ERASMUS UNIVERSITY ROTTERDAM

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MASTER THESIS URBAN, PORT AND TRANSPORT ECONOMICS

WHAT IS THE IMPACT OF AUTONOMOUS VESSELS ON VESSEL – ORIENTED PORT SERVICES AND OPERATIONS IN THE PORT OF ROTTERDAM?

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ABSTRACT

In this era of radical technological progress and innovation, many industries are experiencing a transformation of their business models and operations and organizational structures. The maritime and logistics industries are two of those industries that are impacted by new emerging technologies such as the Internet of Things (IoT), Big Data and autonomous vessels. Moreover, ports as a significant node in the supply chain systems are, also, affected by those developments. The aim of the following Master Thesis is to investigate the impact that the employment of autonomous vessels will have on vessel – oriented port operations and services with the focus on the Port of Rotterdam. The vessel – oriented port operations and services that are being analyzed are those that constitute the vessels' Port Call process in a port. The research method applied in this Master Thesis is that of semi – structured research questions. From the analysis of the qualitative information collected via the interviews the expected effects on the future of vessel – related port operations and services with the employment of autonomous vessels: remote pilotage of vessels, replacement of tug – boats and linesmen by new technologies such as magnets, absence of shipping agents or restructuring of their business model, improved Vessel Traffic Services (VTS) and communication infrastructure, increased autonomy of terminal operations, shift from hard – skilled and manual jobs to soft – skilled and information technology related and establishment of Shore Control Centers for the monitoring and controlling of autonomous vessels' operations by shipowners. There were not significant effects on Port State Control operations identified.

Keywords: autonomous vessels, port operations, vessel – oriented services, Port Call

1. INTRODUCTION

In this era of technological revolution, digitalization and automation, industries are driven by dynamic restructuring forces that lead to their transformation. New business models are emerging as a result of the need to adjust to the new economic, technological, organizational and commercial environment that companies within all industries are facing. This fourth industrial revolution, also described as «*Industry 4.0*» (Rødseth et al., 2019), has impacted the transportation industry and supply chain systems as well, by introducing the «*Shipping 4.0*» (Rødseth et al., 2019) industry. The «*Shipping 4.0*» (Rødseth et al., 2019) is considered to be a major evolution for the maritime industry and it comprises the elements of «*cyber – physical systems*» (Rødseth et al., 2019) in which the physical and computational (computer) aspects are being integrated, «*Internet of Things (IoT) and Services at sea*» (Rødseth et al., 2019) technologies that can offer enhanced connectivity between the vessel and the shore and data analytics (Rødseth et al., 2019).

Moreover, technologies such as Big Data and autonomous vessels, which are part of the Shipping 4.0 industry, are disrupting the traditional business models of the maritime industry (Vaggelas & Leotta, 2019) and are challenging the already well – established ways of conducting day – to – day business of the companies within the logistics chains. More specifically, the technological advances and developments in the field of unmanned autonomous vessels carried out by various companies, organizations and institutes within the industries of shipping, information technology and communications, transportation and logistics aim at enabling the employment of unmanned autonomous vessels in the merchant trade in the not very distant future. The value of the autonomous vessels market for the year 2020 was estimated to be 88,01 billion US dollars, while it is expected to reach 134,90 billion US dollars by the year 2030 (Padalkar & Baul, 2019). Additionally, in terms of maritime trade routes, Asia – Pacific is expected to have the greatest contribution in the growth of the autonomous shipping (Padalkar & Baul, 2019). This positive attitude of the maritime industry towards the adaptation of autonomous vessels is mainly fueled by the advantages that they offer, compared to conventional vessels, in terms of increased cost – related, operational and environmental efficiency as well as safety (massterly - WHAT WE DO). Consequently, there is an evident need for regulatory and institutional intervention, so as to create the appropriate legal frameworks that will be applicable to the entire process of designing, constructing, operating, controlling, monitoring and overall employing this new type of vessels (UNCTAD Review of Maritime Transport 2019 - Sustainable Shipping, 2019).

Ports, being the connection point between maritime and land transportation, linking waterways (sea, rivers, canals) with land infrastructure (railways, roads) in order to facilitate the transfer of cargo and goods, as well as passengers (Carbone & De Martino, 2010), are expected to be greatly impacted by the on – going transformation of the maritime industry (Woo et al., 2011) and the employment of unmanned autonomous vessels (Vaggelas & Leotta, 2019). Furthermore, the previous trends of globalization and containerization in the shipping industry and the international supply chain systems have led to the weakening of the once dominant position of theirs in the transportation systems as the driving force behind the economical, societal and commercial evolution, placing them in a more responsive position (Verhoeven, 2010). Consequently, ports will have to adjust their operational, organizational and technological functions in order to facilitate unmanned autonomous vessels and respond to their requirements and needs (Vaggelas & Leotta, 2019).

This Master Thesis aims at identifying the impact that the employment of unmanned autonomous vessels in the seaborne merchant trade will have on the vessel – oriented Port operations and services and it focuses on the Port of Rotterdam as a case study.

Research question: *What is the impact of autonomous vessels on vessel-oriented port operations and service in the port of Rotterdam?*

The remainder of this Master Thesis is constructed as follows: section 2 includes an overview of the theoretical background on the technology of autonomous vessels, section 3 includes an analysis of the port functions and operations with a focus on those included in the Port Call process on which the research of this Master Thesis is based as well as a presentation of the Port of Rotterdam, the methodology applied in the research of this Master Thesis and the analysis of the results are discussed in section 4, section 5 includes the conclusions of the research and limitations of the study and recommendations for future research are incorporated in section 6.

2. THEORETICAL FRAMEWORK

2.1. Overview of the autonomous vessels technology

This section includes a brief analysis of the various aspects of the autonomous vessels technology. The areas that are being discussed are the origins of the technology and the definitions that have been established for it, the advantages and benefits that it offers compared to the conventional merchant ships, its current developments and the legal concerns associated with its adaptation. The following overview of the aforementioned elements of the autonomous vessels technology and its implementation is considered legitimate for the purpose of this research, taking into account that each of those elements can impact the vessel – oriented services and operations offered in a port in different ways and at different degrees.

2.1.1. Introduction

Nikola Tesla was one of the firsts to work on the concept of «*unmanned surface vehicles (USV)*» back in 1898 (Wróbel, Montewka, & Kujala, 2017). Furthermore, Autonomous Underwater Vehicles (AUV) was one of the first autonomous technologies to be developed and introduced in the shipping and maritime industry back in the late 1990's (Ghaderi, 2019). The main purposes of the use of such vehicles were exploration and inspection (Ghaderi, 2019). Moreover, automation is on-going in the maritime industry, assisting in a number of vessel related operations, such as hull inspection (Ghaderi, 2019).

According to the European Waterborne Technologies Platform (Waterborne TP) Implementation Plan from 2011, an autonomous vessel is defined as follows (Kretschmann, Burmeister, & Jahn, 2017): «*Next generation modular control systems and communications technology that will enable wireless monitoring and control functions both on and off board*» (Kretschmann, Burmeister, & Jahn, 2017). «These will include advanced decision support systems to provide a capability to operate ships remotely under semi or fully autonomous control» (Kretschmann, Burmeister, & Jahn, 2017). Also, another definition of unmanned vessels, as elements of the Unmanned Maritime System of the MUNIN project, is the following: «a maritime system that operates full or part time without humans in direct control» (Kretschmann, Burmeister, & Jahn, 2017).

Frameworks have been developed by maritime organizations addressing different levels of automation of an autonomous vessel (Karlis, 2018). One of these organizations is Lloyd's Register Class that has established the following seven automation levels (Karlis, 2018):

- Level 0 – level 3: The first four levels involve human decision-making. Level zero is non-automated and fully controlled by humans and level 3 has humans acting as supervisors.
- Level 4: Human supervision over autonomous decisions and actions.
- Level 5: Fully autonomous decision-making by the system with sporadic human involvement.
- Level 6: Fully autonomous decision-making by the system with no human involvement.

Moreover, the International Maritime Organization in the context of the Maritime Safety Committee's regulatory exercise on Maritime Autonomous Surface Ships (MASS), has identified the following four distinct degrees of autonomy (Autonomous shipping):

– Degree one: There are automated processes on the vessel and there is decision support by on-board crew. The on-board crew is responsible for controlling vessel's systems and functions.

– Degree two: The vessel is remotely operated and controlled from a different location, while there are seafarers on-board the vessel to operate and control on-board functions and systems.

– Degree three: There is remote operation and control of the vessel from another location and there is no crew on-board.

– Degree four: The vessel is fully autonomous. Decision-making and undertaking of actions is carried out by the vessel's operating system.

Identifying the possible levels of vessel autonomy allows for a categorization and classification of autonomous vessels. Higher levels of autonomy distinguish autonomous from conventional vessels and allow shipping companies and the maritime industry as a whole to benefit from their advantages.

2.1.2. Development of unmanned autonomous vessels – Potentials and advantages

The development of unmanned autonomous vessels has been stimulated by the advantages and benefits that they hold compared to the conventional merchandise vessels (Kretschmann, Burmeister, & Jahn, 2017). The main advantages of those are:

– Lower operational costs, especially those related to the employment of on-board vessel crew (Ghaderi, 2019; masterly – WHAT WE DO), leading to a more efficient trade on an international scale (Kretschmann, Burmeister, & Jahn, 2017). The cost of employing seafarers can make up to 42% of the total operational costs of a vessel (Stopford, 2009). Furthermore, it is estimated by Rolls-Royce that operation of unmanned autonomous vessels will allow for a 20% fuel costs reduction, which is of significant value given that for instance, for a liner shipping company fuel costs make up to 50% - 60% of the total operational (Wang & Meng, 2012), higher availability of space for cargo storage and a 40% decrease in operating costs (Hogg & Ghosh, 2016). The unmanned autonomous vessels are expected to have a different design than the conventional merchant vessels, since there is no need for an accommodation structure in the absence of crew (Hogg & Ghosh, 2016; masterly – WHAT WE DO). Moreover, costs related to the embedment of additional equipment such as «*Autonomous Navigation System and Advanced Sensor Module*» (Kretschmann et al., 2017) that will ensure the safe navigation of the autonomous vessel, was estimated to add an amount of 1.7 million US dollars to the cost of constructing a bulker autonomous vessel (or 5% more costs), while technology related to communication purposes and propulsion systems was estimated to increase the construction costs by almost 10% (Kretschmann et al., 2017). Additionally, special infrastructure needed for communication purposes, the berthing and un-berthing of the autonomous vessel, the handling of the cargo and the port calls may lead to increased costs (Hogg & Ghosh, 2016). Finally, a reduction of crew and manual port cargo handling costs is, also, expected, which are significant for short sea shipping (massterly - WHAT WE DO).

– Eco-friendly and environmentally sustainable operations by employing sustainable methods that will enable the reduction of fuel consumption (Kretschmann et al., 2017). Such methods and techniques including the removal of the on-board life support systems (Kretschmann et al., 2017) and the seamless implementation slow steaming (massterly - WHAT WE DO). Alternative fuels such as LNG and electricity can also, be used in order to reduce the environmental impact of operation of the vessels, combined with the appropriate propulsion system and engine which process is simpler than those of fossil fuels (Hogg & Ghosh, 2016). (Kretschmann et al., 2017)

– The elimination of the human factor. Incidents and accidents that have taken place at sea are being partially contributed to human navigational mistakes and errors. It is estimated that the main cause of almost 75% of the maritime accidents occurred was human error connected to fatigue and loss of attention (massterly - WHAT WE DO). Furthermore,

psychological factors such as stress and job dissatisfaction have a negative influence on the performance of the crew. Despite the apparent need for reducing the human interference in vessels' operation and navigational procedures, many of the projects regarding the development of unmanned autonomous vessels (MUNIN, AAWA, UCSDA) incorporate tasks that have to be carried out by maritime personnel. For instance, personnel is needed for the management and operation of the Shore Control Centers included in the design of the MUNIN project (MUNIN - RESEARCH IN MARITIME AUTONOMOUS SYSTEMS PROJECT RESULTS AND TECHNOLOGY POTENTIALS), thus making it clear that fully autonomous vessels are unlikely to become reality in the near future. (Ghaderi, 2019) Additionally, the employment of more maritime personnel ashore rather than at sea allows for a more balanced professional and personal lifestyle, making the seafarer profession more attractive (Kretschmann et al., 2017). (Kretschmann et al., 2017)

– Maintenance operations of autonomous vessels will take place in the port, allowed by the design of the vessel (few rotating parts) and the operation of the vessel will lead to very low or even zero emissions by utilizing battery or gas/fuel cell driven propulsion systems (massterly - WHAT WE DO).

Empirical evidences support the above mentioned advantages of the unmanned autonomous vessels. Specifically, Kretschmann et al. (2017) investigated the costs of ownership and operation of an autonomous unmanned bulk carrier compared to a conventional panamax bulk carrier that has on-board crew. They found that by employing an unmanned autonomous panamax bulk carrier, USD 945,000 could be saved per year that is spent on crew wages and associated crew costs. Moreover, they found that from the absence of the necessary equipment and facilities needed for the accommodation of on-board crew, an additional amount of 67,000 per year on average could be saved. Moreover, it was estimated from their study that almost 6% of fuel costs could be reduced, since autonomous vessels are expected to have higher efficiency in terms of fuel consumption. That efficiency was derived by «*reduced air resistance*» (Kretschmann et al., 2017), lower weight of light ships and absence of a hotel system dedicated to the crew (Kretschmann et al., 2017). They concluded that when the unmanned autonomous vessel operates efficiently with regards to fuel consumption, the reduction in costs is notable. They, also, concluded that restrictions on the type and quality of the fuel that can be used for the operation of an unmanned autonomous vessel may lead to an increase in voyage costs and make the operation of such vessel financially infeasible in the long-run.

Moreover, Ghaderi (2019) carried out a study to identify the potential cost reduction that can be achieved by employing an unmanned autonomous vessel on a Short Sea Shipping route (SSC) instead of a conventional one. The study had the form of a comparative analysis between a Roll-on/ Roll-off conventional vessel and a Continuously Unmanned Vessel (CUS) that operate on a selected Australian Short Sea Shipping route. Moreover, in the study, the vessel of reference was operated via a Shore Control Center that was manned with a master and a chief engineer. The master and the chief engineer were set to be employed in eight hours shifts, responsible for monitoring and controlling the navigational and mechanical aspects of the autonomous vessel. The completion of the analysis showed that cost-related benefits can be achieved by employing unmanned autonomous vessels, however the realization of these benefits depends on a number of factors related to the demand and the operation scale. Specifically, it was found that savings were higher in markets where there was demand uncertainty and in the case of one shore control center controlling the operation of «*a network of vessels*» (Ghaderi, 2019). Moreover, it was concluded that unmanned vessels are more likely to operate commercially at a local scale in the future, and that their operation will most likely be in the hands of the cargo owners. (Ghaderi, 2019)

Additionally, Krzysztof et al. (2017) studied the impact of the launch of unmanned vessels in the shipping industry on frequency of occurring incidents as well as their implications. They carried out a qualitative safety analysis of a hundred reports of maritime incidents. They found that the absence of on-board crew resulted in a decrease of the probability of a maritime accidents taking place. Specifically, incidents caused by navigational errors were found to be more likely to occur when a vessel is manned compared to an unmanned vessel as a result of, for instance, situation unawareness and negligence of the International Regulations for Preventing Collisions at Sea (COLREGs) by the members of the crew. Moreover, they stressed that in order to mitigate maritime incidents by employing unmanned vessels, the operation, design and safety systems of those vessels must be appropriate. Furthermore, they concluded that in the case of unmanned vessels, designing safety systems that focus mainly on the prevention of incidents is more important and feasible than developing systems for assessing and repairing the damages and the consequences.

Taking into consideration the aforementioned benefits derived from the employment of unmanned autonomous vessels, companies and organizations in the maritime industry are showing increasing interest in undertaking projects associated with developing and operating such vessels.

2.1.3. Developments in autonomous shipping

Projects and developments related to unmanned and autonomous vessels in Europe are (Kretschmann, Burmeister, & Jahn, 2017):

– The Advanced Autonomous Waterborne Applications (AAWA) Initiative, which is an initiative by Rolls-Royce that has Finish funding.

– The ReVolt, which is an unmanned container vessel that can be employed in the short-sea shipping routes of the Norwegian fjords and has battery as its power source. The development of this type of vessel is being studied by the DNV-GL classification society.

