Center. The project made a group of system definitions about the systems and persons involved, and published in their own project report in their website⁹. The definitions are the following:

- *An Advanced Sensor Module, which takes care of the lookout duties on board the vessel by continuously fusing sensor data from existing navigational systems, like e.g. Radar and AIS, combined with modern daylight and infrared cameras;*
- *An Autonomous Navigation System, which follows a predefined voyage plan, but with a certain degree of freedom to adjust the route in accordance with legislation and good seamanship autonomously, e.g., due to an arising collision situation or significant weather change;*
- *An Autonomous Engine and Monitoring Control system, which enriches ship engine automation systems with certain failure-pre-detection functionalities while keeping the optimal efficiency and which takes care of the additionally installed pump-jet that acts as a certain rudder and propulsion redundancy;*
- *A Shore Control Centre, which continuously monitors and controls the autonomously operated vessel after its being released from its crew by its skilled nautical officers and engineers. It comprises amongst others the certain positions:*
 1. *A Shore Control Centre Operator, who monitors the ship operation of several autonomous ships at the same time from a desktop cubicle station and controls the vessels by giving*

⁹ See: MUNIN. MUNIN results. *MUNIN – Maritime Unmanned Navigation through Intelligence in Networks*[online]. [no date] [viewed 9 June 2021]. Available from: <http://www.unmanned-ship.org/munin/about/munin-results-2/>

high level command like, e.g., updating the voyage plan or the operation envelope of the autonomous system;

2. *A Shore Control Centre Engineer, who assist the operator in case of technical questions and who is in charge of the maintenance plan for the vessels based on a condition-based maintenance system ensuring sufficient reliability of the technical system for the next autonomous journey;*
3. *A Shore Control Centre Situation Room Team that can take over direct remote control of one vessel in certain situations via a shore side replica of the unmanned vessels bridge including a Remote Maneuvering Support System that ensures an appropriate situation awareness in direct control despite the physical distance of crew and vessel.*

Finally, they made a protocol to set when the operator will receive the control on board, but also when someone will have to embark in the vessel to solve an emergency. This protocol is explained in the next image:

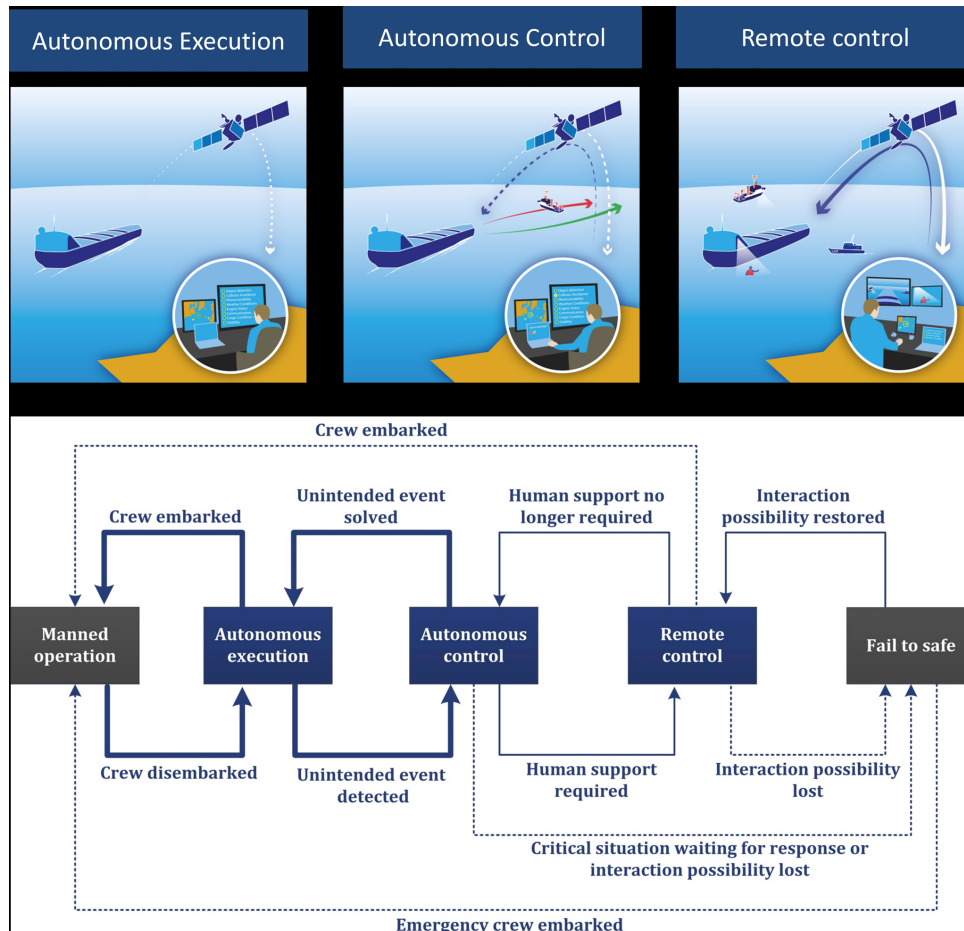


Figure 8. MUNIN Protocol. Source: MUNIN

As it is possible to observe, the different stages are set by the need of human support, and avoids any use of the autonomous control once the human support is required or there is an unintended event detected.

2.3.4. Deseo

Deseo is a semiautonomous ship, owned by the Belgian company “Wennick”. This is a 5.500 DWT vessel, with a capacity for 400 TEU. It was built in 2008, and has a length of 110 m, a beam of 16 m. This Short Sea Shipping vessel does the route between the Belgian ports of Zeebrugge and Antwerp.



Figure 9. Deseo vessel in the port of Zeebrugge. Source: CSP Zeebrugge

The vessel navigates in a semiautonomous mode. The reason is because the route between both ports passes through the Westerschelde river. This is one of the most sailed rivers in the world and supposes a risk for the navigation. The vessel has a high experienced crew on board that can take the control if it is necessary to ensure the safety of the vessel and the other ones.

The ship is using technology provided by the Belgian company Seafar, which provides the control from a shore control center.

The vessel is using a set of artificial intelligence systems that consists in a complex work between sensors and object detection systems that makes the navigation safer.

In order to get a stable communication link between the vessel and the shore control center, Citymesh, a B2B operator, is the entity that provides the project with the needed communication. The communications are actually using a hybrid Wi-Fi net, a private LTE/5G and the 4G public net.