– The Maritime Unmanned Navigation through Intelligence in Networks (MUNIN), which is a project funded by the European FP7 and focuses on investigating the development of unmanned dry bulk vessels for deep-sea routes. (MUNIN - RESEARCH IN MARITIME AUTONOMOUS SYSTEMS PROJECT RESULTS AND TECHNOLOGY POTENTIALS)

It is predicted that by 2030 the technology advancements will allow for fully autonomous vessel operations and that the upcoming unmanned autonomous vessels will be «*smarter, data-driven, and greener, with flexible powering options, full on-board wireless connections, and digital connections through global satellites*» (Hogg & Ghosh, 2016).

In order for the unmanned autonomous vessels that are and will be developed in the future to operate unhindered on international and short – sea routes, adjustment and expansion of the current international, national and coastal legislation and legal framework is considered appropriate (UNCTAD Review of Maritime Transport 2019 - Sustainable Shipping, 2019).

2.1.4. Legal aspects of unmanned autonomous vessels

With regards to the legal aspect of the employment of unmanned autonomous vessels on merchant sea routes, a significantly important issue is that of the compliance of this type of vessels with the international maritime conventions, regulations and rules (Karlis, 2018). Below, there is a brief description of the implementation and complications of some of the main international maritime conventions in the context of autonomous shipping (Karlis, 2018).

- The Maritime Labour Convention (MLC): The Maritime Labour Convention, which was amended in 2006 and entered into force in 20 August 2013 (Maritime Labour Convention, 2006, as amended (MLC, 2006)), is an international convention established by the International Labour Organization (Maritime Labour Convention, 2006, as amended

(MLC, 2006)) and aims at setting the minimum rights that a seafarer should expect (Maritime Labour Convention). It is, also, known as the «*Seafarer's Bill of Rights*» (Maritime Labour Convention). A «*maritime labour certificate*» that proves a vessel's compliance with the requirements of the MLC must be issued by every vessel that has a capacity of over 500 gross tonnage and operates between ports that are located in different countries or within international waters (Maritime Labour Convention). According to the Maritime Labour Convention 216, a seafarer is defined as: «…*Seafarer means any person who is employed or engaged or works in any capacity on board a ship to which the Convention applies*...» Based on this definition, there has to be on-board crew that will be in charge of the operation and navigation of the vessel. In the case of the unmanned autonomous vessels, marine personnel will be, still, employed but not on-board the vessel. Seafarers will be monitoring the operation and navigation of this type of vessels by Shore Control Centers, as mentioned in a previous section of this thesis. This leads to uncertainty in terms of the compliance of the unmanned autonomous vessel with the MLC, given that its crew will not be operating on-board. More specifically, if the flag state considers MLC applicable, the shipowner will have to issue the relevant certificate for the crew, but if not then there is no such obligation. However, if the unmanned autonomous vessel sails on international routes or between ports of different countries, and these countries require an MLC certificate while the flag state does not, then problems might occur with the Port State Control of these countries. Thus, there is a need for the establishment of a common legal framework regarding the applicability of the Maritime Labour Convention on unmanned vessels. (Karlis, 2018)

- The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW): The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers was adopted by the International Maritime Organization (IMO) on the 7th of July, 1978 and was entered into force on the 28th of April, 1984 (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978). This international convention aims at ensuring the protection of life and property at sea and of the marine environment, by establishing international standards for training, certification and watchkeeping for seafarers (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978). The convention was amended on 25 June 2010 and the amendments were entered into force on 1 January 2012 (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978). These are known as the «*Manila Amendments*» (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978). The most

recent amendments of the convention are those that concern the adaptation of the Polar Code in the STCW, that were made my IMO's Maritime Safety Committee (MSC) and were entered into force on the 1st of July 2018 (ALLEN, 2016). Moreover, according to the provisions of the convention a period of 12 to 36 months of «*seagoing service*» (Karlis, 2018) is defined as adequate for a seafarer in order to receive an STCW certification. Given that the certification of the seafarers is obligatory for all the flag states by UNCLOS, the following issue arises for the unmanned autonomous vessel: Their operation is expected to be monitored by seafarers that operate in Shore Control Centers, as mentioned above and not on-board the unmanned vessel. That means that these seafarers might not be able to receive STCW certification because they will not be able to accumulate the adequate «*seagoing service*» (Karlis, 2018) needed for the certification. This situation might lead to competition between companies that will manage unmanned autonomous vessels and companies that manage conventional vessels in terms of attracting certified marine personnel and subsequently higher manning costs. Therefore, amendments of the STCW are considered legitimate. (Karlis, 2018)

- Seaworthiness: The seaworthiness of a vessel is a very significant factor in determining whether a vessel can be employed on merchant sea routes or not. Adequate and proper manning, as well as proper design of the vessel and operation of the main and auxiliary machinery and equipment, are prerequisites for a seaworthy vessel. In the case of unmanned autonomous vessels, given that their operation is controlled and managed by marine personnel operating in Shore Control Centers and their design is expected to be different than that of the conventional merchant vessels, adjustments in the legislation have to be made in order to address the seaworthiness of those vessels and the liability considerations concerning Classification Societies and marine insurance organizations (Karlis, 2018) such as Protection and Indemnity (P&I) Clubs (Wankhede, 2019). (Karlis, 2018)

- International Convention for the Safety of Life at Sea (SOLAS): The main purpose of the International Convention for the Safety of Life at Sea (SOLAS) is to assure the safety of life and merchant vessels at sea (International Convention for the Safety of Life at Sea (SOLAS), 1974). The most recent version of the convention was adopted on the 1st of November 1974 and entered into force on the 25th of May 1980 (International Convention for the Safety of Life at Sea (SOLAS), 1974). Appropriate, efficient and safe manning of a vessel is, also, a prerequisite for this convention. The flag states are those responsible for setting the standards for the manning of the vessels that sail under their flag and therefore, their role in determining the standard safe manning for Shore Control Centers is considered to be extremely significant. Moreover, differentiation in terms of safe manning standards among

different jurisdictions may cause hurdles to the operation and management of unmanned autonomous vessels. (Karlis, 2018)

- The International Safety Management (ISM) Code: The International Safety Management (ISM) Code aims at setting international standards that ensure vessels are safely operated and managed and there is prevention of pollution (ISM Code and Guidelines on Implementation of the ISM Code). The ISM Code was adopted in 1993 and entered into force on the 1st of July 1998 (ISM Code and Guidelines on Implementation of the ISM Code). It is supported that in the case of unmanned autonomous vessels, successful implementation will be achieved much easier than in the case of conventional vessels. The reason for that is that communication between the crew responsible for operating the unmanned autonomous vessel and the company that owns the vessel will be much easier and efficient, since the crew will be in charge of operating from Shore Control Centers and not on-board the vessel. Consequently, decisions and actions regarding the safe operation of the vessel and the prevention of pollution of the marine environment are expected to be taken faster and more efficiently. (Karlis, 2018)

To summarize, from the brief overview of the autonomous vessels technology included in this section it is evident that this new disruptive for the maritime industry technology is being slowly established and will fundamentally impact the industry's structure in the proximate future.

2.2. Vessel – oriented port operations and services

The aim of this section is to provide an analysis of the port functions that are associated with the facilitation of the approaching vessels from the moment of their arrival to the port until the moment of their departure. Identification of the expected impact that the employment of autonomous vessels will have on each of the main operations and services provided by a port as well as on the port labour with a focus on the port of Rotterdam, is the main element of the analysis, based on relative academic, empirical and grey literature.

2.2.1. Introduction

Ports are important gateways a significant connecting node between the different parties of the logistics chains (Verhoeven, 2010). They are areas where transshipment operations of

cargo from one transport mode (deep-sea vessel) to another (truck) take place and their attractiveness for a shipping or logistics company is determined by factors such as accessibility, good hinterland connections, efficient handling of cargo, efficient management and transfer of information and good positioning in the company's supply chain (Carbone & De Martino, 2010).

A port can, also, be viewed as an ecosystem or a cluster of organizations, institutes and companies that participate in the transportation and supply chain systems and offer value – adding services to their customers (Carbone & De Martino, 2010). Ports can, also, be considered as actors in the logistics systems, that enable the «*procurement of raw materials*» (Carbone & De Martino, 2010), manufacturing activities, warehousing, packaging and distribution of finished and semi-finished goods (Carbone & De Martino, 2010).

Moreover, they provide specific operations and services to vessels, the main of which are: vessel loading and unloading, tug – boats assistance/ towing, pilotage, linesmen (IMO REDUCTION OF GHG EMISSIONS FROM SHIPS - Just In Time Arrival Guide: Barriers and Solutions , 2020) shipping agent services (Notteboom, Dock labour and port–related employment in the European seaport system, 2010) and Vessel Traffic Services (Hsu, 2012). All of the abovementioned services and operations provided to a vessel by the port constitute the process of a vessel's Port Call (IMO REDUCTION OF GHG EMISSIONS FROM SHIPS - Just In Time Arrival Guide: Barriers and Solutions , 2020).

2.2.2. The Port of Rotterdam

The Port of Rotterdam is the largest port in Europe in terms of container throughput according to figures of 2018 (Notteboom, Top15 container ports in Europe in 2018, 2019). It holds the 11th place in terms of container throughput and the 10th place in terms of cargo throughput globally for the year 2018 (FACTS AND FIGURES ABOUT THE PORT OF ROTTERDAM).

In the year 2019, the port's freight throughput was 469.4 million tonnes (Port of Rotterdam throughput amounted to 469.4 million tonnes in 2019, 2020). The total gross investments that were made by the Port of Rotterdam Authority in 2019, including participations, were €338.3 million, while the total turnover for the same year was €706.6 millions including income from port dues, site lease charges and other activities, such as sand saling (Port of Rotterdam throughput amounted to 469.4 million tonnes in 2019, 2020). The

infrastructure of the Port of Rotterdam extends at a distance of 42 kilometers (Port infrastructure - Port of Rotterdam) and the produced added value of the port accounts for 6,2% of the Dutch GDP with a total of 385000 port workers and employees (Added value & Employment - Port of Rotterdam).

The port of Rotterdam offers a variety of services to its customers. These services are briefly described as follows:

– Maritime services include (Maritime services - Port of Rotterdam):

▪ include bunkering of vessels with a wide variety of fuels such as fuel oil, biofuels and Liquified Natural Gas (LNG)

▪ shipbuilding, maintenance and repairs operations on vessels and offshore constructions, as well as inspections

▪ supplies of crew provisions, nautical equipment, spare parts and «*cleaning agents*»

▪ vessel clearance services, such as vessel representation and provisioning, provided by agents and ship agents located in the port

– Nautical services include (Nautical services - Port of Rotterdam):

▪ pilots of the «*Rotterdam – Rijnmod Pilotage Service*» that provide safe and efficient navigation of the vessels in the port

▪ towage services that assist in the operations of berthing and un-berthing the vessels as well as manoeuvring and shifting vessels and offshore platforms and objects (the three companies that provide the towage services in the port are: Fairplay, Boluda Towage, Svitzer)

▪ operations of berthing, un-berthing and shifting vessels provided by the linesmen from the «*Royal Dutch Boatmen's Association (KRVE)*». These services are required to be used by sea-going and tanker vessels which length's exceeds 75 meters. The linesmen are located in 13 different locations in the port.

– Port Community System (Port Community System - Port of Rotterdam): Efficient and smooth operations, coordination and exchange of information of the different parties that participate in the supply chain and logistics become viable via the Port Community System. PortBase, which is a non-profit organization that was established in 2009 by the Port of Rotterdam and the Port of Amsterdam, aims at serving the port community by providing seamless, efficient and fast sharing of information and data between the companies that participate in the logistic chains of the Dutch ports, as well as between companies and governments, at lower costs, via the Port Community System (PortBase - About us). Moreover, the PortBase organization strives for the increase of the attractiveness of the Dutch

port community and making Dutch ports «*the smartest ports*» among European ports (PortBase - About us).

Furthermore, the Port Community System provides special services for information exchange for each of the different markets of the maritime industry: container shipping, break bulk, dry bulk and liquid bulk (Port Community System - Port of Rotterdam). Companies have to pay a relatively small fee for using added-value services offered by the Port Community System, while other services are offered free of charge (Port Community System - Port of Rotterdam). Services that are of strategic importance are funded through the general revenues of the Port of Rotterdam Authority and the Amsterdam Port Authority, which are the shareholders of the PortBase organization (Port Community System - Port of Rotterdam).

–Port Customs (Port Customs - Port of Rotterdam): As an external border of the European Union, the Customs Administration in the Port of Rotterdam is responsible for providing clearance and releasing freight that either leaves from or arrives at Europe. Then, the cleared cargo can be transferred freely through Europe. The control and check of cargo and containers takes place via high-tech scanning equipment at the port terminals while there is also, scanning of trains. These procedures enable the reduction of unnecessary openings of containers that would result in delays and costs.

Supply Chain Optimization Engine (SCOPE) (SCOPE - Port of Rotterdam): SCOPE is a tool that aims at enhancing reliability throughout the supply chain that connects the Port of Rotterdam to its hinterland and the other way around. SCOPE allows for a better understanding of the supply chain's performance, the different processes and interests, for distinguishing bottlenecks and obstacles by analyzing sound data and for creating a common point of view over improvements on the supply chain.

The expected effect, based on existing literature, of autonomous vessels on the aforementioned port services, as well as the on introduction of additional services for their facilitation by ports is explored in the following sub-sections by analyzing the Port Call process of vessels.

2.2.3. The Port Call process

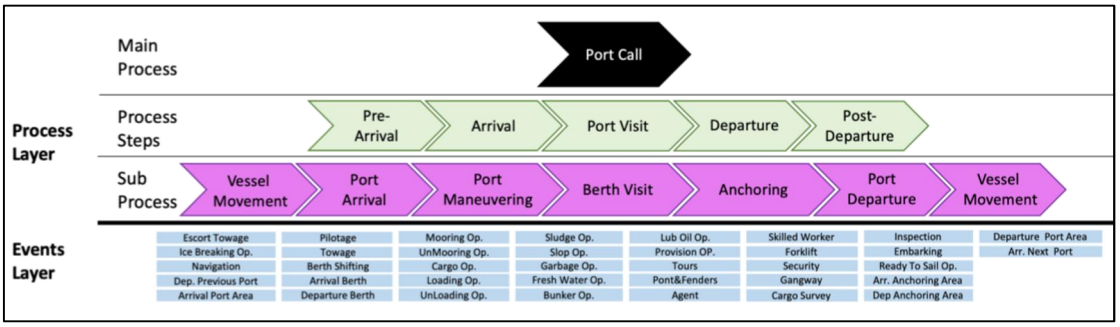

Figure 1. The Port Call process (Lind et al., 2019).

An extensive overview of the Port Call process of a vessel is presented in Figure 1 above. In Figure 1 the main process of a Port Call is analyzed in five process steps (Lind et al., 2019). From those steps, arrival, port visit and departure are considered to be the main steps, while the steps of pre – arrival and post – departure play a «*linking*» role (Lind et al., 2019). Furthermore, each of those steps is further divided in sub – process which comprise a number of events (Lind et al., 2019). During a port call, the most of the sub – processes and events take place in a sequential order, while some, such pilotage and towing, may be performed at the same time (Lind et al., 2019). Moreover, during a port call, the various sub – processes and events are combined in a way that uniquely serves the aim of the port call (Lind et al., 2019).

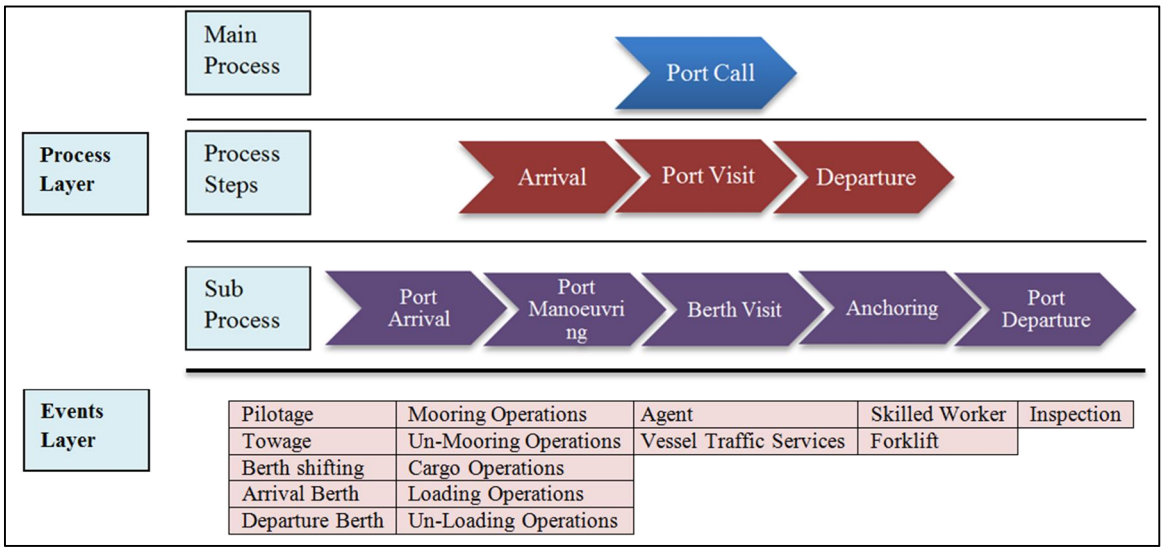

Figure 2. Schematic illustration of the main Pot Call process, process steps, sub – processes and events analyzed, based on Figure 2. (Source: Author)

The main steps in the process of a Port Call are: vessel's arrival, port visit and departure of the vessel (Lind et al., 2019). Port arrival, port manoeuvring, berth visit anchoring and port departure are the sub – processes that correspond to the aforementioned main steps, and the main events and actors included in those sub – processes are: pilotage, towing / tug – boats operations, berthing and mooring operations (linesmen (Appendix to Port Call Process, 2020)) cargo handling and terminal operations, shipping agents, Vessel Traffic Services (Röhner, 2020), port labour (skilled workers and forklift operators) and inspection from the Port State (Lind et al., 2019). A schematic illustration of the main steps, sub – processes and events, based on Figure 1, is presented in Figure 2.

Regarding the expenses of a vessel's Port Call, the cost of a vessel's Port Call is the agglomeration of all the costs corresponding to all the included operations and services and it varies between different ports, given that is mainly defined by the pricing policy of each port (Kretschmann et al., 2017). For instance, the cost of a Port Call for a panamax bulk carrier that sails from Australia to Europe is estimated to be USD 147,000 according to literature, while in general the cost for a port call by a bulk carrier might range between USD 35,000 to USD 40,000 (Kretschmann et al., 2017).

An analysis of the impact of autonomous vessels on the main actors and events included in the main steps of the Port Call process, based on existing literature, is carried out in the remainder of this sub – section. The actors and process involved in the arrival step are the same with those of the departure step (Lind et al., 2020) and therefore the step of departure will not be analyzed separately. Additionally, the impact of autonomous vessels according to literature on the labour associated with the aforementioned services and operations will be analyzed in a separate sub – section.

2.2.3.1. Step 1: Vessel's arrival at the port

In this step the main actors involved are (Lind et al., 2019):

- marine pilots (Lind et al., 2019)
- tug-boats operators (Lind et al., 2019)
- linesmen (Appendix to Port Call Process, 2020), and
- shipping agents (Lind et al., 2019)
- Vessel Traffic Services (VTS) (Röhner, 2020)

Marine pilots

Marine pilots are certified vessel's captains that receive special training on how to manoeuvre vessels critical port and coastal areas (Orlandi & Brooks, 2018). They are responsible for the safe navigation of the vessel through the critical areas and for that purpose they interact with the bridge team, the captains of the tug-boats, the vessel traffic services and associated electronic equipment (Orlandi & Brooks, 2018).

Systems such as the Automated Identification System (AIS) and the Global Navigation Satellite Systems (GNSS) can provide important and adequate information that can be used to assist autonomous vessels in sailing in ports without the need of an on-board pilot (Guerra, 2017). Furthermore, according to Rolls Royce's vision for the future of autonomous vessels, berthing and un-berthing operations will take place remotely while a pilot or an on – shore operator that holds a pilot's license will assist the unmanned autonomous vessel's navigation in the port in specific areas (Guerra, 2017). However, the law on mandatory pilotage will have to be amended or altered so as to regulate remote pilotage or even allow the absence of pilot operations when it is not considered necessary for the safe navigation of an unmanned autonomous vessel (Guerra, 2017).

An amendment of the Pilotage Act was proposed to be adopted on the 17th of January 2019 by the Finnish Government that allowed in the public channels in Finnish waters and in the Saimaa Canal lease area, which are routes that require pilotage, to perform remote pilotage «*subject to authorization*» (Remote pilotage allowed, 2019). Specifically, according to the amendment, the pilot would be permitted to perform his or her duties from another location and not from on-board the vessel. In order for a pilotage company to be permitted to perform remote pilotage, it has to submit an application for authorisation from the Transport and Communications Agency. Authorization is granted after the following requirement is met by the pilotage company: «*remote pilotage will not as such or in combination with other functions cause any danger to vessel traffic safety or any harm to other vessel traffic or the environment*» (Remote pilotage allowed, 2019). (Remote pilotage allowed, 2019)

Regarding the authorization, it is granted for a period of maximum five years with the possibility of renewal if it is necessary. Moreover, in the authorization the following are determined and defined: routes and parts of routes where remote pilotage is allowed, the participating vessel and the «*origin and destination of the remote pilotage*» (Remote pilotage allowed, 2019). (Remote pilotage allowed, 2019)

The bill was expected to be approved by the President of the Republic on the 18th of January 2019 and entered into force on the 1st of February 2019. (Remote pilotage allowed, 2019)

Taking into consideration the importance of pilotage operations for the safe and smooth navigation of vessels together with the latest adjustments in the relative registration by European countries such as Finland, it is concluded that the possibility of implementing remote pilotage in the proximate future is high and that it can be used together with the employment of unmanned autonomous vessels.

Tug – boats and linesmen

Tug – boats and linesmen offer assistance in the nautical operations of a vessel (Appendix to Port Call Process, 2020). Linesmen assist the vessel in order to berth safely by the key-side of a port (Port of Hamburg - Linesmen).

Tugboats are assisting vessels involved in the vessel's operations of berthing alongside and un-berthing from port docks by towing and pushing the vessel (Hsu, 2012). The employment of one or more tug-boats is somewhat compulsory in order for a vessel to safely manoeuvre and enter or depart from a port (Mansson & Lützhöft, 2016). Important research has been carried out over the years to examine the possibility of developing systems that will enable automatic berthing of ships. There is a significant body of literature (Im & Hasegawa, 2001, 2002; Im et al., 2007; Ahmed & Hasegawa, 2013) focused on the research for the use of an Artificial Neural Network (ANN) controller for automatic berthing with encouraging results, so as to develop this technology and increase its feasibility and applicability.

The abovementioned developments in the area of automated berthing operations are indicative of a possible future where towing and linesmen operations will no longer be needed and where the vessels will berth and un-berthing on their own. Taking into account the fact that fully autonomous vessels are expected to operate without any human interference and on their own (Autonomous shipping), implementing such berthing and un-berthing technologies is considered to enable this type of vessel operations.

Shipping agents

Shipping agencies are: «*businesses that act on behalf of ship-owners and which look after marketing and the interests of a ship while the ship is in port*» (Lu, 2007). Shipping agents are responsible for preparing the nautical services of a visiting vessel such as marine pilots, tugs and linesmen (IMO REDUCTION OF GHG EMISSIONS FROM SHIPS - Just In

Time Arrival Guide: Barriers and Solutions , 2020), as well as coordinating and monitoring all the operations related to the vessel's Port Call process (Lind et al., 2020).

They are located in ports and have an established network of relations with companies and service providers in a port (Lind et al., 2020). Furthermore, they are organized in a way that allows them to deal with local regulations, laws and features of the port successfully and efficiently (Lind et al., 2020). Therefore, they are able to effectively assist the port operations of a vessel. Moreover, they guarantee the payment of the parties involved in those processes (Lind et al., 2020). Additionally, they provide port actors with significant information regarding the visiting ship (Lind et al., 2020), such as for instance information regarding the reporting of the vessel that they provide to the Port State (Rødseth et al., 2019). As mentioned in the Communication subsection that follows, the reporting of the vessel to the Port State can take place with the use of Public Key Infrastructure, removing the necessity of employing an agent (Rødseth et al., 2019). It is expected that in the future with the digitalization of communication and information sharing, ship agents will no longer be needed to provide such information (or they will become better in providing up-to-date real-time information) (Lind et al., 2020).

Therefore, it can be concluded that the services provided by shipping agents might be carried out in a different way without their involvement. Moreover, it is possible that they will cease to exist in the future with the autonomy introduced by autonomous vessels.

In this sub-section is considered relative to mention a few things about the future of shipping companies and shipowners who own and operate merchant vessels and who are represented by the shipping agents in the ports (Lu, 2007), in the light of the autonomous vessels developments.

The development of autonomous vessels in the future is expected to lead to the emergence of new business models for shipping companies that will own and operate such vessels. Specifically, «*neo – shipowners*» and «*Autonomous Shipping Fleet Operators (ASFO)*» (Duru, 2019) are expected to be the future shipping companies that will own fleets of autonomous vessels (Duru, 2019). This new business model might be adapted not only by existing shipping companies, but, also, by companies in the fields of technology and logistics (Duru, 2019). Technology – oriented firms are expected to move faster in terms of fostering and developing autonomous vessels' technologies and operations, while already established shipping companies will have to transform their operations and business so as to adapt to these new technologies and remain sustainable and relevant (Duru, 2019).

In order for shipping companies to successfully prepare for the arrival of autonomous vessels and for the increased digitalization of the maritime industry in the proximate future, they not only have to invest on new and emerging technologies, but they, also, have to attract the maritime personnel that has the required digital skills and knowledge and utilize communication management techniques (Johns, 2018).

Vessel Traffic Service (VTS)

Vessel Traffic Services (VTS) originate back in the 1946 and are used in order to provide vessels with real – time port information such as nearby vessel's positioning and type and the weather and sea conditions, to ensure smooth and safe operations of vessels within ports (Hsu, 2012). They are, also, used so as to coordinate through, for instance, congested waters and channels, as well as sea areas within the port limits (Lind et al., 2020). Moreover, they operate in a radius of approximately 20 nautical miles within the ports (Hsu, 2012). Furthermore, they are provided by the national maritime authorities of a port they have to follow the standards of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) (Lind et al., 2020).

Vessel Traffic Services (VTS) are considered to have a significant role in the deployment, as well as the standardization of autonomous unmanned vessels by the Port of Rotterdam authority. Interaction and exchange of information and data between vessels, especially while sailing within the port area, are extremely important for the avoidance of occurring incidents. Therefore, in order to ensure safety of vessels operation within the port are, where density of vessels and movements is, also high, Vessel Traffic Services operators assist the vessels by providing valuable insight based on their experience and knowledge of the area via VHF channels or voice messages. Moreover, standardization in communication, data and information exchange and terminology and interoperability of systems are considered vital for the cooperation of unmanned vessels with the various port actors such the port authority and terminal operators. In order for standardization to be successful, it must be followed by all the ports that facilitate seagoing and inland unmanned autonomous vessels, so that these vessels can sail, load and unload at any port at any time smoothly and safely. (van Dorsser, 2020)

Furthermore, it is expected that in the proximate future of the Maritime Autonomous Surface Ships (MASS) that fall into all four degrees of autonomy will be able to carry out voyages from one port to the other, while their operation and behavior in traffic will be monitored by a person that will be given such responsibility. A major challenge that has been

identified for the MASS operations is: safe and untroubled sailing through port areas, sea-lanes and areas of high traffic density with the presence of smaller vessels. E-navigation technologies are, also, expected to significantly contribute in the connectivity between MASS vessels and VTS services offered by port authorities, as well as in ensuring safety of operations. (van Dorsser, 2020)

Vessel Traffic Services (VTS) are very likely to evolve into information and data exchange services, as well as enablers of interactions between vessels and other port actors, such as the port authorities, moving away from their traditional roles as communicators of messages regarding safety issues (van Dorsser, 2020). Thus, the following three areas have been defined for examination regarding the future of VTS (van Dorsser, 2020):

–«*Full digital situational awareness*» (van Dorsser, 2020): In order to reach a level of full (100%) situational awareness, there has to be complete integration and utilization of automatic applications. Such applications are: automated piloting and automatic route/ voyage planning. Moreover, in order to achieve real –time and exact awareness of the environment surrounding the unmanned autonomous vessel and its characteristics, such weather conditions and floating objects, digital applications and equipment such as cameras, sensors and radar, have to be employed. Overall, situational awareness is essential for the avoidance of collisions, groundings and other maritime incidents that endanger life at sea and the marine environment (for instance pollution) as a whole. (van Dorsser, 2020)

Issues of situational awareness may arise when an unmanned autonomous vessel sails in waters and passages where there is high density of traffic or where the configuration of the passage does not allow for the equipment of the vessel to gain full sight of the vessels surrounding. In such circumstances, data and information shared by nearby vessels and objects, as well as by shore stations will assist in obtaining a more complete image of the vessel's surroundings. Information from the shore can be send to the vessel via VTS and they are collected through «*coastal sensor systems*» (van Dorsser, 2020) that included radar and AIS equipment. In the Port of Rotterdam there are 4 AIS stations and 42 radar stations. (van Dorsser, 2020)

–«*Interacting objects*» (van Dorsser, 2020): Interaction and connectivity between unmanned autonomous vessels and shore control and support systems fall into the concept of «*interacting objects*» (van Dorsser, 2020). Moreover, interaction between MASS vessels, objects and shore stations is expected to expand beyond just the exchange of information and data via messages, and include more intelligent communication. Therefore, standardization and development of the required infrastructure need to take place. (van Dorsser, 2020)

– «*Human behaviour and advanced decision support*» (van Dorsser, 2020): It is predicted that vessels under the MASS definition will plan their routing with the assistance of information about surrounding objects and Artificial Intelligence (AI). This information has to, also, be shared with the shore and specifically the person that operates the Vessel Traffic Service. In order for the VTS operators to interpret the information and data that they receive from the unmanned autonomous vessel, there has to be suitable VTS equipment. Furthermore, given the importance of the tasks that VTS's operators have to carry out (monitor and control traffic so as to ensure that collision and incidents are avoided), their work could be assisted by «decision support systems» (van Dorsser, 2020) allowing them to improve their situational awareness while leaving part of the monitoring process to the system. (van Dorsser, 2020)

From the above-mentioned in is concluded that the technologies and infrastructure used for Vessel Traffic Services (VTS) will have to be improved in the future in order to successfully respond to the needs of autonomous vessels.

Communication

Dynamic and real – time sharing of data and information between the various actors in the port is considered extremely important in order to optimize the Port Call process, especially for the parameters of the Estimated Times of Arrival and Departure and the Estimated Times of commencement and completion of the related operations (Lind et al., 2020).

Communication operations between the autonomous vessel and the Shore Control Center are expected to increase the expenses of the vessel during the journey (Hogg & Ghosh, 2016). Communication and transmission of data and information between the autonomous vessel and the shore can take place with a number of instruments such as radar, GPS, «*echo sounder data*» via satellite (Hogg & Ghosh, 2016). Moreover, in order for the Shore Control Center to remotely control the autonomous vessel, it has to be equipped with high – quality video imaging technologies (Hogg & Ghosh, 2016).

The International Electrotechnical Commission (IEC), with the contribution of the MUNIN project, has developed standards for «*shipboard data networks and ship to shore interfaces*» (Hogg & Ghosh, 2016). For instance, «*the standard IEC 61162-460 specified how to build a highly resilient bridge data network with secure connections to external networks and shore*» (Hogg & Ghosh, 2016). This standard has not, yet, been implemented but it is set to be the «*international standard on integrated communication systems with multiple*

channels, including protocols for routing ship to shore communication» in the future with the employment of autonomous vessels (Hogg & Ghosh, 2016).

Moreover, Public Key Infrastructure (PKI) and Blockchain are two technologies that are considered suitable for the abovementioned processes of communication and data transfer (Rødseth et al., 2019).

Public Key Infrastructure entails Public Key Cryptography which includes the use of a private and a public key as means of coding and de-coding of data, signing, verifying electronic signatures and allows for the authentication and secure and valid transfer of data (Rødseth et al., 2019).

The Public Key Infrastructure is considered adaptable for the following maritime operations (Rødseth et al., 2019):

– Transmission of nautical safety information. Information regarding nautical safety is, at the moment, being transferred from coastal states and shore based entities to vessels via Maritime Safety Information (MSI) carriers. These carriers mainly use radio frequencies to transmit safety – related messages. In this case, Public Key Infrastructure is considered a suitable option for validating the identity of the entity that transmits the messages, given that cyber-crime and cyber-attacks pose a significant threat especially for autonomous vessels which have autonomous bridge operations. (Rødseth et al., 2019)

– Vessel reporting to the Port State. Automatic reporting of a vessel to the Port State before its arrival at the port is being increasingly used by vessels and it requires Internet satellite connection. Trustworthy and correct reporting is significant for the smooth arrival of a vessel at the port and can be achieved by creating PKI – based system in which vessel is able to send a signed report and receive a signed acknowledgment of reception and acceptance of its report by the Port State automatically. (Rødseth et al., 2019)

Blockchain technology was launched for the first time back in 2008 with the Bitcoin cryptocurrency created by Satoshi Nakamoto (Nakamoto, 2008) and it uses similar key cryptographies as the Public Key Infrastructure (Rødseth et al., 2019). The technology has the form of a public ledger in which transactions data are stocked in a chain of blocks (Rødseth et al., 2019). The blocks are created by «*mining nodes*» (Rødseth et al., 2019) that also verify the transactions and distribute the blocks to the rest of the nodes (Rødseth et al., 2019). The Blockchain technology offers decentralization, verification, validation and authentication of transactions as well as user anonymity (Rødseth et al., 2019).