The project is being done with the cooperation between the MOW department, the Maritime Authorities and De Vlaamse Waterweg. This cooperation has the intention to promote and validate the possibilities that the autonomous navigation offers and involve the Maritime Authorities in the development of further technologies.

The future vision of the parties is to reduce the number of crew on board to create a better efficiency but also to solve the seafarers scarcity problem that is facing the maritime industry. The objective is to improve the technology and analyze the data from the tests to optimize the autonomous navigation during the upcoming years. With this improvement the intention is to reduce step by step the crew on board to achieve a maximum number of crew between the 3 and 5 members.

The project is also receiving the support from other authorities like the Blauwe Cluster and VLAIO (Agency for Innovation and Entrepreneurship).

CHAPTER 3. DIGITALIZATION OF SURVEYING PROCEDURES

Once the automation of vessels appeared, it was a matter of time that the processes that take place in the maritime industry become automated. Surveys are one of those processes that benefit from being remotely done.

3.1. Definitions

The digitalization is the process to convert a traditional way into a digital one using computerized processes or algorithms. There are different levels of digitalization that can be defined as:

- **Remote working:** establishes a work flow method to work in the distance. As some works are not designed to be done in the distance, it has to include new working ways that ensures the same result as the one obtained in the traditional procedure. It is useful to reduce the necessity of displacement and becomes essential to improve the efficiency of the work once the distance increases.
- **Semi-automation of a procedure:** this involves a mixture between an automated process and the human influence on it. It needs to have the attention of persons that can ensure the correct working in some fields. This can be because of the necessity to verify difficult parts in the process or to identify incorrect working of it. It reduces the work to be done by the operator and can increase the focus on specific areas of the process. It also increases the quality of the work done and reduces the costs. It will introduce extra costs because of the need to automate some parts of the work chain.
- **Automation of a procedure:** is the digitalization of it to be self-fulfilling and to remove the need to involve persons that do the job. It uses higher grades of sensors and computerized algorithms that ensures high quality and safety. They are costly to design but on the long term they suppose a reduction in the human costs and time costs.

3.2. Background

Processes that happen around a ship are time consuming and usually last for several days or hours. This means that processes like customs documentation can delay the loading and unloading operations, surveys can suppose longer port berthing time, etc. In the shipping industry, more time is translated into added costs.

The use of remote procedures and automated ones supposes a benefit for the companies, as the time involved can be reduced or inclusive avoided, which is translated into cost reducing procedures that makes the whole chain faster.

For example, in the European Union the customs procedures have been updated to digital ones for those vessels sailing from a communitarian country to another communitarian country. This supposed a big improvement for the shipping logistics, as the vessels can start discharging once they arrive at port, without any waiting needed like happened time before.

Using remote or automated processes opens a new door to optimization of time and the efficiency of procedures. The new technologies make possible to upgrade the traditional procedures to new more efficient and more reliable ones.

Surveys have become the new focus of digitalization. Several modes of inspection have appeared in the last years. This is a great addition that lowers the port time and also can be done before the vessel arrives at port, thing not possible before.

In the current situation of the entire world, the use of different types of vessel surveys are becoming popular. From digital procedures to drone use for hull inspection, the whole inspection services are becoming more reliable for both the shipbuilder and the ship inspectors.

Like any other field in the maritime industry, the balance between benefits and negative points is important.

3.3. Benefits of remote and automated procedures

As any new technology emerging in the maritime industry, benefits tend to make the different parts more reliable and less costing.

3.3.1. Time Saving

The use of remote procedures removes the necessity to be on board of the vessel in order to perform the activity. The use of remote surveys means a big improvement in this field.

Before these revolutionary techniques existed, ship inspectors needed to wait for the vessel and embark on it in order to inspect the vessel. Once this was needed, it supposed for the vessel an extra time in a lot of cases, where documentation was missing or faults were found. Nowadays, the

crew on board can start the inspection time before the vessel arrives, which saves a lot of time for the ship when it is in port.

In the other part, the inspector can benefit from this too. Before the remote surveys, the inspector lost a lot of time to do his job. Most of the time they needed to travel to other countries and ports. Waiting for the ship to come and spending long waiting hours in planes, hotels and any other transport mode supposes a lot of lost time. So, the quantity of inspectors needed to cover the inspections is high. With this processes, one inspector can do its journey from an office and inspect more vessels in their working journey. This reduces the time lost and also the inspectors needed to perform surveys. This also supposes more family time and an increase in job time quality.

The use of drones, in the other hand, can provide time saving benefits for the surveyor. Drones are versatile and agile devices that can make the work easier. They can access difficult zones without risk. For example, the use of a drone to inspect a hull can lower the times exponentially, as the cameras and sensors can detect imperfections that a person could need to dedicate lots of attention. It also can save the preparation times that an inspector needs, leaving it just to the necessary time to set up the drone ready for the job.

3.3.2. Faster documentation

Another benefit and related with the one before is the ability to get faster documentation.

When automated procedures become efficient, the documentation can be done in a faster way than traditional procedures. This for example can impact in vessels as a faster release of the vessel for navigation after a fault is found. It can imply to get the documentation needed before the vessel is in port and avoid the long waiting periods that can make a vessel stay in port longer times.

In remote surveying, the documentation can be done at the same time that the inspection happens. The office job makes able to have one person making the needed documents at the same time, and being ready to survey another vessel once the inspection ends. This supposes a great time saving benefit for both parties, the vessel and the inspectors.

3.3.3. Reduction of costs

Another important point is the high reduction of costs that supposes for all the parties involves. Whether some automation special equipment can be costly, in the long term can make a difference.

As mentioned before, the autonomous vessels suppose a big reduction on costs in the long term thanks to the low crew in the semiautonomous vessels or inclusive the non-existing crew in the fully autonomous vessels.

It also reflects on all the automated processes. The precision that they can have and removing the human factor usually involves less costs.

The remote surveys can benefit from best of both worlds. They have less costs involved than traditional surveys. First, they remove the need to move an inspector to the port and to allocate them in hotels if he is far from home. Working remotely, there is no need to pay for transport and hotels, but also for the food costs. This reduces the price that the vessel has to pay for this service. In the other hand, the vessel can do this inspection without the need of high technology devices. The use of a camera included in phones and an internet connection is the necessary for a crew member to do the inspection in real time. The inspector just needs to ask for what they need in order to cover all the inspection points. The great part here is that this removes the need to be at port, which makes possible to have all the documentation ready before the vessel departure time.

It also speeds up the times of meeting and documentation revision, which gives the surveyor the ability to proceed fast and get any documentation inclusive before the survey starts.