The Blockchain technology is considered a suitable solution for the following maritime operation (Rødseth et al., 2019):

The process of «Approval letter» (Rødseth et al., 2019). This process takes place during the time of a vessel construction and entails communication and sharing of documentation and information between the classification society, the shipyard, the shipping company and other third parties involved. By implementing blockchain technology in this process, each of these sharing interactions can be verified and stored in the blockchain system, ensuring the transparency of the process and enabling the tracking of interactions between the various parties involved. (Rødseth et al., 2019)

From the above it is concluded that in order to for the communication and the transmission of data and information between unmanned autonomous vessels, the port authorities and other vessels, new technologies need to be adapted.

2.2.3.2. Step 2: Vessel's visit

In this step of the Port Call process the main actors and processes involved are (Lind et al., 2019):

- Port State control (Lind et al., 2019)
- Cargo handling and terminal operations (Lind et al., 2019)

Port State Control

Alongside Vessel Traffic Services (VTS), the national maritime authorities of a port are, also, responsible for the Port State Control of the visiting vessels. The Port State control aims at verifying the compliance of the visiting vessels with the requirements and provisions of the International Maritime Organization (IMO) regulations in implemented by the flag state that has been assigned to each vessel, together with the requirements of the Coastal State (Lind et al., 2020).

Terminal operations

The loading and un-loading operations of vessels take places in port terminals by port terminal operators and stevedores (Lind et al., 2020). Specifically for container vessels there are dedicated Port Container Terminals (Martín-Soberón at al., 2014). A port container terminal (PCT) is an area of the port where handling of goods and cargo takes place. In the Port Container Terminals cargo is loaded, unloaded and transshipped from one mode of transport to the other, as well temporarily stored. The containerization of the cargo carried by

sea has allowed Port Container Terminals to offer more standardized operations and handling of cargo. (Martín-Soberón at al., 2014)

Nowadays, Port Container Terminals operate mainly automatically (Martín-Soberón at al., 2014). The idea of an automated Port Container Terminal was introduced for the first time in 1993 by ECT Delta, which established an automated ECT Delta terminal in the Port of Rotterdam that was equipped with «*Automated Stacking Cranes (ASCs)*» (Martín-Soberón, Monfort, Sapiña, Monterde, & Calduch, 2014) and «*Automated Guided Vehicles (AGVs)*» (Martín-Soberón, Monfort, Sapiña, Monterde, & Calduch, 2014) and was characterized by the absent of operators. Since then, more developments of automated Port Container Terminals have taken place. (Martín-Soberón at al., 2014)

In automated Port Container Terminals, the operations that are mainly automated are the yard and dock-yard «*interchange*» (Martín-Soberón, Monfort, Sapiña, Monterde, & Calduch, 2014), while crane-to-ship operations as well as operations between yard cranes and inland means of transport remain manually operated and assisted at a certain degree, but they are expected to be automated in the proximate future. (Martín-Soberón at al., 2014)

One example of a fully automated Port Container Terminal is that of APM terminals in Maasvlakte II in the Port of Rotterdam (Martín-Soberón at al., 2014). The APM terminal in Maasvlakte II area of the Port of Rotterdam was opened in 2015 and is one of the most automated Port Container Terminals (APM TERMINALS: Rotterdam Maasvlakte II - Our Terminal). Almost 80% of the crane movements performed in the terminal is automated, with the remaining 20% being performed remotely (APM TERMINALS: Rotterdam Maasvlakte II - Our Terminal). Automated Guided Vehicles (AGV) are being employed for the transport of containers that are powered by batteries and, therefore have zero emissions (APM TERMINALS: Rotterdam Maasvlakte II - Our Terminal). Additionally, the equipment in the terminal is powered by green sources of energy and electrification leading to zero emissions of CO2, NOX and particulate matters, while the separation between the fully automated and non – automated infrastructure increases the level of safe operations (APM TERMINALS: Rotterdam Maasvlakte II - Our Terminal).

Automated container terminals are, also, considered better fitting for the facilitation of unmanned autonomous vessels by terminal operators (Negenborn, et al., "Autonomous Ships in the Port of Rotterdam", 2018). Therefore, based on the above we concluded the loading and un-loading of unmanned autonomous vessels will take place on Automated Port Container Terminals.

2.2.3.3. Associated labour

It is expected that the general trend of automation in the transportation industry will lead to a shift in terms of the jobs' context and the skills and knowledge required from the workforce and not in a decrease in labour. Specifically, the increased efficiency that is expected to be realized by automating many of the processes in the supply chain and transportation systems is one of the main driving forces behind this wave of automation in the industry. Automation is predicted to pose a significant threat for low – skilled and physically demanding tasks and activities, while jobs such as «*remote operators*» (UNCTAD - REVIEW OF MARITIME TRANSPORT, 2019), maintenance personnel and providers of «*mobility-as-a-service*» are expected to be benefitted from it (UNCTAD - REVIEW OF MARITIME TRANSPORT, 2019). The future workforce in the shipping and transportation industry is foreseen to be highly qualified and knowledgeable so as to meet the requirements of the future automated solutions, and for that purpose it is considered legitimate that the countries all over the world need to adequately prepare the future workforce of the sector. (UNCTAD - REVIEW OF MARITIME TRANSPORT, 2019)

Seafarers

In the next ten years, it is expected that there will be an increasing shortage of available seafarers (Johns, 2018). More specific, it is predicted that in 2025 there will be a shortage of 147.500 officers, which is more than 18% of the global demand for officers on - board vessels (Johns, 2018). At the same time, it is expected that the demand for seafarers will increase with a rate of 10 percent every five years (Johns, 2018).

A scenario developed by BIMCO envisages that by 2025, 1000 vessels will be operating fully autonomously and 2000 semi – autonomously, while the demand for seafarers might decrease by 30000 to 50000 (Johns, 2018). Even in such case, trained and highly skilled remote operators and pilots will still be needed to ensure the safe and successful operation of those vessels (Johns, 2018). Seafarers will be required to receive training and will have their role redefined in the future with digitalization and autonomous vessels. Moreover, seafarers will have to become more skillful so as to be able to work with remote control systems (Johns, 2018).

International Conventions such as the STCW and MLC will have to be adjusted so as to regulate the operation of autonomous vessels and specifically notions and definitions such as

the definition of a seafarer when a vessel if remotely operated by a Shore Control Center operator and when it is manned (Johns, 2018).

The personnel that will be working with autonomous vessels is expected to be on-shore based, equipped with a set of high skills and knowledge in the field of technology and substantial corresponding salaries that will possibly counterbalance the expected savings from on – board crew reduction (Guerra, 2017). Moreover, the risks of system failure and cyber-attack, render the frequent control and monitoring of the autonomous vessels from the remote operators extremely significant (Guerra, 2017).

The Captain or Master of the vessel is held most responsible for the safe and successful operation of the vessel with some of his/her duties being: retaining order on the vessel and obey to the navigational rules and customs (Guerra, 2017). According to the planning of the Shore Control Centers by the MUNIN project, those centers will be manned with an operator that will control and monitor the operation of the autonomous vessels and will have duties very similar to those of a vessel's Master, an engineer that will be of assistance to the operator and a «*situational room team*» (Guerra, 2017) that will take charge of the remote operations in the case of emergency circumstances (Guerra, 2017).

Port - related labour

Vaggelas and Leotta (2019) reached to the conclusion that automation and digitalization of the port operations will require from the port workers to acquire a new set of soft and hard skills through training programs and certifications in the proximate future.

Automation is considered to be of substantial contribution to the increase of the productivity of companies and organizations, as well as their labour productivity, providing employees and workers with improved safety and health conditions in the workplace and replacing tasks that are repetitive and dangerous, it also endangers job positions that have low skills requirements, such as the port related jobs, and a forces them to shift towards more high-skilled, technology – related positions (Vaggelas & Leotta, 2019). Unions in the port of Rotterdam have stated that around 800 job positions out of the total 3700 in the container division of the port could be eliminated and replaced by automated solutions and technologies (Vaggelas & Leotta, 2019).

Despite the aforementioned challenges that the technology of unmanned autonomous vessels creates for port labour, a positive effect is expected for the onshore employment (Negenborn al., 2018). Negenborn et al. (2018) identified two main types of onshore employment that are considered to include jobs be of high quality and high-skills

requirements. These are: «*technology creating jobs*» and «monitoring and control of technology» (Negenborn et al., 2018).

From the above it can be concluded the seafarers' job positions, port labour and on-shore employment in general will experience a shift from low-skilled to high-skilled job positions in the future as a result of the general trend of industry's automation and the employment of unmanned autonomous vessels.

To conclude, according to literature, the employment of autonomous vessels in the future is expected to affect the main actors and processes incorporated in the main stages of the Port Call process in the ways analyzed in this section.

3. METHODOLOGY AND ANALYSIS

This section includes a description of the research methodology used for this Master thesis and the analysis of the outcomes of the research. The analysis will be divided in sub-sections, each of them addressing each of the main actors and services included in the three main stages of a Port Call process, as presented in the previous section. In this way, the identification of the impact of autonomous vessels on vessel – oriented Port operations and services will be identified through the identification of the autonomous vessel's impact on each of the main stakeholders and activities involved in the Port Call process.

3.1. Methodology

The research for this Master Thesis was carried out in the form of semi-structured research interviews that provided qualitative information. This method of research was considered to be suitable for studying the research objective of this Master Thesis for following two reasons: 1) it generates responses form the interviewees that are based on their knowledge and experience on the matters addresses in the questions of the interview and 2) all the interviews are being asked the same open – end questions that allow for comparability of the collected information and gives interviewees the freedom to answer the questions in the way they prefer (McIntosh & Morse, 2015). Interviews on a focus group consisted of «*nautical experts and students*» were used by Wahlström et al. (2015) so as to determine the main functions and challenges of the operation of Shore Control Centers (Human factors

challenges in unmanned ship operations – insights from other domains). Qualitative interviews were, also, conducted by Mansson and Lützhöft (2016) in order to gain insight on the navigational and manoeuvring operations of vessels within ports from «*ship masters, maritime pilots, tug masters and Vessel Traffic Service operators active in Australia*» (Mansson & Lützhöft, 2016). Furthermore, Carbone and De Martino (2003) carried out semi – structured interviews with managers and suppliers of the Renault car manufacturing company, as well as with port operators in the Port of Le Havre so as to determine the characteristics of the supply chain and port operators with whom the company cooperates locally. Finally, Mallam et al. (2020) investigated the perceived potential impact of autonomous technologies on future of maritime operations and on the future role of humans within the shipping industry by conducting semi – structured interviews with experts and academics from the industry.

The main areas that were addressed in the semi-structured script of questions were the following: 1) the port actors, services and operations that are expected to impacted by the autonomous vessels technology, 2) the way in which these actors, services and operations are expected to be impacted and 3) the future employment of autonomous vessels and subsequent port developments required for their facilitation. A total of 5 experts were interviewed individually and they were of various professional backgrounds and disciplines such as scientific research, logistics, information technology and management, and organizations mainly situated in the Port of Rotterdam. The interview with Expert A was conducted via a phone call, while the interviews with the rest of the experts were conducted with the use of the Microsoft Teams software. The full text of the interviews (including the questions and the interviewees' answers) is provided in the Appendix, as well as a brief description of the features of the interviews which is presented in Table 1 of the Appendix. The full texts of the interviews with Experts A, C, D and E include the author's interpretation of their answers and some of their exact quotes after having received their written confirmation for the information included, while the full text of the interview with Expert B includes the answers given by Expert B as transcribed post – hoc with the use of the AmberScript transcription software.

3.2. Analysis of the interviews and results

In this sub-section the information collected form the interviews will be used to analyze and identify the impact of autonomous vessels on each of the main stakeholders and activities that constitute the process of a vessel's Port Call. As mentioned in section 2 of this Master thesis, the main steps in the process of the Port Call are: vessel's arrival, port visit and departure of the vessel (Lind et al., 2019) and the main actors and processes included in those stages are: the Port State control, pilot operators, tug-boat operators, linesmen, terminal operators, ship agents (Lind et al., 2019) and Vessel Traffic Services (VTS) (Röhner, 2020), as well as the associated labour. The actors and processes incorporated in the arrival step are the same with those of the departure stage, (Lind et al., 2020) and for that reason the stage of departure will not be analyzed. Additionally, new requirements and port developments that are expected to take place in the future with the employment of autonomous vessels, as identified by the interviewees, will, also, be discussed.

3.2.1. Port Call process step 1: vessel's arrival at the port

In this step the main actors involved are (Lind et al., 2019):

- marine pilots (Lind et al., 2019)
- tug-boats operators (Lind et al., 2019)
- linesmen (Appendix to Port Call Process, 2020), and
- shipping agents (Lind et al., 2019)
- Vessel Traffic Services (VTS) (Röhner, 2020)

Marine pilots

The opinions given by the interviewees on the future of marine pilots with the employment of autonomous vessels were quite homogeneous. The majority of the interviewees agreed that in the future there will no longer be a need for marine pilots to board vessels in order to assist their navigation in the port, given that autonomous vessels will have autonomous navigation systems and that they are expected to be remotely piloted as well. That finding is consistent with what was expected to happen according to literature.

However, Expert D argued that vessel navigation within the port limits will still require the assistance of marine pilots mainly because of traffic – related reasons that might restrict the guidance abilities of the navigation system of an autonomous vessel or of a remote pilot,

especially in the Port of Rotterdam which is a very busy port. Expert E expressed the same view with Expert D on the challenges of guiding a vessel in a port. Furthermore, Expert C emphasized the importance of developing and adopting the appropriate communication technologies and infrastructure as well as information systems for both the autonomous vessel and the remote pilot, in order to successfully implement remote pilotage operations.

Moreover, another view that was common between a few of the interviewees was that if pilots remain in place in the future, it is very probable that they will have to either offer different services or offer their services in a different way than the way they offer them today, in order to comply with the requirements and needs of the future autonomous vessels. Expert A mentioned that the Port of Rotterdam is not, yet, exploring the remote piloting possibilities and technologies but other ports such as the port of Singapore have.

Tug – boats and linesmen

With regards to the tug-boats and linesmen operations, there was a general consensus among the interviewees that such operations will be redundant in the future and autonomous vessels will complete the berthing and un-berthing operations on their own with the use of relative new technologies, a finding that is in line with the literature expectations. Such technology, as mentioned by Expert C and Expert D, is the use of magnets for the operations of berthing and un – berthing of the vessel by the key-side instead of the traditional towing and linesmen operations. Additionally, it was mentioned by Expert C that improved positioning systems and maps that display information and data with high level of accuracy will further enable the automatic operations of (un) berthing and (un) mooring of an autonomous vessel but such technologies are expected to be costly. Moreover, Expert C mentioned the possibility of replacing tug – boat operations with remote towing operations from a local Shore Control Center.

Nevertheless, Expert A stressed the importance of tug-boat operations in the Port of Rotterdam, since it is a port that receives numerous port calls a day, and rejected the possibility of tug-operations being completely removed even for autonomous vessels. Furthermore, once again it was mentioned by the interviewees that if tug operators and linesmen stay in place, they might have to change their operational model and improve the communication - related technologies that they use in the future so as to facilitate autonomous vessels.

Shipping agents

The majority of the interviewees mentioned that the role of shipping agents will be greatly affected in the future by the employment of autonomous vessels. More specific, the majority of the interviewees predicted the absence of shipping agents in the future. The main reason why that is expected to happen, according to the interviewees, is that autonomous vessels will be enabled, with the new technologies implemented on them, to carry out the shipping agents' tasks on their own. Additionally, it was supported by the interviewees that if the shipping agents want to remain relevant, they will have to diversify their offering and provide custom – made services to autonomous vessels. Furthermore, it was mentioned by Expert C that there have to be changes in the legislation concerning the responsibilities and tasks of shipping agents, and especially those related to payments of third parties, so as to enable their absence and allow autonomous vessels to perform those tasks on their own. According to Expert C, the new European directive for acceptance of electronic signatures for the countries inside the European Union that has been adopted is an important step in the direction of removing shipping agents. Furthermore, Expert C mentioned that the sufficiency of this directive remains uncertain but it can contribute in resolving the legal issues related to the future absence of shipping agents.