3.3.4. Removes physical barriers

One of the points that has increased in importance on the last times due to the COVID-19 crisis is the physical barriers that has been created.

The use of remote services supposes a great option to avoid physical barriers. We understand for this all problems that can encounter a person to arrive to its destinations, or inclusive to block the total ways to go. In the coronavirus crisis between the years 2020 and 2021, the country restrictions and transportation services cancellation supposed a handicap for everyone that tried to travel to other countries.

The delays on flights and ships, or inclusive the cancellation of them are normal. It increases the risk of them to happen when natural disasters, political affairs, wars or sanitary risks are happening.

The benefits of remote surveys remove those barriers and makes easy to make an inspection whatever it is the situation around the place to go. This is a cost saving and time saving solution that increased in popularity.

3.4. Negative Points of Remote and Automated Procedures

The use of new technologies also has some negative points that can limit the use of them and make slower the development. The use of remote and digitalized processes has a test period of time before being massively adopted.

3.4.1. Optimization Needed

Before any of the processes can be used widely by all companies, they need to be tested and improved. This is essential and needs to be done cautiously.

The remote surveying processes have to be equally or better than traditional surveying processes in order to gain popularity. They have to ensure that vessels are safe and that all required points are inspected.

The experience gained and the feedback from the shipping companies that can benefit from them is necessary to develop better procedures and make it reliable.

It also has to be legally compliant, and this has relation with the point before. This supposes that the remote inspections, or automated processes have been approved by the legal institutions. For this to happens is needed to comply the rule before: to be equally safe or more than traditional processes.

3.4.2. Limited situations

The use of remote and automated processes can be limited by some situations. There are special cases when it is not possible to accomplish the necessary procedures, they have increased levels of complexity or they can't be digitalized.

The most common remote inspection cases are usually those general surveys that need to cover standardized points and have standardized protocols.

Nowadays, the most used remote surveys used are the port state controls, occasional inspections, minor damage inspections and periodic surveys that had minor elements to rectify.

Those inspection types are in general terms easy and efficient to do as they don't have complexity or bigger difficulties to cover. Otherwise, those are related with common procedures that can become a relief on the working pressure that inspectors hold and they can work easier and more efficiently.

3.4.3. Technology dependent

The use of technology is essential when digitalization happens. It is needed to convert the procedures to computerized ones and this involves a big research and development process around it.

This need for technology usually involves two requirements: development unit in the company or contracting a development company.

The need to involve a team that investigates and designs the technology is essential in order to digitalize a process. It also needs to know all the process with details and work together to create an improved version of the work path. This dedication needed supposes increased costs to start the new process.

In the other side, the use of technology can be expensive. Depending on the grade of digitalization, some sensors, connectivity antennas, motors, high technology devices and computer programs and algorithms can become a high-cost option. This added costs can define if a project is worth it or not and can be decisive at the time of upgrading to automated or remote processes

3.5. Classification Societies and Digitalization of Procedures.

The classification societies have started a relevant process of digitalization of their procedures.

The use of different processes to make a more precise work and optimize their procedures costs and times has become a new standard in a lot of jobs around the maritime industry.

Last years have become a trigger for companies to develop new strategies that not only are a benefit for them, but also for the ship owners. Remote services have been demanded more during the last years.

Two of the pioneer classification societies doing remote inspections are DNV (Det Norske Veritas) and Bureau Veritas. To do the inspections they are using several devices that offer improvements in comparison with the traditional methods. These are the following ones.

3.5.1. Remotely Operated Vehicles (ROVs)

In this category we can find both aerial and submarine devices. They are controlled by operators near or in the vessel. They offer several benefits in comparison with the manual procedures. We can find underwater remote operated devices in the submarine category, and drones in the aerial category.

Underwater ROVs

This kind of devices, also called underwater ROV, can be submerged in order to inspect the hull of the vessel and submerged elements. They have been used since time ago to perform underwater operations in deep seas. Their function is to perform operations where divers have difficulties, because of the situation of the emplacement to visit or high deep areas where submerging is difficult.



Figure 10. Underwater ROV used in Costa Concordia accident. Source: VideoRay

Those devices have become more popular in the last years because they can take photos and record videos in difficult access areas. They have been used in some sink vessels to study it and make inspections of the accident.

One example of this application is the Costa Concordia salvage. The use of underwater ROV was crucial in the reflecting operation. They helped to record each second underwater and also provided the necessary images for the study of the reflecting. They were important to construct the structure that helped to right the vessel, because of the quantity of images and videos provided. Those played a big role in the investigation in order to plainly the procedure. The total recording time was about 45,000 hours during the salvage and reflecting study, but also to coordinate the whole operation.

The good results in accidents have increased the popularity of those devices in vessels, gaining interest in the surveying sector.

The Surveying Laws make mandatory two hull inspections in the period of five years. They also imply that both inspections have to be done in less than 36 months.

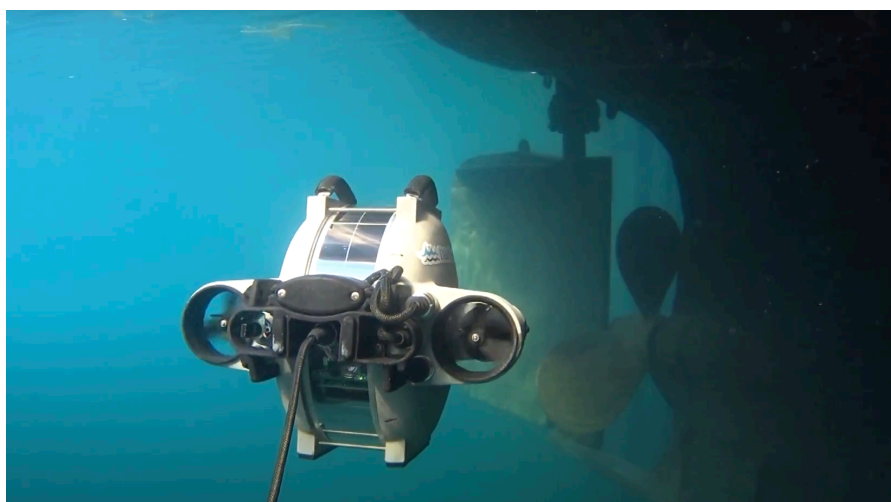


Figure 11. Underwater ROV used for hull inspection. Source: deep trekker

The inspections done can be law compliant, which makes them valid to cover the laws. They also can become popular and not only a surveying procedure, but also a preventing procedure that can help to spot problems sooner and avoid accidents.