The Directive 1999/93/EC of the European Parliament and Council of the 13th of December 1999 established a legal Community framework at European level for electronic signatures (eSignatures), as well as for the the recognition and regulation of certification - service providers (eSignature in the EU, 2015). The aim of the Directive is twofold: a) to enable easy use of eSignatures and b) to enable the legal recognition of them within all the countries of the European Union. The Directive was entered into force on the 19th of January 2000 (eSignature in the EU, 2015).

The Directive regulates the following (eSignature in the EU, 2015):

- «*common requirements for certification-service providers in order to secure cross-border recognition of eSignatures and certificates throughout the European Union (EU)*» (eSignature in the EU, 2015)
- «*common rules on liability to help build confidence among users, who rely on the certificates*» (eSignature in the EU, 2015)
- «*cooperative mechanisms to facilitate cross-border recognition of eSignatures and certificates with non-EU countries*» (eSignature in the EU, 2015)

The following concepts were determined in the Directive (eSignature in the EU, 2015):

- «*the electronic signature*» which is defined as «*data in electronic form which are attached to or logically associated with other electronic data and which serve as a method of authentication*» (eSignature in the EU, 2015)
- «*the advanced electronic signature*», which has to meet the below criteria (eSignature in the EU, 2015):
    - it has a unique link to the signatory
    - it has the ability of identifying the signatory
    - its creation is based on means that can be maintained by the signatories
    - there is a link between the "advanced electronic signature" and the electronic document that has to be authenticated, that allows the identification of any changes that might happen to that document
- «*the qualified certificate*», which has to incorporate the following (eSignature in the EU, 2015):
    - indication of its use as a "qualified certificate"
    - certification-service provider identification
    - signatory's name
    - another element of authentication of the signatory if needed and if possible, such as her or his date of berth
    - data for the verification of signature that is consistent with the data related to the signature creation under the signatory's control
    - beginning and end dates of the period through which the certificate is valid
    - certificate's identity code
    - the advanced electronic signature of the certification service provides that issues the qualified certificate. The certification service provider is ought to comply with the requirements set by the directive.

The European Parliament's and Council's Directive on eSignatures was repealed and replaced by the Regulation «*on electronic identification and trust services for electronic transactions in the internal market*» No 910/2014 of the 23rd of July 2014 (REGULATION (EU) No 910/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 July 2014).

This Regulation, also known as the «*Electronic Identification and Trust Services (eIDAS) Regulation*» and it was applied from the 17th of September 2014 (More secure

transactions on the Internet, 2016). The iIDAS regulation encompasses the following (More secure transactions on the Internet, 2016):

- the establishment of a new system for electronic interactions that are secure across all countries within the European Union (EU) and between public authorities, citizens and businesses
- amelioration of trust in electronic transactions within the EU and enhancement of the efficacy of e-commerce and online services in the private and public sector
- simplification of the use of electronic identification (eID) within the countries of the EU

Regarding electronic identification (eID), it is defined as: «*tangible or intangible forms of identification containing personal ID data as used for authenticating an online service*» (More secure transactions on the Internet, 2016). When it has been issued in a country within the EU, it is compliant with the requirements set by the regulation, it has been notified to the European Commission and it has been published in a list, it is ought to be mutually recognized by the rest of the EU countries. The mutual recognition of electronic identification has become mandatory from the 28th of September 2018. Moreover, the form of the electronic identification has to be issued under a specific eID scheme that defines the «*level of assurance*» (More secure transactions on the Internet, 2016) of the form which can be low, substantial or high. (More secure transactions on the Internet, 2016)

In addition, Expert C revealed that there are works in progress in IMO in order to examine the possibility of establishing an international electronic signatures regime. Nevertheless, according to Expert C this new Directive for electronic signatures will not bring a solution to the payment related activities and services that an agent provides, but it can provide a mechanism through which reliability of people can be verified.

These findings are the expected according to the literature as well.

Vessel Traffic Services (VTS) and communication

With regards to Vessel Traffic Services (VTS) and communication between the autonomous vessel and the port as well as between vessels, the majority of the interviewees emphasized the importance and necessity of improving the technologies and infrastructure already used in these areas, so as to facilitate autonomous vessels. This is in accordance with the expectation derived by the literature analysis. Moreover, it was mentioned by Expert A that the increased digitalization of the port operations would lead to a reduction of

communication activities by almost 85% in the Port of Rotterdam by automating the process that are being carried out via communication methods.

3.2.2. Port Call process step 2: vessel's visit

In this step of the Port Call process the main actors and processes involved are (Lind et al., 2019):

- Port State control (Lind et al., 2019)
- Cargo handling and terminal operations (Lind et al., 2019)

Port State Control

There were not significant effects of autonomous vessels on the task of Port State Control mentioned by the interviewees. Nevertheless, Expert E emphasized that in order for Port State Control and all the authorities that are responsible for controlling and inspecting the compliance of the vessel with international, national and local regulations and legislations to complete their tasks, there has to be a person on – board the autonomous vessel.

Terminal operations

The interviewees acknowledged that port terminals, and especially in the Port of Rotterdam, are already quite automated and therefore they did not expect any dramatic changes by the employment of autonomous vessels in the technologies already used for loading and un – loading a vessel. This is in line with the derived by the literature expectation. According to Expert C, in the big ports, such as the Port of Rotterdam, there is a lot of automation already, such as automated and remotely controlled cranes, and there are developments taking place in automation and digitalization of ports, but there is still a long way to go. Expert C mentioned that port terminal operators are aiming at minimizing the equipment and infrastructure needed for the loading and un – loading operations by using the autonomous vessel's equipment to load and un – load cargo and loading cargo on other transport modes directly from the port's key-side. Moreover, Expert B mentioned that terminal operations could be carried out autonomously in the future, without any manning needed, and be controlled and monitor by a Shore Control Center operator instead.

3.2.3. Associated labour

Seafarers

Expert D mentioned that there have to be adjustments to the existing regulations in order to employ autonomous vessels in the future and especially to those that regulate the safe manning of vessels. Moreover, both Expert C and Expert D expressed the opinion that the position of the Master or Captain of the vessel will have to be retained. More specifically Expert D mentioned that especially during the first stages and years of testing and operating autonomous vessels, the Captain will still be needed on – board those vessels. Furthermore, many of the interviewees supported the view that there will be establishment of Shore Control Centers or Shore Control Stations form which a small number of marine personnel (1 or two operators) will remotely monitor and control the operations of autonomous vessels. These findings are consistent with the expected impact according to literature.

Port labour

With regards to port labour, there was a general consensus among the interviewees that the context of the port – related jobs and the knowledge skills that will be required by port workers will be different in the future. The majority of the interviewees mentioned that the automation of the port processes, which is considered to be a prerequisite for the employment of autonomous vessels, will lead towards the prevalence of jobs that are contextually related to information technology and programming. Therefore, they expect that traditional port manual procedures will disappear and will be replaced by automation and high – skilled job positions. Moreover, it was revealed by Expert B that the future port workforce will have to receive the proper education so as to be prepared for the new more technology – driven type of job positions and tasks. These expectations are consistent with the expectations formed by literature. Additionally, it was mentioned by a few interviewees that the total impact of employing autonomous vessels on port employment as value creation for the port area will not be significant.

In conclusion, it was supported by the interviewees that the transition from the extant, traditional job positions both on-board vessels and on the port to the new type of more Information Technology oriented and digitalized job positions and tasks will not be realized in the immediate future, but will take a few years, taking into account the time needed for both the companies and the workforce involved to prepare for this new reality.

3.2.4. Shore Control Center

There was a general consensus among the interviews that there will be an establishment of Shore Control Centers in ports in the future from which Shore Control Center operators will be responsible for remotely controlling and monitoring the operations of multiple autonomous vessels, as, also, identified in the literature. Expert A and Expert C also mentioned that they expect these Shore Control Centers to be established by the shipping companies and the shipowners and not the Port Authorities of the ports. Furthermore, with regards to the workforce of those Shore Control Centers, the majority of the interviewees disclosed that it will be consisted of highly – skilled and knowledgeable marine personnel that will perform tasks and operations of connected to the handling, monitoring and controlling of digital systems and operations. A brief analysis of the concept of Shore Control Centers, based on literature, is conducted in the following paragraph.

Maritime Unmanned Navigation though Intelligence in Networks (MUNIN) project of the European 7th framework programme introduces the concept of a Shore Control Center from which the monitoring and controlling of the operations of unmanned autonomous vessels will take place (Porathe, Remote Monitoring and Control of Unmanned Vessels – The MUNIN Shore Control Centre, 2014). Form these Shore Control Centers, the operators are expected to be responsible for the monitoring of more than one autonomous vessels (Porathe, Remote Monitoring and Control of Unmanned Vessels – The MUNIN Shore Control Centre, 2014).

The Shore Control Centers of the MUNIN project are designed to control and monitor a number of 90 autonomous vessels each. Furthermore, it was estimated that the yearly cost of the employment of the Shore Control Center personnel could reach 10.4 million US dollars and when divided by the number of vessels, it reached the 116,000 US dollars per vessel. The estimated investment costs for a Shore Control Center are 2.1 million US dollars, while the estimated overall operating costs per year are almost 875,000 US dollars. (Kretschmann et al., 2017)

The main tasks and operations of Shore Control Centers have been identified by Porathe et al. and Man, Lundh, and Porathe (2014) as follows (Wahlström et al., 2015):

- «*Monitoring the voyage and updating the ship route*» (Wahlström et al., 2015): this comprises the monitoring of the weather conditions, of vessel traffic and of warnings connected to navigation.

- «*Monitoring the vessel's health and status*» (Wahlström et al., 2015): this comprises the monitoring of the situation of the numerous technical elements and of the equipment of the vessel, such as the condition of the engine and communication technologies.
- «*Communication with other ships*» (Wahlström et al., 2015): the Shore Control Center has to be responsible for radio and distress channels communications with other nearby vessels.
- «*Decision making in view of all of the above*» (Wahlström et al., 2015): the Shore Control Center is expected to be in a position of making decisions regarding the various aspects of the unmanned autonomous vessel's operations.

Furthermore, aside from the SCC's expected functions, there were a number of challenged identified as well, such as (Wahlström et al., 2015):

- «*Limited situation awareness due to reduced sense of the ship*» (Wahlström et al., 2015): the use of means for remote operations such as sensors, radars and cameras allow a certain degree of situational awareness to be achieved by the operator. Therefore, the operator is unable to fully understand the situation of the vessel when, for instance, the vessel sails through waves that impact its sailing.
- «*Information overload due to the plurality of ships and ship sensors*» (Wahlström et al., 2015): the operators of the Shore Control Centers could be easily overwhelmed by the plethora of information received, since they will be responsible for controlling and monitoring more than one autonomous vessels and they will be updated for the vessels' conditions by a virtual representation consisting of various and numerous information and data.
- «*Communication challenges due to limited knowledge on the local conditions or language issues*» (Wahlström et al., 2015): Issues might arise when a Shore Control Center covers a wide area within which there is a high level of cultural and linguistic diversity and the SCC's operators are not well equipped so as to communicate and interact with the locals effectively and successfully.

It is very likely that the remote operation of autonomous vessels and subsequently Shore Control Centers will take place from the port area (Wahlström et al., 2015). Therefore, establishment of Shore Control Centers in ports should be considered as highly possible

adjustments to the ports' infrastructure in order to remotely monitor unmanned autonomous vessels.

3.2.5. General remarks on the autonomous vessel technology

Expert C mentioned the type of vessels that are expected to be the first to operate autonomously are mainly small vessels, such as barges and feeders. Two are the main reasons for that, according to Expert C: 1) the employment of smaller vessels allows for more flexibility of the supply chains and logistic systems in which there is less cargo loaded on smaller vessels that approach smaller ports with higher frequencies and 2) the benefits from the absence of crew are expected to be greater for smaller vessels compared to larger vessels, given that for small vessels the crew costs are a higher percentage of their operating costs. Moreover, according to Expert C this is expected to have an impact on ports and port operations, given that small autonomous vessels visit both big and small ports. Nevertheless, the technology used for the automation of smaller vessels can is considered to be applicable for bigger vessels as well, according to Expert C. Furthermore, Expert C revealed that it is more cost – efficient, especially for small ports, to have one or two people assisting the mooring operations of a small autonomous vessel in the port rather than having people monitoring and controlling their operation in the port 24/7.

Furthermore, Expert C emphasized the importance of fully automating the cargo handling operations so as to achieve cost – reduction especially for the transshipment of cargo and especially for feeder vessels and barges that transfer the cargo to the final destination. In this way, Short Sea Shipping can become more attractive for the transfer of cargo than truck transport.

Expert A mentioned that in small ports, autonomous tug – boats can be employed that can be operated remotely by a Shore Control Station so as to reduce operating costs and especially those related with the manning of the tug – boats. By doing so, up to 80% of needed Captain capacity can be reduced, according to Expert A.

Expert B and Expert C mentioned that the cost of building an autonomous vessel will be more less the same with that of a conventional vessel since the cost for the electronics and communication navigation – related equipment will offset the savings from the absence of equipment and accommodation dedicated to the on – board a fact that is, also, supported by the study of Kretschmann et al. (2017).

Moreover, Expert A and Expert C mentioned that port efficiency will not be achieved only by employing autonomous vessels, but mainly by automating and standardizing the port processes. For instance, according to Expert C, by standardizing the size and the weight of the containers (for example, 20 feet and up to 30 tons respectively), then cargo handling operations will become more efficient and there will be more effective use of the associated port equipment (such as cranes). Expert A and Expert C, also, mentioned the need for standardization of communication protocols such as the Estimated Time of Arrival (ETA) of a vessel in the port so as to have efficient communication between the autonomous vessels and the shore.

Furthermore, Expert C mentioned that the pioneers in the autonomous vessels technology are mainly cargo owning and logistics companies and not so much ship-owning companies. Finally, he mentioned that for big port such as the Port of Rotterdam the main issue that have to be dealt are the efficiency of transshipment operations (with automation) as well as the possibility of them losing traffic, if smaller autonomous vessels are preferred over big vessels (such as 20000 TEUs containerships), because they can offer more frequent services.

3.2.6. Conclusion

In conclusion, from the analysis of the interviews, the main effects of the employment of autonomous vessels in the future on vessel – related port operations and services and specifically on the main actors and operations involved in the Port Call process were identified. The future impact on each of those actors and services as identified by the interviewees is briefly described below:

- Marine pilots: They will be redundant or perform their work remotely.
- Tug – boat and linesmen operations: They will be replaced by new technologies such as the use of magnets or tug-boats will be remotely operated.
- Shipping agents: They will be absent and the autonomous vessels will complete their tasks by their own. In order to remain relevant in the future and not disappear, they will have to diversify and transform the services they provide so as facilitate autonomous vessels.
- Vessel Traffic Services (VTS) and communication: Improvements in the technologies and infrastructure used is considered necessary.

- Port State Control: There was no significant impact identified.
- Terminal operations: Increased automation of operations and reduction of manning and unnecessary equipment.
- Seafarers and port labour: Shift form hard – skilled manual job positions to high – skilled information technology related jobs based on shore, but without a significant effect on the value creation of the employment in the port.
- Shore Control Centers: Establishment of Shore Control Centers in the port by shipping companies and shipowners form which the controlling and monitoring of the autonomous vessels' operations will be performed. Shore Control Center operators will be responsible for monitoring and controlling multiple vessels.

The abovementioned impacts were, also, specifically identified for the Port of Rotterdam, which is the port on which this Master Thesis focuses on.

4. CONCLUSIONS

The aim of this Master Thesis was to identify the impact that the future employment of autonomous vessels in the merchant fleet will have on the vessel – oriented port operations and services with a focus on the Port of Rotterdam. The investigation of this research question is considered of great importance, taking into consideration the technological developments that are taking place in the maritime industry and the significant role that Ports have in the international supply chain systems. The radical and somehow disruptive digitalization of the shipping industry, also, referred to as «*Shipping 4.0*» (Rødseth et al., 2019) is transforming the traditional business models, operations and activities in the industry with the introduction of new emerging technologies such as the Internet of Things (IoT) (Rødseth et al., 2019), Big Data (Vaggelas & Leotta, 2019) and autonomous vessels (Rødseth et al., 2019). Moreover, companies and organizations in the maritime industry are showing increasing interest in the development and employment of autonomous vessels mainly due to the advantages that they offer compared to conventional vessels, in terms of increased cost – related, operational and environmental efficiency as well as safety (massterly - WHAT WE DO). Nevertheless, in order for autonomous vessels to operate and sail in deep-sea waters, ports and inland waterways with safety, regulatory and institutional intervention has to take place, so as to create the appropriate legal frameworks that will be applicable to the entire process of

designing, constructing, operating, controlling, monitoring and overall employing this new type of vessels (UNCTAD Review of Maritime Transport 2019 - Sustainable Shipping, 2019).