The benefits of this technology are the ease of use, even if it needs prepared operators to make it work. They are less risky than divers in some situations, so these devices can do several activities that could put divers in unsafe situations.

The negative points are that, due to the complexity of their function and the need to comply several law standards, it could need a prepared operator that has the knowledge and the validation to use them according to law norms.

Drones

The other popular devices are drones. Those remote flying devices can provide a lot of versatility in order to inspect high areas and difficult access ones. They also can be provided, like underwater ROVs, with cameras and systems that provide the tools needed for the inspection.



Figure 12. Drone flying in port. Source: professionalmariner.com

The versatility that those devices can provide is immense. They can inspect the exteriors of the vessel and record each centimeter of it, but they can also enter on the most difficult areas.

The use in confined spaces is gaining popularity. They aren't affected by contaminated air or spaces with lack of oxygen like tanks. This has a relevant paper in the surveying industry because the operator can inspect all tanks of a vessel faster and safer, without missing a detail. They also can inspect the images taken with care in the computer.



Figure 13. Drone flying inside the cargo hold by ClassNk. Source: gcaptain.com

The use of drones inside tanks and cargo holds can help the inspectors to monitor rust, corrosion and cracks in easier ways. The classification society ClassNK made a demonstration in 2018 in conjunction with Hitachi Systems and Mitsui Co. where the drones become the main attractive. They inspected the ballast tanks and cargo holds in a classification class survey simulation done in one of the vessels from the shipping line Mitsui O.S.J Lines using drones. The flying ROV recorded videos of the confined areas showing high details of the conditions and they show the effectiveness of using drones for this.

The drones used in the inspections have particular tools in order to perform their activities. For example, the use of LiDAR technologies can make 3d mapping and then give the exact measures of distances and angles. This is useful in areas like tanks and cargo holds and generates an added value to the traditional techniques used. In order to perform the flights safely, they can be provided from object identification systems that make them avoid objects founds in their trajectory. They also can include thermal cameras, X-ray cameras, and other tools that ensure that the use of the drone gives features that human inspectors can't provide.

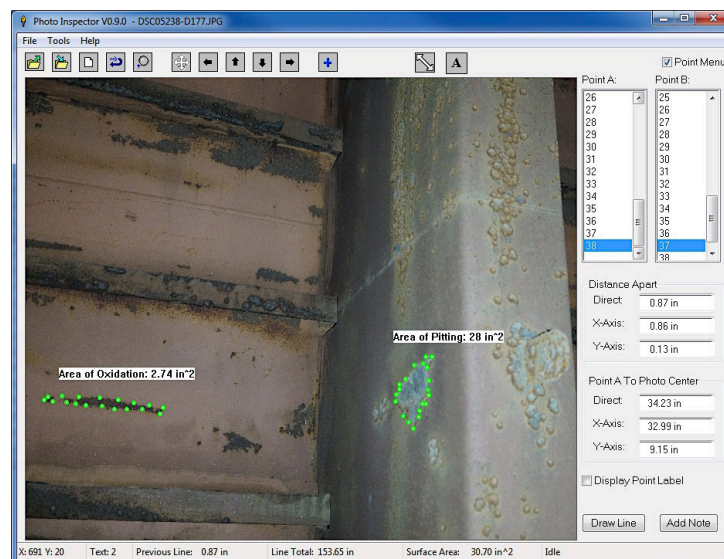


Figure 14. Analysis of a picture made with a drone. Source: ProfessionalMariner

Those drones can also be provided with automated processes that make the remote controller do other jobs while for example is recording a whole hold. The use of autonomous drones can make a game change in the industry becoming a relief of drone controller persons and let them flight several drones at the same time to make faster operations.

In the International Association of Classification Societies, the Lloyd's Register became a leader in the regulation of this new techniques. The initiatives that Lloyd's Register proposes includes improvements in the survey guidance and introduced requirements for service providers.

As an example of application of drones, the Lloyd's Register performed an inspection for the cargo operator CSL. The company needed to make a detailed survey in one of their self-unloading bulk carriers and the surveyors needed to access the holds. The vessel was not intended to go in a dry-dock in a long time, and the team from Lloyd's Register used drones to assist the surveys. It was an

improvement in time and costs for CSL which had the vessel operative in record time compared with traditional procedures.

The American Bureau of Shipping, an American classification society, published in 2019 the “Guidance Notes on the Use of Remote Inspection Technologies”. There the company made a guidance project with notes for the use of drones, underwater ROVs and robotic crawlers for their use in survey class inspections and non-class inspections.

The negative points that can be found in the use of drones is the interferences that can find near a ship. Because of the high communication levels, in different frequencies and between devices, a ship supposes a challenge for connectivity related issues. A drone can lose signal several times due to those interferences, high quantity of metal structures and also magnetism produced in the vessel by machines. Those issues can also limit the use of live stream from those devices. In order to avoid this, it is needed that the technology around those vessels make them less sensible to the environment they have around but also that make stronger wireless connections.

Finally, the use of drones was popular in the ship industry from time ago. The COVID-19 pandemic made more popular the use of those devices and supposes an inflection point in the future of this technologies.

3.6. DNV GL (Det Norske Veritas - Germanischer Lloyd)

Det Norske Veritas began its first remote inspections near 2017. The units of DATE (Direct Access to Technical Experts) based in the Maritime Operative Center in Høvik, Norway, and working together with bases in Hamburg, Singapore, Houston and Piraeus, got the chance to complete more than 1,000 remote surveys during the pilot stage and the widening stage. They first started in 2017 with the technology test, and their first tests were in June 2018. Nowadays they opened the remote inspection to all vessels that have being classified by Det Norske Veritas.

To use the service, the vessels from the float of DNV just need to go to their platform “Veracity” and the system automatically shows the possibility to use the remote inspection. Once the option is selected, one inspector needs to revise it and decide if it can be provided remotely. They have to verify before doing it to ensure that the safety levels are equal to the ones provided with an inspector onboard.

They included in their services the use of electronic certificates. This supposes a major improvement for the surveys as they can provide the documentation once the inspection is finished.

The most used surveys are those that are based in documentation revision, test systems and extra surveys needed for particular situations. Otherwise, there are some inspections that require that an inspector does the survey onboard, and those are not included in the remote surveys program.

The company also complements those procedures with the use of Drones. In order to adapt the flying technology to different types of vessels, they have more than 4 types of drones in their toolbox. All those drones are customized for DNV needs and improved in order to fit all the inspection purposes that they have.