Ports, being the connection point between maritime and land transportation, linking waterways (sea, rivers, canals) with land infrastructure (railways, roads) in order to facilitate the transfer of cargo and goods, as well as passengers (Carbone & De Martino, 2010), are expected to be greatly impacted by the on – going transformation of the maritime industry (Woo et al., 2011) and the employment of autonomous vessels (Vaggelas & Leotta, 2019). Furthermore, their responsive position in the supply chain systems is making them vulnerable to the changes that happen in the maritime and logistics industries and to their transformation (Verhoeven, 2010). Consequently, ports will have to adjust their operational, organizational and technological functions in order to facilitate autonomous vessels and respond to their requirements and needs (Vaggelas & Leotta, 2019).

The research method that was applied for the investigation of the research question was semi-structured research interviews that provided qualitative information. The main areas that were addressed in the semi-structured script of questions were the following: 1) the port actors, services and operations that are expected to impacted by the autonomous vessels technology, 2) the way in which these actors, services and operations are expected to be impacted and 3) the future employment of autonomous vessels and subsequent changings required for their facilitation in the ports. A total of 5 experts were interviewed individually and they were of various professional backgrounds and disciplines such as scientific research, logistics, information technology and management, and organizations mainly situated in the Port of Rotterdam.

The identification of the impact of autonomous vessels on vessel – related port operations and services was achieved through the identification of the effect that autonomous vessels will have on the main activities and actors included in the Port Call process. The main stages in the process of the Port Call that were analyzed are: vessel's arrival, port visit and departure of the vessel (Lind et al., 2019) and the main actors and services included in those stages are: the Port State control, pilot operators, tug-boat operators, linesmen, terminal operators, ship agents, Vessel Traffic Services (VTS) (Lind et al., 2019) and the associated labour. The actors involved in the arrival stage are the same with those of the departure stage (Lind et al., 2020) and for that reason the stage of departure was not analyzed separately. Through the analysis of the interviews, the expected effects on those actors and operations, as well as new requirements and port developments that are expected to take place in the future with the employment of autonomous vessels, were identified by the interviewees as follows:

- Marine pilots: They will be redundant or perform their work remotely.
- Tug – boat and linesmen operations: They will be replaced by new technologies such as the use of magnets or tug-boats will be remotely operated.
- Shipping agents: They will be absent and the autonomous vessels will complete their tasks by their own. In order to remain relevant in the future and not disappear, they will have to diversify and transform the services they provide so as facilitate autonomous vessels.
- Vessel Traffic Services (VTS) and communication: Improvements in the technologies and infrastructure used is considered necessary.
- Port State Control: There was no significant impact identified.
- Terminal operations: Increased automation of operations and reduction of manning and unnecessary equipment.
- Seafarers and port labour: Shift form hard – skilled manual job positions to high – skilled information technology related jobs based on shore, but without a significant effect on the value creation of the employment in the port.
- Shore Control Centers: Establishment of Shore Control Centers in the port by shipping companies and shipowners form which the controlling and monitoring of the autonomous vessels' operations will be performed. Shore Control Center operators will be responsible for monitoring and controlling multiple vessels.

From the abovementioned expected impacts identified by the research carried out in this Master Thesis, it is evident that in the future ports digitalization and automation of processes and operations will play a significant in their transformation and the increase of their efficiency. Specifically, the same impact was identified by the interviewees for the Port of Rotterdam, but at a smaller level. The reason for that was the Port of Rotterdam has already incorporated digital and automatic solutions in its operations and therefore, its level of readiness for the arrival of autonomous vessels is considered to be higher than that of smaller ports. However, further investments on infrastructure and communication technologies were mentioned to be important for the port.

Form the aforementioned expected implications it can be concluded that autonomous vessels in the future will not only transform the maritime and logistics industry but also the ports by redefining the business models, the procedures and the technologies necessary to accommodate this type of vessels with efficiency and safety.

5. LIMITATIONS AND SUGGESTIONS

5.1. Limitations

In this Master Thesis the method of semi – structured research interviews was applied. The participants in the interviews were of various professional backgrounds and disciplines, a feature that was considered to be of great importance and contribution in the research. Furthermore, the information collected form the interviews were considered of good quality and sufficient for the purpose of this Master Thesis. However, the total number of interviewees was 5 which is considered somewhat small. Incorporating more interviews in the research would allow for a stronger support and validation of the results and evidences.

5.2. Suggestions

This Master Thesis contributed in the identification of the impact of the employment of autonomous vessels on vessel – oriented port operations and services with a focus on the Port of Rotterdam. Further research could be carried out to identify the impact on other ports in the world, as well as on the relations between different ports. Moreover, another interesting area of research is that of the economic impact of autonomous vessels on ports once there are sufficient information and data available to such research.

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APPENDIX – INFORMATION ON INTERVIEWS

Date of Interview	Form of interview	Duration and recording method	Interview reference name	Position	Organization
17-06-2020	Individual	60 minutes, voice recording and notes	Expert A	Project Manager	Port of Rotterdam
24-06-2020	Individual	35 minutes, voice recording and notes	Expert B	Project Developer	SmartPort
03-07-2020	Individual	65 minutes, voice recording and notes	Expert C	Senior Scientist	SINTEF
07-07-2020	Individual	16 minutes, voice recording and notes	Expert D	Co - Founder	Captain AI
08-07-202	Individual	30 minutes, voice recording and notes	Expert E	Logistics Solutions	BlockLab

Table 1. Description of the features of the interviews. Source: Interviews and the organizations mentioned in the table.

SmartPort: «SmartPort is a neutral knowledge platform, stimulating alliances, financing scientific research and provides public knowledge dissemination» (About SmartPort). It aims at speeding up innovations that take place in the Port of Rotterdam and is a non – profit partnership between the Municipality of Rotterdam, the Erasmus University, Delft University of Technology, TNO and Deltares (About SmartPort).

SINTEF: SINTEF is a Norwegian independent research organization that carries out projects for its customers. It is active for more than 70 years and it aims at developing innovative solutions for societies and companies worldwide (SINTEF - APPLIED RESEARCH,TECHNOLOGY AND INNOVATION).

Captain AI: Captain AI is a company located in the Port of Rotterdam that «is developing the world's first safe and fully autonomous shipping solution using high-fidelity

simulation, cutting-edge sensors and state-of-the-art deep learning techniques» (About Captain AI).

BlockLab: BlockLab is a subsidiary of the Port of Rotterdam with the City of Rotterdam as a co-founder (BlockLab - ABOUT US). It is a «Smart Industries Fieldlab» (BlockLab - ABOUT US) that develops use cases based on blockchain technology in cooperation with «engineers, developers, system players and end users» (BlockLab - ABOUT US) with a focus on energy and logistics (BlockLab - ABOUT US). It operates in the Port of Rotterdam and it is a participant in the Dutch Blockchain Coalition (BlockLab - ABOUT US).

INTERVIEW WITH EXPERT A – FULL TEXT

Question 1

I have read the paper on Smart Shipping published by SmartPort that you, also, co – wrote and is a very nice paper, very inclusive and it really gives a very nice overview of what is expected to happen with the arrival of autonomous vessels for the ports from the various aspects. If I remember correctly, in the paper you have reached to the conclusion that the overall outcome for employment will be negative?

Answer

The impact of the employment of autonomous vessels on the employment of seafarers is expected to be negative. Nevertheless, there will be new job positions emerging related to the technical aspects of autonomous vessels that will offer support of the systems.

Question 2

Can you quantify, for instance, the expected impact on job cuts or what does that mean for the Port Authority in terms of costs and possible revenues from the employment of autonomous vessels?

Answer

–The technology of autonomous vessels is based on communication. The Port Authority is expected to face increased costs from the digitalization of their operations, assets and processes that has to take place. There will be a shift from processes that involve paper-work, mail and human effort. There will be a change of mindset. Need for new people, new employees with new skills and knowledge.

– For instance the Port Call process in the port of Rotterdam. Process to give permit to enter port area via telephone or VHF. It is expected that 85% of the communication to happen automatically, when that process will be automated. The employees will communicate less with the vessels and will have more time to devote on solving any issues and problems that the vessels face. So, in the future the hours of work are not expected to be reduced, but their context and the «normal element of the jobs» is expected to change. It might reduce the number of personnel needed for those jobs, but the aim is to allow for more time to be spent on special vessels' needs and therefore, provide vessels with better service and reduce human failures. 85% on the jobs in the planning process.

– In order to serve and accommodate autonomous vessels, the port (and the Port Authority) needs to digitalize its processes such as Port Calls and Birth planning systems.

– There is, also, more need for «security- based systems». There is an incremental use of Artificial Intelligence. For the digitalization to take place, security and human elements involved are extremely important. A «Superior Architecture» has to be created. A CTO said: «Within ten years every company will be an ICT company only doing different things». But this opinion is not considered completely true for Ports, since they accommodate vessels. However, the global trend of digitalization is leading towards a change of mindset, skills and of the way that processes occur.

– Port operations: a reduction of manual work will take place. Humans will be used mainly for digital and specific issues and problems and interaction. For example, humans communication with language and words and there is, also, the element of intonation that machines do not have. They just speak the words.

– Autonomous shipping is not considered to be a "goal" but a "tool", because autonomy can be used to improve the way that a vessel completes its job. When you look at autonomous vessels, you ask yourself the following question: «What does it need to make something like that possible?»

– With the employment of autonomous vessels, standardization is achieved. Standardization of solutions. Digitalization of ports must take place in cooperation, in a network, because vessels travel to many ports all over the world, not only to one port.

Question 3

I would, also, like to ask you, you mentioned that 85% of the man – hours will be cut?

Answer

«No, 85% of the communication down-line. That is just on the planning process.»

– Increased safety with system-to-system communication. There is a need for developing a system were systems can communicate with one another. Therefore, there will be a reduction of jobs. Nevertheless, new types of jobs will emerge such as system developers that will create and maintain the systems. Create programs that will enable communication between systems, sharing of information, exchange of data, connection of systems and understanding between them. Also, standardization is needed to be established.

– The ETA (Estimated Time of Arrival) is different for each port and there could be, for instance, two hours difference because the ETA was communicated and perceived differently. Therefore, when moving towards autonomous shipping precision is very important, for instance precision of definition such as the ETA, definition of port call.

– Digitalization will enable business optimization: solution for reduction of amount of work, increased safety.

– Effect of digitalization on Port Economics: in the future it is expected that cranes will operate autonomous without an operator or a supervisor/ remote operator that will be in charge of monitoring and operating more than one cranes.

Question 4

Is there an observed shift from the ordinary port – related jobs to a different type of jobs that will be more related to automation and digitalization?

Answer

– The skills and knowledge of the workforce is evolving alongside the evolution of the jobs and their demands. That is a more social aspect. Port-related jobs have transformed over the years and there have been great changes in the port jobs. Automation and now digitalization are not considered as disruptions when it comes to the port – related jobs because the context of these jobs evolves over time. «I am optimistic about jobs in the future, because what teenager would like to still work on a fixed crane while he, also, can use his play-station device to handle ten cranes at once.»

Question 5

What about the construction of Shore Control Centers in ports in order to monitor and control the operation of an autonomous vessel? Has that been part of the planning, let's say, of the Port Authority of Rotterdam?

Answer

–The Port of Rotterdam does not intend to explore the concept of establishing Shore Control Centers for itself. The port is interested in that exploration as a customer. Nevertheless, the companies that are located and operate within the port, especially shipping companies, are way more eager to explore this concept so as to benefit.

–One of the dredging companies in the port has its own shore control station and for two of its ships it does for instance the voyage planning via the shore control center/ station. →Reduction of amount of work on the vessel, creation of more job positions on shore that are cheaper and can be combined, for instance one person taking care of the supplies for many vessels, for instance one person doing that for 20 ships. Shore control centers are expected to be mostly owned – based by shipping companies, such as Carnival Cruises' SCC nearby Hamburg. SCC for remote piloting or remote ship management. Remote piloting is being explored in Singapore but not in the Port of Rotterdam yet. SCC → They will allow more local knowledge on a digital bridge. «The first who will develop SCC will be the ship – owners that have vessels that operate all around the world and are employed for particulate moments during a week. For example, when you have in a port somewhere in Africa where the tug – boats from one operator are handling two or three ships a week, those tug – boats have Captain and engineer on – board.»

Captains will be removed, engineers will remain on the vessel and perhaps take the command of the ship (in the port), remote control centers will take command of the vessel for the sailing period. «When you have one worldwide control center and you have multiple ports with a couple of tug – boats, with only two or three ships a week, you can reduce 80% of the captain capacity, because you can have one guy or two guys handling those tug – boats all over different ports at once in different times. So, you only need your shipmate and your engineer on – board to maintain the ship and keep everything ready.» SCC will allow ship-owners to optimize operations and reduce costs.

But it is not expected that the Port Authority will establish SCC to control and handle vessels, because it is beyond their compliance, rules and scope. The Port Authority delivers information to the vessels, while ship handling takes place by the ship-owner or the Captain.

–The question that arises is: «Will there be a general Shore Support Center where all the companies work together?» Because companies tend to keep their business and operations private. It is most probable that each company will have its own SC station and handle its own vessels within the port areas that are located nearby.

Question 6

So, you believe that companies that are located in the port and especially ship – owners would be the first ones that will, perhaps, create and construct Shore Control Centers for the operation of autonomous vessels?

Answer

«Yes. I think there will be a Shore Control Station somewhere or a Shore Control Office. A Shore Control Center looks like a very futuristic, new to build center where everybody works with each other or at least that is the image I get form that word.»

–There are already SC stationaries where voyage planning takes place, for instance Rolls-Royce Marine which is more of a stimulator that needs a digital image of the vessel and its surroundings and then digitally operate the vessel. So what is needed is standardization of image and information.

Question 7

Which services that are offered in a port do you think will be mostly impacted from the arrival of autonomous vessels, for instance towing services and those services that are essential for the handling of the vessels and their operation?

Answer

Port actors that are expected to be impacted by the arrival of autonomous vessels:

o Shipping agents/ Agents: They are the connection point between ships and the Port Authority, but with the automation and digitalization of the processes there will not be a need for such person/ job position. They will have to diversify and re-evaluate the service they offer to their customers in order to remain relevant.

o Pilots: Pilotage services are expected to be different in the future. Remote pilotage is expected to be used more often. There will not be a need for employing a helicopter to fly a pilot on board a vessel, instead there will be use of information and drone operations that will provide data and information on the surroundings of the vessel.

o Tug operations in the Port of Rotterdam are not expected to change in the future, because it is a big port with many tug operations taking place, but tug operations might change in small ports in the future.

o Automated docking stations in the future instead of linesmen → What about the weather conditions such as strong winds.

o «Humanless Terminal»: No humans on the terminal doing manual work, but humans in SCC or Support centers monitoring, operating and supporting the terminal operations and the automated systems.

Question 8

Would you like to share with me your opinion on what you believe will be the overall outcome for the port in terms of efficiency of operations as well as cost efficiency and environmental efficiency from having autonomous vessels being employed?

Answer

Efficiency in a port is not directly impacted by the employment of autonomous vessels, by indirectly via the automation that is requested for the operation of autonomous vessels. «Autonomous ships do not create better transport processes.» Automated systems are more eco-friendly. Reduction of emissions can be achieved by using more efficient engines. Moreover, using electricity as a fuel allows for a more streamline and simple propulsion system and more environmentally efficient, regardless of whether it is used on an autonomous or a non-autonomous vessel.

Benefits for the Port Authority from autonomy and automation:

o Reduction of risk

o Reduction of collisions

o Improved safety, improved safety KPIs

Benefits for insurance companies:

o Reduced number of collisions

o Cost reduction

Benefits for ship-owners:

o Workforce reduction by minimizing on-board personnel and replacement with on-shore personnel which is cheaper

Overall: a lot of benefits from automation. «The main benefit I have in looking forward to autonomy for the future is that we learn a lot about automation and how at the end we will be able to create a more digital solution. When we have digital solutions, we will probably find lots of benefits which we cannot describe right now.»

INTERVIEW WITH EXPERT B – FULL TEXT

Question 1

I would like to ask you, what do you think as an overall point of view will be the economic impact of autonomous vessels, let's say on operations that are taking place in the port and are very much related to the facilitation of the vessel, the loading and un - loading and its operations?