During the 2019 year, DNV GL made remote inspections to vessels from the company Wilson ASA. The first ship inspected was the Wilson Fedje, which operations finished in December 2019.

The last remote inspection made to the Wilson ASA vessels was performed in July 2020, in the Bergen port. The remote topography expert finished the survey in the DATE (Direct Access to Technical Experts) center at the Greek city of Piraeus.

To perform those remote inspections, they collaborated with VUVI AS, a certified Norwegian company by DNV that cover submarine inspections to vessels and off-shore platforms using Remotely Operated Vehicles (ROV).

The most relevant benefits of the VUVI AS equipment were the ability to scan the hull at the same time that they located with the sonar included in the ROV. They performed the remote inspections in a similar time that traditional operations are done, but with more safety and the same thrust that a human inspection can offer.

They provided stable connections during all the time and the information and data obtained had been uploaded to the Veracity platform, the digital platform used by DNV GL to perform remote inspections. With this platform they ensure that the video recorded and the information is private and safe.

3.6.1. Digitalization Processes

DNV GL has been transforming their services with digitalization processes in order to make them easier and faster to perform.

The digitalized options not only include the surveying and inspecting services. The company also included the internal remote audits.

Those are intended with the same aim than the processes before explained. They can be done fully virtual or they can have physical visits. DNV GL also ensures that they require lower investment in software and hardware and in some cases, it is not required. The service is provided for all kind of companies, and they also affirm that the companies could be auditing their products and supply chains by themselves.

Luca Crisciotti, the CEO from DNV GL - Business Assurance affirms that *“With the communication tools available today, any remote audit is plug-and-play from a technology perspective. We can deliver using both off-the-shelf tools, catering to the default software of our customers, and apply*

*our dedicated remote auditing platform when required*¹⁰. This makes possible for companies to include the service in their upgrades to digitalized processes with all the tools in hand. The use of tools provided by DNV makes the process faster and less costly than adapting third party tools to their own system. It avoids a lot of developing and compatibility issues, which makes this process easier for both companies and DNV GL.

The benefit list that can give the use of remote audits is great. Those virtual audits are a path to the new era of efficiency. The traditional procedures were travel dependent. This remotely done processes remove the necessity to travel abroad and this reduce the associated costs but also the time spend on displacement. The reduction is also bigger in special circumstances that make difficult or nearby impossible to travel to other places. Another benefit is the possibility to connect members of the company that are separated by distance, which makes easier to perform the tasks needed.

In order to provide an according service, the auditors have to be trained in remote auditing delivery modes. The procedures are established to comply with requirements and law.

3.7. Bureau Veritas

Bureau Veritas is another of the classification societies and surveying services provider using digitalized processes in their inspections and surveys.

3.7.1. Pilot Survey

In 2019, Bureau Veritas completed one of their first remote surveys on a ship. It was performed using a Kongsberg's DP Digital Survey solution in an Offshore Support Vessel stationed in Angola.

MAC, a company that is specialized in dynamic positioning systems and part of Bureau Veritas, was crucial to determine in collaboration of Kongsberg the functionality and reliability of the remote survey system.

The DP Digital Survey provided by Kongsberg makes available to survey in a remote way the data output, and the solution supposes a next step in the road to smart ships.

This tool runs on an industrial data management system. It ensures the consistency of data to verify the systems onboard. The ships' control systems send the information to the tool and this delivers

¹⁰ See: *DNV GL's remote audits enables efficiency, access and reach*. DNV[online]. [no date] [viewed 21 June 2021]. Available from: <https://www.dnv.ee/news/remote-audits-enabling-efficiency-access-and-reach-170901>

it to the auditors. The transfer bridge is done by secure cloud infrastructures and provide real proof data to ensure the proof of test completion evidence.

3.7.2. Bureau Veritas use of drones

In 2020, Bureau Veritas inspected a bulk carrier using drones. The job performed using the drone was the close-up inspection of the cargo holds and also the ultrasonic thickness measurement that needed the hold walls.

In order to perform the inspection, it had to comply with the requirements found in the ESP Code (Enhanced Survey Programme) in the “Enhanced Programme of Inspection During Surveys of Bulk Carriers and Oil Tankers” version from the International Maritime Organization (OMI). The other decisive requirement was to get the permission from the vessel flag country state.

The company, Bureau Veritas, has their own code since 2019 to regulate their techniques of remote inspection (RIT). In addition, the drone operator is certified by Bureau Veritas for both the operations or remote inspection and ultrasonic thickness measurement.

3.7.3. Enhanced Reality in the ship inspections

The classification society and the Dutch shipping company Anthony Veder completed a test for the in real time remote class inspection surveys. The innovative process used the enhances reality technology.

The test was performed in one of the vessels from the company, in particular in the bridge, cargo control room and machine room.

The Bureau Veritas inspectors gave the necessary instructions to a crew member in the vessel, using the enhanced reality device and through in time video and sound connectivity. The member was able to capture all the necessary footage for the offices from both the shipping company, in Rotterdam, and Bureau Veritas, in Paris.

3.7.4. Audit Digitalization

The idea behind the remote audits offered by Bureau Veritas is the same that the one of DNV GL. They intend to do the audit of company processes, policies, procedures and personnel in a remote way and it is done by an offsite auditor. The task is realized using Information and Communication technology that gives the ability to perform real time communications. The auditor can interview auditees using video conference, and they can review all the documents in real time with processes of screen sharing.

Otherwise, those services are intended for all the processes that don't require physical visits.

In order to perform the remote audit, Bureau Veritas developed the eight steps of Remote Auditing Process. These are shown in the next image:

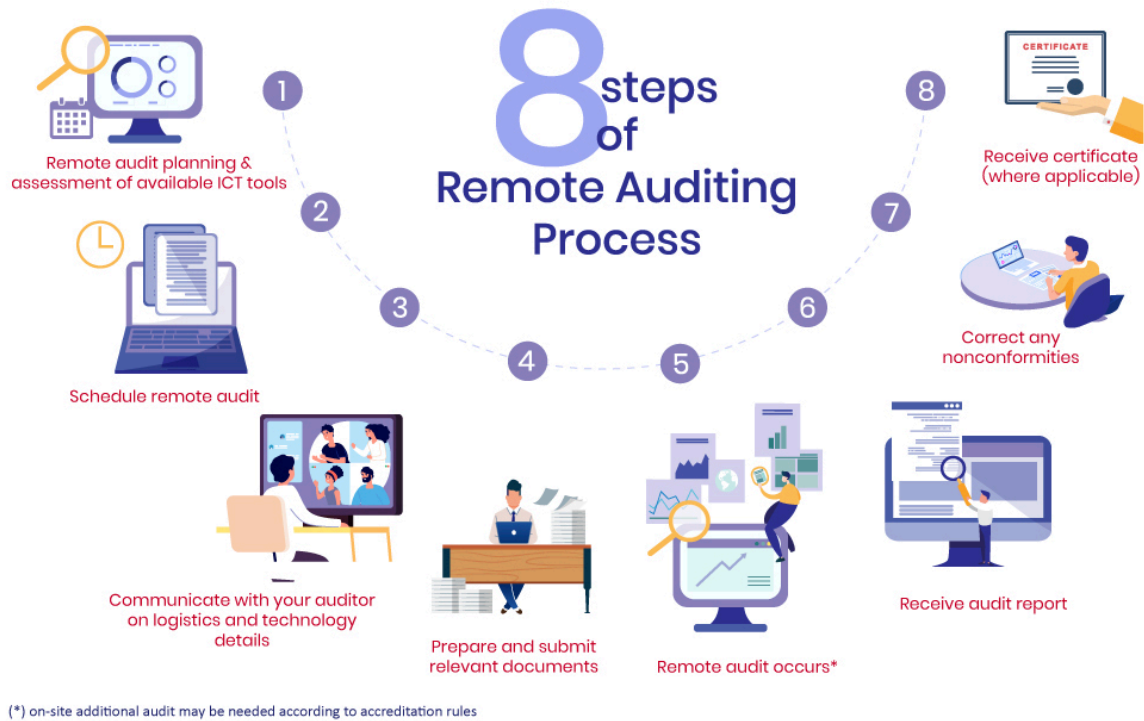


Figure 15. 8 steps of Remote auditing process. Source: Bureau Veritas

They also provided a list of the key prerequisites needed to perform an effective and efficient remote audit. They are provided in the next table:

<p>Document preparation: Make sure the documents are ready and available to be shared on the screen with the auditor. As an on-site visit is not possible, make sure all documents are accessible remotely and can be shared online.</p>
<p>ICT tool & good Connectivity: Make sure your network has enough bandwidth to support multiple connected people on the digital meeting with screen sharing. In case a specific room is needed for better connectivity assure its availability for audit time.</p>
<p>Security & confidentiality: Make sure you have a secured network with VPN (Virtual Private Network) system that can be used for connecting to the ICT system. Bureau Veritas auditors, on their side, will use BV VPN.</p>
<p>Team availability: As any certification audit, make sure all necessary people can access (and are invited) to the video conference and participate in the remote audit. People can connect anytime they need or are required to.</p>
<p>Time management: Remote audit requires specific time management compared to on-site audit. BV auditors will adapt their auditing program accordingly.</p>

Figure 16. PREREQUISITES OF Remote auditing process. Source: Bureau Veritas

All the process of Remote Audits was agreed by the majority of accreditation bodies to perform during the COVID-19 crisis in order to validate certificates and ensure the business continuity. The authorizations were given using the IAF MD4/MD5 guidelines that regulate how to conduct the remote audits.

The audits are compliant in a lot of ISO standards. The most of the cases can move the 50% of the audit to remote procedures and in some cases the totality of the audit can be done remotely. The cases were 100% can be done remotely are those in which there are no manufacturing processes involved in the activity of the business or there is no physical activity on-site.

CHAPTER 4. APPLICATIONS OF AUTONOMOUS VESSELS

The technology around the shipping industry is becoming more relevant nowadays. The maritime industry is evolving fast. The new techniques used to reduce the contamination, the use of new materials, construction techniques and designs and the implementation of greener alternatives like hybrid and fully electric vessels supposes a new generation of ships.

The new technologies in the electronics field and the investigations in new sensors and devices is helping the whole industry. Also, the upcoming generations of shipbuilders and naval architects are absorbing tons of new concepts and are learning to implement in their designs all these new inventions.

Another important fact is the availability of those new upcoming technologies. The production techniques and the availability of materials made a reduction in the production times, the difficulty and also the associated costs. In other words, the technology becomes better, faster and cheaper. This is thanks to the contribution of technology developers and the shared knowledge. The growing is becoming faster and the available devices are being decisive in order to investigate, develop and produce.

With all this included in the shipping industry, the upcoming generation of vessels will be high technology machines, less pollutant and more sophisticated.

Examples of this are both remote controlled ships and autonomous ships. The automation of processes turns the shipping industry into a more efficient era.

Removing the need of the human job on board a vessel but also in the associated tasks performed in the shipping cycle is a way to solve the lack of seafarers. The variable and irregular schedules, the large times out of home and far from families and the implication needed to become a seafarer supposes that young generations prefer other careers in their lives. This produces a problem in the industry, where demand is growing day by day and this involves more human hand demand too.

The solution offered by the new generations of vessels not only improves the navigation and the port operations, but also makes possible to optimize the seafarers available to perform tasks that can't be automated, or at least, tasks that need being monitored and supervised.

Remotely piloted vessels are one of the new attractive jobs in the shipping world. They offer the possibility to be trained in a growing industry, that is moving fast into the new emerging sector. They offer the possibility to drive vessels from a shore center and make regular schedules and be at home day by day. It also needs to have people trained specifically which supposes a great opportunity for new seafarers. It also removes the fear and the bad decision-making situation that happens because of the stress of accidents at sea, as there is no danger involved to the own body.

The functions of the upcoming generations of vessels are widely extended and depends on each type of vessel.

4.1. Categories

The main classification to take into consideration are the IMO established ones that were mentioned in the first chapter. Otherwise, once the autonomous vessels industry grows and advance, they can vary and can be upgraded to fit the upcoming types of MASS vessels.

In order to provide real life expectations of this new generation of ships, it is nice to do it using the categories provided by the International Maritime Organization.

4.1.1. Degree One

Defined by the IMO as ship with automated processes and decision support. This means that the vessel will have crew on board. The tasks of the seafarers have to be ready to take control of the operations that take place on board in an automated way. Those automated operations haven't to be supervised, but seafarers on board need to be ready to take the control on them if it becomes necessary. They also are on board to control the vessel and do all the not automated operations.

This is the first step and the most basic one. The automation of processes is a nice way to relief tasks and use the human presence to make more complex tasks.

Autopilot

The use of technologies that automatize the processes on board is wide. The autopilot is one of those applications.

The vessel is guided following a route. The system moves the vessel according to the coordinates that the master of the vessel has set. Once the vessel arrives to a waypoint, the rudder changes the course to the needed to arrive to the next waypoint.

While the autopilot is working, the seafarers can do other tasks. The navigation using autopilot has it's own limitations that involves supervision and human control taking at some point.

If the system detects that an unexpected object is on the way of the vessel, like a lost container, a vessel or any big body that can suppose a problem, it makes alarms sound and the seafarer have to take the control. This is because autopilot is only a guidance tool, that makes the transoceanic routing easier. It doesn't include object avoiding systems, so if an object is found in the way it needs to be cleared manually.

The use of systems like this needs a person that at least can take the control and act according the situation. It also increases safety not relying in a system like autopilot because the reaction can be faster and more precise if a seafarer does it.

Automated Position Sending:

Another common automated process is the position sending. The AIS (Automated Identification System), sends the current position and other data automatically. The seafarer has to set up the AIS system before the navigation, completing basic information like destination port, ETA (Established Time of Arrival), etc.

Whether it is an automated system, the need of a human member to configure it, makes it not an autonomous process.

The automated position sending is not only limited by the AIS. The distress function in some devices can include automated position sending options. This is intended to work together with the AIS or other GPS (Global Positioning System) in order to send the exact position of the vessel once an emergency happens. This avoids mistakes on manually tipping the position, but also gives time in an emergency situation to perform other tasks.

The distress needs to be activated by the human presence, so this is not autonomous, and needs to be checked that the position send is the correct one.

Automated Tank Filling

Once the technology advances, the automation of processes like stability related ones, using the ballast water, can become automated. For example, the automated process of filling ballast tanks with water and the sequences needed can be done and adjusted by the system and supervised by the crew on board. They would have only to take control in case of an unexpected event and then solve it before continuing.

The same concept can be applied to other tank filling in chemical vessels or petroleum ones, liquified natural gas vessels and liquifies gas vessels, etc. The automated system can regulate the filling sequences in order to respect both stability of the vessel but also the safety of the vessel and members.

4.1.2. Degree Two

The degree two of MASS vessels classification made by the International Maritime Organization makes a step further in the automation process.

It is defined as a vessel controlled remotely provided with crew on board. This implies that the control of the vessel is produced remotely, from another location. For example, the shore center. The people on board also have the ability to take the control and operate the shipboard systems.

Unexpected Events

In unexpected events like losing connection with the shore center, the crew on board can operate the vessel and control it in order to arrive to a safe zone and recover the

connectivity. It also makes possible to the members on board to recalculate the route in order to avoid weather events like hurricanes or tornadoes, fog and storms.

High Traffic Areas

Another situation that could be solved with the control taking from the ship by crew members is the high-density traffic situations. This makes possible to give the control from the remote operator to the master on board and change the navigation to a one more adequate that ensure the safety of people on board, the vessel and the other vessels.

It also can move the control from the operator to the master on board in order to pass through channels and difficult zones, that need special attention to details and special procedures.

Tests

One of the most common situations where the remote-controlled vessels will have crew on board is when the tests are done. Before upgrading into the 3rd degree or inclusive the 4th degree, it is important to be sure that the vessel is working as expected. It is necessary that all systems work right and there are not appearing fails on systems that can affect the control of the vessel. It is needed to ensure that the remote-control systems have connectivity in all situations, and in case of losing the connectivity, it is important that all the safety procedures to recover the connection work.

Mooring

The last possible utility of the 2nd degree is using the crew on board to assist in the mooring procedures. Before the next generation of port berths appear and new systems to assists the mooring exists, the crew is necessary to help in the mooring tasks. This supposes that, once the remote vessel enters at port, the mooring will need to be performed whether it is with the crew on board or embarking crew before the mooring starts.

Finally, this kind of vessels can become really popular within the next years, as they are a nice way to upgrade the actual navigation system at the same time that safety remains the same or increases.

4.1.3. Degree Three

The Degree Three vessels characteristics established by the International Maritime Organization removed the crew on board.

The definition says that those are fully remote-controlled vessels, without crew on board. It specifies that the vessel is fully controlled from another location.

The possibilities of those vessels are wider and safer than the autonomous ones. There are several uses that will fit into this place.

Control Recovery from Autonomous Navigation

The first utility is to provide a safety environment when autonomous navigation fails or need assistance.

As autonomous vessels (Degree Four) are intended to become fully autonomous, they are not intended to have crew on board. They need to have a safety procedure that enables connectivity with shore centers and transfers the control to pilots in land.

This is when the downgrade to Degree Three is useful. It can help to solve several situations where autonomous systems are not working properly or the environment in the vessel zone can suppose a safety risk. The connection to shore centers give to the pilots in land the ability to solve those situations, to redirect the vessel to a port to solve incidences or repair malfunctioning equipment and damage.

Advanced Testing

Once the first steps of remote-controlled navigation with crew on board are done, the tests using the Degree Two, before upgrading to fully autonomous systems it is important to do tests without the crew on board. Those tests can be alternated between autonomous shipping, like the Degree Four, and the Degree Three. This can provide a more extensive test data recollection with extra safety.

Oceanic Shipping

Application of remote-controlled vessels in the long distance can become difficult. Otherwise, in some oceanic shipping where connectivity is stable and vessel can be controlled, is an option to avoid using the autonomous shipping and have the possibility to lose the tracking of the ship or enter in unstable connectivity zones.

4.1.4. Degree Four

This is the most automated and autonomous classification degree established by the International Maritime Organization.

It is defined as an autonomous vessel capable of taking all the decisions and action by itself. This means that the human presence is not available, and also the remote service is not activated.

It can have a lot of uses in the future once the regulations and the technology advances. Otherwise, nowadays is limited as it has to become safer and has to improve the interaction between ships.

Defined Routes

This kind of vessels can have a wide range of applications in predefined routes. The Yara Birkeland ship is an example. Using autonomous vessels that make the same route with high frequency and use routes with low and medium traffic density is a nice option. They can move the cargo, and if

they are used in conjunction of automated ports, they can become a big alternative to road transport.

The use of those ships can also become popular in the next years in the short distance, and they can become hybrid or electric to be more fuel efficient and less pollutant. This reduces the maintenance of those vessels and they can do the same route without time waste.

Coastal Military Patrols

The use in coastal patrols can be another good use for autonomous vehicles. It enables the option to increase the number of patrols and needing less prepared pilots. They also can turn if needed into the Degree Three level or fix objectives to follow. It can be a good option to develop safer coasts and avoid drug traffic in some areas or also to make piracy areas safer for vessels.