Answer

«So, I don't think there will be a, as far as I can see right now, I don't think that there will be a big economic impact. At least on a positive economic impact, because it will, well, on the one hand, I can imagine that it can reduce costs. If you're going to visit a port, it might become a bit cheaper to arrive and leave the port due to the fact that you might need less guidance. So, for example, you do not need a pilot on-board or other kinds or tug - boats maybe. On the other end, so that reduces the cost for a ship, but also reduces the work for the companies in the port. So that could have a negative impact for the companies operating in the port. On the other hand, I can also imagine that those kind of operations will be done in a different way. So that you need to have other kind of service providers there or maybe the same. But they have to adjust to these kind of vessels. So things will change. So maybe in the end it will not have a huge impact also with the loading and unloading of an autonomous vessel, this will not be different than with the current vessels, I think. So I don't think in overall the economic impact will be very large on the port ecosystem so to say.»

Question 2

Which port actors do you believe that their day to day operations might change because of the introduction of autonomous vessels? For instance, if remote pilotage is introduced, will pilots be affected or agents that might not need to be there because the vessel will communicate directly with the Port Authority, etc. and so they will not need to play a role in between? Any other actors that will be impacted?

Answer

«So for the pilots, there will be a big change, of course. So remote pilotage could be an option, but maybe that's not even necessary any longer. So the question is, will they remain in place? Then we have the tug - boats. They probably also will be maybe done in a different way or with different approach and then we have I think the linesmen or the boats-men. The ones connecting the vessel to the key side. Probably that will, also, be done in a different way,

for example, with magnets. I can imagine. Then the Port Authority. Probably there will be a difference in how they need to communicate with such kind of vessels in order to guide them or allow them in and out of the port. And, of course, for agents, there will also be a difference because you might need to arrange other kind of services around the ship, so I can imagine that maybe you don't need to ask a vessel to collect waste, but maybe you need to have some services or maintenance of the vessel. So you need to have, probably, other kind of services around the vessel when it's in the port and to organize that or maybe the vessel can organize that for itself. That's something we need to see. So probably the agents will be affected as well. And, also, other vessels sailing through or in and out of the port will be affected because you also need to communicate in some way with an autonomous ship, and there will always be vessels which are not autonomous. So how are they going to communicate? So there's also something you need to think of I guess. Maybe, some inspection authorities might also be influenced for when you need to inspect the vessel or something like that. So I think those are the most important ones.»

Question 3

Do you believe that the communication aspect will be, for instance, the main thing, the key to the operation for autonomous vessels like to have efficient, smooth communication with both the nearby vessels and the shore?

Answer

«Well, that's an important part, because as a vessel, you also need to anticipate on what others are doing. So, either the vessels are able to inform he autonomous vessel about their predictive path so that you have, for example, the auto-pilots exchanging information with each other so that you can improve situational awareness. Or you have a sort of maybe people on board of a normal vessel can give information via speech to the autonomous vessel, which it can translate into what that means. Well, maybe with AIS you might be giving a direction or something like that. So that will be important, I would say. But there, also, needs to be communication with shore, for example, the Port Authority, but maybe also with the terminal now where it's headed. Or pilots and the tug - boats and other service providers if they are still in place. So, yeah, it's in most cases due to the fact that a vessel is not calling a port very frequently at least that depends on the type of vessels. If you have a ferry then you know that you have fixed schedules and you go or you come every week or twice a week or maybe even more frequent. But if you are a deep-sea vessel sailing around the world, then you probably call Rotterdam once every two, three months or so. So then you, as a vessel, there's not so

much knowledge about such specific port and it's different in size of the vessel so you will probably always need assistance for sailing in and out of a port. So I can imagine that then communication with the service providers or Port Authorities or other organizations which are relevant to that need to take place to some extent. So that communication between the ship, the vessel and other parties is very relevant.»

Question 4

Are there any companies in the Port of Rotterdam specifically that are willing to, for instance, invest on Shore Control Stations for the operation of autonomous vessels? For instance, shipping or dredging companies in order to control and monitor them via those stations?

Answer

«I know that there are some pilot projects. That you control the ship from on shore, for example. So, if that would become much more common practice, then you probably get sort of control towers where you navigate from a distance with a joystick or whatever through a port, so you don't need to have people on board of the vessel or maybe less people. I could also imagine that, for example, that you have for the Intercontinental lags or the maritime lag you can sail autonomous, and when you arrive at the port you need to have sort of control from a control center. And probably if you're actually dredging companies with sort of a home base in Rotterdam, I could imagine that you have such a control tower or center in Rotterdam. And maybe that's even close to the control center of a Port Authority or those kind of things.»

Question 5

Are you aware of any companies in the port or for instance, like tug companies or like what you said about pilots that might at the moment be investing or looking into solutions when it comes to preparing themselves for autonomous vessels and their arrival?

Answer

«Pilots are, of course, are interested in these kinds of developments, right, because they need to prepare themselves for how are you going to help these vessels. How are you going to facilitate them? But I know, for example, the “Cotech” a tug-boat company, they are doing some projects in remote controlled vessels and they're also interested in smart shipping or autonomous vessels. And there's a company called, I think it's called “The Shipping Factory”, which is developing all kinds of software services to make a vessel smart or maybe even autonomous. And there's also “CaptainAI”, which is developing software, also, for vessels to

be able to sail, well, almost autonomous. So you see that there are different companies either from the technology side, but also with vessels are looking into these developments in Rotterdam.»

Question 6

May I ask a little bit more about your work as SmartPort? Specifically, what is your input and what part of autonomous shipping are you exactly focused on, what's your main focus?

Answer

«Well, the idea is that there are a few, I think, regions or boards trying to focus on these kind of developments. In Rotterdam there are many organizations, also, quite active in relation to the smart shipping and autonomous vessels and SmartPort is actually trying to further stimulate that, these kind of developments are a bit more long-term. What SmartPort is trying to do is to connect companies with science, with universities and research institutes to gain more knowledge on these kind of developments so that it can also bring Rotterdam a competitive advantage and prepare itself for the future. As SmartPort we are trying to connect those kind of things with each other and sometimes also have some sort of thoughts on what kind of research that can be, but the in-depth knowledge is more vested at the research institutes and the companies, of course. So they need to discuss with each other about what relevant research is to bring this a step further. And we are trying to apply that and in the end if technology has been developed also to make sure that this knowledge will be accessible for other companies as well, and, also, share this information with different organizations, and help the ecosystem in Rotterdam advance further in this perspective.»

Question 7

I have reached to the conclusion that there's a lot of technology involved into the preparation for autonomous vessels and that there's going to be a lot of digitalization of operations as well, but there's also still the human element that's involved. At what degree do you believe that the involvement of human element will still be there and whether there will be jobs and let's say, tasks that will no longer be done the same way in the Port, as an ecosystem?

Answer

«I would say that as long as things are programmed by people, they need, also, care or maintenance by people, because you see that what we program a vessel to do or a software to

do then that's it what it can do. So I think we're also sort of in charge of what we want and what we don't want to give away or to make or digitalize or digitize. But I would say that it probably takes a long time before you see a big change. But there will always be people involved for maintenance because a lot of things just can't be done, at least in the near future, I would say maybe remotely, so you can you can have a software update, but if there's a damage that probably can't be fixed by a computer or a robot. Because it's customized, or it's specific, which is difficult to do robots or through IT. So there will always be people involved, I would say and it's up to us to determine to what extent you want to automate or digitize. I think maybe for some ports you could go quite far in automation and all those kind of things, but since shipping is a very international activity, you also need to be able to facilitate that around the globe. Right. So, if you want to visit all kinds of different ports, then you need to make sure that it's also possible at those locations, which are maybe not that advanced to, also, serve those kind of vessels. So, you can maybe fly in a mechanic once in a while if necessary, but also that costs a lot of money. Right. So, yeah, I think that you always need people to some extent.»

Question 8

Do you believe that the context of the work will be the same or for instance, there will be a shift towards more technology related and IT jobs? So, for instance, that there won't be a person that will operate the crane, but there will be a person that will sort of remotely monitor the operation of an autonomous crane in the port?

Answer

«Yes. Or if you need maintenance that could be also different, but also a bit more technology driven or I.T. related, I would say.»

Question 9

Do you, also, think that there will be some jobs that will no longer exist because like the operations in the port are sort of changing and so the workforce needed will be changing as well and the skills and knowledge will also be different?

Answer

«Yes definitely. What I expect is that what you are aiming when you are going to automate things or change things is generally that you are going to adjust things which is repetitive work or which is dangerous work. So those kind of jobs will probably be lost because it's either very boring or very dangerous. So you want to delete those kinds of

activities, right? So, for example, linesmen, that is probably also a bit dangerous work. So I could imagine that technologies will arise to overcome or to delete this work maybe. And then you see that those kind of people are out of business, but on the other hand maybe they will go to service the technology that will facilitate the mooring of these vessels. So, maybe you don't need as much as people, but the type of work, well, will change and to some extent, you'll always have work related to such things. But maybe that is a bit more technology related. So you need to also educate people. That's a big question in general. What are the skills of the future you need for the port of the future? It's very difficult to say. The problem in most cases is that is that you educate people for the skills they need now, but probably don't need any more in 10 years time. So either you need to think about how are you going to educate your people to prepare them or you just need to have lifetime - long learning.»

Question 10

We live in a in an era where technology plays an important role in our lives in general. Especially younger people now are way more familiar with technology like smartphones, etc. So I think it's also, in a way, part of their skill set that they already have and they're moving along with the evolvement of technology as well. As an overall do you believe that autonomy and autonomous vessels and the digitalization in general of the operations in a port will improve the efficiency of operations and will contribute in cost reduction?

Answer

«Well, the new technologies are also quite expensive, so I don't know if it really becomes cheaper. My expectation would be that it becomes a lot more safer. So you will see less accidents and that is, also, very important. Maybe even more important, but yes, sometimes those things come at a cost. I doubt if it really becomes a lot more efficient.»

Question 11

I think if you would like also to conclude this interview you in respect to time as well and if there's anything more, you would like add, please go ahead.

Answer

«You have probably seen the white paper about autonomous shipping form SmartPort. Martijn, also, worked on that. Maybe there there's also an initiative called “SMASH”. I don't know if you've heard about that, which is sort of initiative from the government to promote smart shipping. Maybe it's also good to just maybe you can Google it a bit. Smash, It's called and it's from the Governmental organization on the Dutch infrastructure, and they're also

investigating on how you need to serve this development in the future. What do they need to do in order to make it possible for autonomous vessels to sail through canals, locks, bridges and those kind of things? Do you need to have really smart infrastructure? Or will the vessels become really smart? So that's a big thing, right? If you know what, if you have really big or smart vessels, then you probably don't need to adjust a lot on infrastructure. If it will not be that smart, then you probably need to do something. So that's a big challenge for them, I would say. So, that might be an interesting avenue for you to look at.»

INTERVIEW WITH EXPERT C – FULL TEXT

Question 1

I would like to ask you which do you believe are the main operations in a port that will be impacted from the arrival of autonomous vessels as a new technology?

Answer

One of the main reasons why there is this interest in autonomous vessels is that they are unmanned, without any crew on-board. So, there is no need for crew accommodation on the autonomous vessels. Therefore, there is no crew on – board the vessel to assist in the various operations. So, there are two ways to carry out the vessel operations in the port: one by having people at the, for instance, the berth to assist the vessel and two by automating the operations in the port. For manned vessels, there is need for safety equipment on – board the vessel. So, the plan is to have fairly automated operations on the autonomous vessels. The autonomous vessels that are being constructed and we will be constructed in the future are mainly smaller vessels (such as barges and feeders), because by having smaller vessels you can create more flexible supply chains/ logistic systems in which there is less cargo loaded on smaller vessels that approach smaller ports with higher frequencies. Nevertheless, the technology used for the automation of smaller vessels can be applied to bigger vessels as well. However, smaller vessels benefit more from the absence of crew than bigger vessels. That is one of the reasons why on the present time there is more focus on constructing small autonomous vessels.

This is expected to have an impact on ports and port operations, given that these small autonomous vessels will visit both big and small ports, mainly as feeder vessels.

Regarding the autonomous vessels and its operation, everything needs to be automated. That can happen by either fully automating port operations as well or but, for instance, having people from the port assisting during the berthing of the vessel which is still unclear and will depend on the available technology. The operation of the berthing of a vessel does not have a

high level of complexity and can be carried out automatically by having a good positioning system. Technologies that will enable automatic positioning can be placed on small autonomous vessels, but these are costly. Furthermore, a vessel might need to be equipped with some additional systems such differential positioning corrections for having a correct positioning of the vessel towards the berth, as well as maps that will have high level of accuracy. Moreover, there is a need for the creation of a suitable digital interface between the autonomous vessel and the port that will be more detailed than the existing systems. Mooring systems are needed. Ships will operate with either fuel or electricity or batteries or diesel. Additionally, there will be the need for automated cargo handling. So, in a nutshell all the operations surrounding the vessel will have to be automated but there is a possibility that there will be people on shore assisting the vessel. The 24/7 operation of smaller vessels is an interesting case to look at, because it is not cost-efficient, especially for small ports to have people controlling and assisting their operation 24/7 but have one or two people assisting the mooring process for instance could be helpful. For small vessels, fully automated operations are what is expected to be the reality.

Question 2

I was interested in what you mentioned regarding smaller vessels being easier to make autonomous than larger vessels, could you please expand on that a little bit more?

Answer

The technology that is used is more less the same in both small and big vessels so it is not a matter of easier implementation for smaller vessels. For the smaller vessels there is, at the moment, installation of batteries and high power propulsion systems. When a vessel is being constructed, there is matching between the propeller and the propulsion system in order to have the highest level of efficiency possible in the propulsion system. With electric propulsion, there is the possibility of forming a system where the electric generators or batteries allow to have more power and simplify the manoeuvring of the vessel towards the berth, because with more power it is easier to control the vessel. Electric propulsion, also, allows for the installation of more power in the vessel, without losing efficiency during transit. For instance, Yara Birkeland has twice as much installed power in the thrusters as a vessel would normally have. Unmanned autonomous small and big vessels will use more or less the same equipment, so it is not a matter of easier construction of small autonomous vessels. It I more related to manning cost that is being saved and is more significant for smaller than for larger vessels. «Maersk, they say that for large containerships the manning

costs are around 2% of operating costs and there is no sense in trying to save that much money, but for smaller vessels the manning costs are a higher percentage of the operating costs and, also, the accommodation structure takes a lot space on smaller vessels, so the savings for smaller vessels are significant. This is another reason why smaller ships will be the first to be constructed to operate autonomously.» The driving forces behind the construction of large unmanned autonomous vessels will be more related to operational techniques, such as slow steaming in which case manning costs increase. Smaller vessels are less risky when it comes to damages than larger vessels, as well as economically. That is because it is cheaper to build a small autonomous vessel than a bigger one.

Furthermore, adding more automation on a conventional ship does not contribute in cost-saving the way that an unmanned autonomous vessel does. An unmanned autonomous vessel has to be built from scratch / brand new. So the economic risk is high. This is why there more focus on constructing small unmanned autonomous vessels than big one for the time being.

Question 3

Another important element that unmanned autonomous vessels are considered to have is improved safety, especially regarding the elimination of the human element and subsequently of the human error in incidents. What are your thoughts on that?

Answer

«That point is tricky.» Seafarers are working too much too long shifts, watchkeeping, but it is more about the interface between humans and the vessel and operational commissions. But then again, by removing the crew safety will be improved.

Question 4

Regarding the workforce in the port and the skills that will be needed, do you believe that there will be a reduction of port-related jobs or more of a shift towards jobs related to Information Technology, programming and in overall more technology – oriented job positions?

Answer

This does not happen so much because of the autonomous vessels. This is the development in ports as well. In the big ports there is a lot of automation already, for instance automated and remotely controlled cranes. There is still a long way to go but there is development taking place in automation and digitalization of ports. There will be a shift

towards this direction but not solely because of the autonomous vessels. Autonomous ships will require higher levels of automation. Smaller autonomous vessels will be easier to operate, so there will be a loss of jobs. Nevertheless, this shifting is happening due to the need of automating transport and the supply chain in order to keep costs under control. Ship transportation is the cheapest way of transport, especially for long distances but for short as well. Cargo handling for vessels is expensive. So, there is a need for automating candle handling in order to reduce the transshipment costs. It is difficult for vessels to compete with truck transport, especially in short and medium distances, because they do not have transshipment costs. They just pick-up the cargo from the origin, transport it to and deliver it to the destination. The vessel operation is a little bit more complicated: the truck unloads the cargo, the cargo is loaded on the vessel, transferred and unload it and load it on another truck. In northern Europe, such as the Netherlands, Germany and Belgium there are issues with road congestions that have to be dealt, but due to high transshipment costs, truck transport is preferred. So, there is a strong drive towards automated cargo handling and shipment cargo handling. The smaller ports have a higher need for automation. Moreover, in the port of Rotterdam the container terminals are already highly automated. The feeder vessels in the port of Rotterdam have issues and small feeders do not have priority. The feeder vessels are important, because they transfer the cargo to the final destination, if the cargo is not being transferred by trucks, and they need to be more automated, even in the port of Rotterdam. In the port of Rotterdam, there is a need for automation for the smaller vessels. Large vessels are not in such need in the port of Rotterdam. Automating the process of cargo handling is considered necessary in order to successfully employ unmanned autonomous vessels, but it is, also, expected to be a driving force for other types of vessels. Therefore, automation of cargo handling is foreseen to be realized in the future. However, there is still a long way to go.