Port Service Vessels

Another use is application of the autonomous vessels to port service vessels, like waste barges, petrol barges or any kind of vessels that assist and support merchant ships.

This use ensures a faster reaction time and having always available vessels to make port operative faster. It also supposes a reduction in seafarers needed to perform those activities.

Search and Rescue Vessels

Using the autonomous technology to move search and rescue vessels can be useful. It can let people on board assist injured persons while the vessel navigates to safe places. It also enables the possibility to move rescue equipment to a certain coordinate and let the SAR personnel do its job.

CHAPTER 5. CONCLUSIONS

FIRST -

The autonomous vessels industry is evolving fast. In the last years, technologies around ships devices and systems become more sophisticated. Automation of processes also become popular in all the industries, including shipping. During last years, automation has been transformed to make autonomous vehicles. Since the first ideas and projects appeared, the regulations and the interest by authorities like the IMO increased. The International Maritime Organization decided to make some research on how the next generation of ships can affect in the traditional navigation and how can be included in the current maritime world. It supposes a great challenge to combine the traditional ships in the same environment that the remote and autonomous vessels. It also has to have the same level or more safety and security than the past generations.

SECOND -

The actual regulations in the shipping industry are not planned to allocate the remotely controlled and the fully autonomous vessels in their rules. There are several references to the seamanship, which makes difficult to apply to algorithms as seamanship is based in experience and navigation knowledge. Also, there are a lot of references to active watch and listening, which are applicable to the human senses. They can't be done by systems, but there are several sensors and devices like radar and LIDAR (Laser Imaging Detection and Ranging) that are able to imitate the human senses. Those systems and can be really precise, inclusive more than the human senses, but it is necessary that new regulations include them and establish standards and rules around their use.

THIRD -

It is important that the liable figure of the captain become updated to the new generations of vessels. This implies that new regulations or modifications on the existing ones have to be done. The actual conventions and treaties need to fit the future liable figure and the autonomous navigation itself in order to enable the industry to grow safely and ensure that not only the navigation is protected, but also the parties around it that can be in trouble. It also has to experience an upgrade in the documentation process in order to fit also this new scenario, as there will not be captains on board and it has to be more digital without refusing to the secure environment that has now. Otherwise, the next steps in the documental process have to be clear and adapted to the new figures and the modern environment. It also has to include all the regulations that make it possible to work with new liable persons, like shore captains.

FOURTH -

The benefits that remotely controlled vessels and autonomous vessels can provide to the shipping industry are great. It also increased the utility of them with the COVID 19 crisis, where remote work has become essential and a part of the new normality we are facing.

This supposes that a lot of improvement in navigation could be done with the use of this technology and a lot of the actual problems can be partially removed. Providing a cleaner navigation, a reduction of the human factor, and other benefits, the use of this vessels can suppose a more reliable and safe transport way. They also can implement newer systems as there are few requirements that are needed. The use of less complex ships is essential to low the levels of maintenance needed. This can be achieved using more electrical motors that need less maintenance, and also are less pollutant. In order to give them energy, the vessels can include renewable energy systems like solar panels. Finally, piracy is another great point to focus, as it will be reduced significantly because of the lack of interest that pirates will have. The reason is that these vessels can be more sealed as they are not intended to embark persons, and the non-existence of crew on board make pirates have more difficulties and not able to make hostages to negotiate.

FIFTH -

The challenges that experience the introduction of this new generation of vessels can make difficult their implantation. They are linked with the update of the regulations and the technology and supposes a big level of study and observation required. The use of technology implies that at some point it can suppose a risk for the others. Cyberattacks are the equivalent to piracy, and cybersecurity becomes essential. This implies that the use of technology has to be provided with new safety standards and procedures in order to be as safe as traditional navigation and avoid that hackers can do terrorism. Also, connectivity issues can increase the problems. The algorithms can need at some point the use of remotely control the vessel, for example in emergency situations, but if connectivity fails the remote control can become impossible to get or can work erratic.

SIXTH -

With the introduction of this technology, the first projects are appearing. The first semiautonomous vessel, the “Deseo” ship, has being tested successfully as an adaptation of an existing vessel to include some of the features. Also, the first fully autonomous project, the “Yara Birkeland”, is in their process of testing to gain the last degree of autonomy. It also provides a fully electric vessel and port operation which contributes to a cleaner navigation. Other projects, like the MUNIN, give tools to the industry to provide safer environments. Finally, other projects have been paused, but also the knowledge has been applied in other projects, like the DNV-GL project “ReVolt”, which actually is not being processed but the company is collaborating with Yara Industries.

SEVENTH -

The digitalization is not only limited to the ships itself, but also to the procedures around them. The digitalization of documental processes and inspections has increased the efficiency in procedures that normally take several amounts of time and increases the costs. It also has proved their utility during the pandemic, where travelling to other countries was difficult due to closed borders and flights cancelled.

EIGHTH -

The use of new technologies in inspections, like the use of ROVs, provide more precision and detail at the same time that more versatility is acquired. The leading companies are investing in new technologies in order to get those benefits and increase the quality of their services at the same time that they optimize their processes. The use of remotely controlled devices like drones gives the ability to access difficult zones and take images, and permits the surveyor to make a detailed inspection that would be difficult by traditional methods. The last surveys done remotely included other tools and procedures. The leading companies like DNV are using the remote inspections with the help of the seafarers on board. They can be equipped with cameras to make retransmission with the surveyors. The inspectors also can make in time documentation and deliver it faster than with traditional procedures. They also can make a higher volume of surveys in less time, as they don't need to move around different places. Finally, other companies like Bureau Veritas are trying to do a next level surveying using enhanced reality to see in time retransmission of what the seafarer sees. These kinds of inspections will become popular during next years and will make a more efficient shipping industry with less time waste.

NINTH -

The uses of those vessels will become wider as they are tested. The categories established by the IMO show that they can be used in the different stages of the ship creation. Once they are navigating, they can change between levels of autonomous navigation and remotely controlled navigation. They are useful to test the systems or to gain control in determinate zones and situations. One of the industries that will benefit the most is the Short Sea Shipping. As they are coastal navigation and not too far from land, connectivity issues are not the main preoccupation. They can give a lot of benefits and will solve some problems that this industry is experiencing, like the increase in the quantity of vessels needed while the interest in seafaring career is being reduced and the number of new seafarers is decreasing. The next generation of vessels and the modern remote seafaring activity can increase the interest in the shipping industry and adapt this to the modern da

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