Question 5

What about the legal aspect of employing autonomous vessels and regulations?

Answer

Norwegian officials have good cooperation with Dutch and Belgian officials. In northern Europe the agreement (among flag states) is the following: «if you can prove this is safe (autonomous vessels) will not create any problems to you, but you need to prove its safety». Both Belgians and the Dutch are currently working on changing the national legislation in order to allow autonomous inland transport. This process is ongoing, and for as long as there is liner shipping that connects ports between for instance Norway and the

Netherlands and both authorities agree on employing autonomous vessels, then the legal issues can be resolved. The legal aspect of unmanned autonomous vessels is important and it remains an issue that has to be resolved, but (he thinks) that it will not hamper the development and employment of unmanned autonomous vessels. North European countries show great interest in adjusting their legislation and adapting new legislation so as to facilitate the development of unmanned autonomous vessels. So, legislation is not the biggest problem in the process of adapting autonomous vessels.

Question 6

Regarding, again, the port operations, there is this ongoing discussion about Shore Control Centers that might be used in order to remote control and monitor the autonomous vessels, do you believe that Shore Control Centers will be developed and if so what do you believe will be the scale of that development in the ports?

Answer

«It will happen.» In Norway there is a company that is preparing a business case out of it. However, the details regarding the way such centers will be arranged still remain a question. It is more probable that the shipowners or the vessel management companies will be interested in constructing Shore Control Centers for their vessels. This, also, depends on the legislative system. The Master of the vessel is the one legally responsible for its operation and he or she is connected to the owner or the operator of the vessel. So, this link has to be preserved by connecting the Shore Control Center to the Shipowner of the vessel operator company. «I do not think that there will be a Shore Control Center in the port of Rotterdam that will be handling, controlling and monitoring the vessels that will approach the port.» What is expected to happen is that the Vessel Traffic Services that are operated by the Port State will need to have more efficient digital communication with the various Shore Control Centers so that they can have a better control and coordination over the vessel's arriving process. Furthermore, there may, also, be some additional services in the port so as to assist the vessel's operation digitally. For instance, tug operations might be controlled by a local Shore Control Center. Nevertheless, the responsibilities of the Port (Port Authority), the shipowner or vessel operator and the Master of the vessel (as a servant of the shipowner) have to be maintained. Within Europe cooperation is more flexible because there are more options in terms of cooperation within Europe so as to make other arrangements. The first changes might take place in the third legal and liability regimes that already are in place between the

vessel, the flag state, the coastal state and the port and the port operations. Therefore, those entities have to be maintained, but they are expected to be different in the future.

An unmanned autonomous vessel that sails to for example the Port of Rotterdam of the Port of Antwerp, might be remotely controlled by the shipowner via a Shore Control Center located in Norway, but communicating with a local coordination center in the port, or assisting services or sensor systems. There are a number of possible configurations and that makes it a little bit difficult to foresee the way the Shore Control Centers will be developed.

Question 7

You mentioned that for instance there will be one control center located in Norway and all shipowner's vessels will be remotely controlled from there?

Answer

Nowadays, a large number of vessels are managed by ship management companies, so the shipowner hands over the management of their vessels to ship management companies. In Norway there is a company named Massterly, which is a cooperation between Kongsberg automation and Wilhelmsen Ship Management operation which have management services and Wilhelmsen Ship Management is managing a couple of hundred vessels. This is considered a logical way of developing a Shore Control Center by combining traditional ship management operations with technical knowledge on how to control the vessel. So, every entity (the Port Authority, the shipowner etc.) will retain their responsibility and liability in case of an event taking place.

Question 8

Are you aware of any estimations related to the costs of developing a Shore Control Center and autonomous vessels?

Answer

«Yara Birkeland is a great example. It is the first vessel of its kind.» Building an autonomous vessel is considered to be quite expensive. «For Yara Birkeland, the construction of the vessel costed around 33 million euros with 7 million Euros spend on the batteries, which is a high amount for this kind of vessel (a small container vessel).» It is quite difficult to estimate the cost. «Operators on inland waterways are claiming that the costs of an unmanned autonomous vessel will be about the same with a conventional vessel», because you save money from removing the accommodation but there is a lot of money that have to be invested in electronics and communication equipment on board the vessel and so the price of

these vessels will be about the same. Hull and machinery (engines) contribute the most in the total cost of building a vessel, while electronics are a small part. Small autonomous vessels will not be more expensive than bigger vessels. That, also, depends on the number of vessels that are being handled and controlled by a Shore Control Center. If you have a big Shore Control Center that operates 24 hours a day for 7 days a week to remotely control and monitor only one vessel, you will need at least three shifts of a two people personnel and that is not cost – efficient.

Shore Control Centers are considered to be developed more as a service, in order to be a more attractive choice than having crew on-board the vessel from a cost saving perspective. Autonomous vessels will not necessarily be cheaper in total costs than conventional vessels. One of the main driving forces for the development of unmanned autonomous vessels is flexibility. It will be a cheaper option not to operate a small vessel 24/7 because night watches are expensive. Autonomous vessels allow for more flexibility and better use of services, because they allow for 24/7 operations and higher frequency. (He thinks that) it will not be cheaper to replace a conventional with an autonomous vessel. Costs are not the main driving force, but the new type of transport systems that are emerging.

Question 9

Do you believe that autonomy applied on port and vessel related operations will improve the efficiency of the transport and logistics systems?

Answer

That will not happen necessarily for the big vessels, because they are already highly automated, but smaller vessels will benefit more from higher levels of automation, as well as smaller ports. The issue that arises is the high costs of automating cargo handling. Having big cargo cranes that are expensive. So it is, also, a matter of reducing the costs of cargo handling equipment. «We have a new project that looks into ways to automate cargo handling in small ports in a cost-effective manner.» The big cranes are too expensive to be installed at small ports.

Another interesting concept is that of higher standardization of unit carriers. In Norway there are a lot of 45 feet containers used and they are normally put on a trailer or truck for their transfer. This size of containers is considered more efficient than the 20 feet containers for truck transport. 45 feet container is not always an optimal solution, because it cannot be fully loaded always, but is an optimal solution for the cargo handling operations. Cranes will not to be configured to handle all the types of containers such 20 feet, 40 feet and 45 feet if

everything is standardized. 40 feet containers have to be placed on bigger vessels and that is more expensive. Standardization will allow for a reduction of the cost for cargo handling. Moreover, there should, also, be a limit of for example 20 ton or so, on the maximum container weight so that the cargo handling equipment will be much cheaper. The maximum weight today is something more than 30 tons but most of the containers weight less than 30 tons. So, if there is automated cargo handling for, for instance 20 feet containers, then the related cost is being reduced and it can be lower than the cost related to a non-standardized size, for example 45 feet.

Standardization will be one of the key factors in the process of automating cargo operations and in the adaptation of autonomous vessels.

Perhaps, also the small vessel should be standardized for inland waterways such as barges and feeders for instance at the Fjords. For example, having a standardized small type of vessel that can carry 40 containers that would allow for everything to be standardized, the reduction of costs and easier replacement of barges. That would have implications for the ports.

There a lot of different types of cargo and commodities such as containers, dry bulk, liquid bulk and general cargo that create complexity in the port operations. Ports need to be equipped to handle all these different types of cargoes and that might create difficulties in the automating process.

«Future standardized handling of cargo is a very interesting case to look at.»

Question 10

Does there have to be standardization of the language used for the communication between the autonomous vessel and the port, for example the ETA differs from port to port, in order to achieve seamless and efficient operations at any port?

Answer

There are developments in that field. «I expect that that will happen quite soon, in a couple of years.» In this field, everything has to be automated and standardized as well.

Question 11

What about the use of blockchain and electronic contracts that enable safe electronic transactions?

Answer

Blockchain will not be used in certain operations. The use blockchain is very interesting for the cargo – related papers and documents such as the Bill of Lading, because they are often negotiable. So, in their case there is a need of mechanism that maintains the transactional information, an aspect in which blockchain is very good at. However, regarding standard electronic documents between parties, electronic signature is a better fit, given that it is less complicated. The issue with signatures is its association with identity and blockchain cannot give you that. In the blockchain technology, there has to be a centralized authentication server for the documents. So, in order to get authentication, there is a public key infrastructure. Therefore, blockchain is not suitable for all the processes related to the vessel, but for instance is good for Bills of Lading and other vessel certificates. For some messages, electronic signatures are more than enough.

Question 12

Regarding the port operations and specifically pilotage, do you think that we will see more remote pilotage in the future?

Answer

«I think that that will definitely happen in the future for independent autonomous vessels», because in principle it is a better solution, but there has to be the appropriate communication infrastructure and information systems (from the ship to the pilot) to support it. There have been some trials carried out and with the extant technology it is easy to do.

Question 13

Do you see autonomous vessels will be very frequently used in the proximate future (five years from now) and being commercially attractive as an option/investment?

Answer

«Yes.» In Norway there is the Yara Birkeland project and there is, also, another project coming up with a small type of vessel. In Belgium a waterway project that will most likely illustrate autonomous operation within five years from now. It will, still, be at a small scale due to the time needed to convince people for its safety and viability, but it is expected to evolve very rapidly. Yara Birkeland was set to sail next year, but there were some issues with the port infrastructure that lead to a delay of the project. «It is a bit complicated getting the port to work properly.» However, they hope to see it sailing by the year 2022.

There is a need, especially for the smaller ports, to keep up with the advancements in autonomy so as to be able to facilitate autonomous vessels and be an efficient node in the

transport chain. The Yara Birkeland autonomous vessel will provide dedicated services between few specific ports. Ports and even terminals are generally aiming at not having any special infrastructure at all but directly load/unload the cargo on the vessel with the vessels equipment and pick up the cargo directly from the key-side. So far, it is evident that autonomous vessels will require a handful of special services in the port, communication and positioning facilities. So in the short-run the autonomous vessels' services are more likely to be dedicated. Inland transport entails a number of unloading places on the key-side and so for example, it is possible today to deliver the cargo directly on the key-side with the automatic cargo handling equipment of the inland waterway barges. It depends a lot on the transport service.

Question 14

Is there anything more you would like to add?

Answer

All of these developments will be driven by business models. There will be technological developments that will aim at satisfying the requirements of the operators, but they will impact port operations as well. For big ports, like the Port of Rotterdam, there are some issues regarding the possibility of carrying out transshipment operations for instance from big liner vessels to inland waterway vessels like feeders in a way that is more efficient. Who is going to develop such technologies and systems and what will be the requirements. One of the key drivers for the inland waterways is the need for utilizing smaller ports in order to save money from bigger ports in port fees. «Autonomous vessels can be considered as a disruptive technology in the sense of developing new types of transport systems and challenging the existing ones for both ports and operators.» Many projects that are focused on the new technology of unmanned autonomous vessels are being carried out by cargo owners and logistic companies and not shipping companies that operate conventional ships, because they can grasp the emerging business models that are escaping the traditional business models. Subsequently, the development of new business models can cause issues to the ports by reducing traffic in conventional ports. It is of extreme importance for the ports to realize that there are changes taking place in the business models and they will have to adapt to them in order to be safe, from an economic perspective. This might take some time, but it can happen quite fast. Ports are a very significant connecting point in the supply chain.

Downsizing ships can be beneficial, also, for deep-sea vessels. «I think that the large containers vessels that are employed at the moment (20000 TEUs or so) are not logistically

efficient enough, since they can sail only once a week for instance and they can call only extremely big ports that are, also, expensive.» «My question would be: Would it be more logistically effective to have smaller ships, for instance a couple of thousand TEUs, sailing more directly and not relying on feeder transshipments?. The value of the global fleet is estimated around a hundred billion dollars or so, which about the price of Amazon.» Therefore, if these logistics giants decide to build a fleet of small vessels they can do it very fast because they have a lot of capital and then that would negatively affect big ports such as the Port of Rotterdam.

«Inland and short-sea shipping will be a driving force of change.»

INTERVIEW WITH EXPERT D – FULL TEXT

Question 1

What are the regulatory challenges of employing autonomous vessels?

Answer

The current regulations require the presence of at least one captain on-board a vessel. When it comes to autonomous vessels, that is considered to be a little bit difficult. It might take some lobbying influence in order for regulation to change and include autonomous vessels. There is, also, a lot of communication happening between vessels and between a vessel and the shore so that raises the question: «How can you respond to an autonomous ship as a human being, how do you know its intentions, how do you know where it is going?». These issues have to be resolved and this is considered to be a challenge.

Question 2

What about the technical challenges?

Answer

There are issues to tackle. In order to control the vessel one needs to be aware of the motions and the waves effect. They use a simulator for this purpose. A human, also, uses their perception so as to understand a situation, so cameras and radar can be used in order to be able to detect water, the key-side, boats, waves, and objects in the water. The vessels have to be able to detect and avoid such objects. Prediction is, also, very important. For instance, prediction of the intentions of other vessels. A captain can have an idea of what another ship might do and they can also verify its intentions by communicating with the captain of that

vessel. Such situations are considered challenging for autonomous vessels. So, prediction, perception and motion planning are considered challenges for autonomous vessels.

Question 3

Is your software being used only for navigation purposes or for more operations such as berthing and un-berthing of the vessel and the work of linesmen?

Answer

It is mainly used for the voyage of the vessel but it is, also, used for optimizing berthing operations. However, such operations need to be researched further because there are issues arising that need to be resolved: port infrastructure such as magnets that can assist in the mooring of the vessel instead of using boats.

Question 4

So far on what type of vessels have you installed your software?

Answer

The software has been installed on vessels that operate within the port of Rotterdam and are: a water taxi, a survey vessel, a port commission boat and another vessel, so four boats in total.

Question 5

So, they are smaller vessels?

Answer

«Yes.» At the moment the software is been installed on vessels that are active in the Port of Rotterdam and not for instance on big containerships.

Question 6

Does the software operate on its own or is there a need for assistance from, for instance, a real captain or from an operator that knows how to work with the software?

Answer

The software is basically an autopilot so it can operate on its own but then there is the Captain that is in charge and can engage and disengage autopilot whenever he likes. So the Captain is still in charge but the autopilot can handle many situations on its own.

Question 7

Can your software be used by the Port Authority or other companies in the port ecosystem and not only by shipping companies?

Answer

«Yes.» The Port of Rotterdam believes that the route planning that is part of the software that they are developing is very useful. «When go somewhere with a car you use Google Maps and you put origin and destination and it shows you the route. Our company's system does that on the water.». They are developing such technology that can, also, be useful for the port. In the future, by knowing the routes of all the vessels in the port area and have an "helicopter" view of all the vessels and where they are heading and that can increase the possibilities of predicting whether an incident is going to happen or not and even prevent it from happening. A comparison can be drawn between our developing technology and the robots that are used in warehouses and their algorithms. One algorithm has the ability to control all the warehouse's robots, so that can also happen with the vessels in a port in the future. They could be controlled by one algorithm that would control their routes and movements so as to mitigate the risk of accidents happen, as well as prevent them from happening.

Question 8

Are you planning to develop software for autonomous operations on the port side as well, for instance autonomous vehicles that transfer containers?

Answer

«No. We only focus on the water».

Question 9

Do you see your software being scalable in the future, being used by larger vessels and for deep-sea voyages?

Answer

They are aiming at developing software that can be applied to various types of vessels and that is scalable.

Question 10

Anything else you would like to add?

Answer

«Autonomous does not mean unmanned.» Vessels might carry out voyages autonomously by algorithms but there will be crew on-board for purposes such as maintenance, assistance in mooring operations and when an intervention is considered necessary. In this way saving in costs can be achieved, when you only have manning for emergency situations. That is considered to be the biggest advantage for the port. It can happen pretty soon because not all the crew will be removed from on-board an autonomous vessel.

Question 11

Do you believe that there will be Shore Control Centers where remote operations will take place?

Answer

«Yes, definitely.». Probably for a start the Centers will control the movements of vessels from one side of a terminal to another (very short routes) autonomously and the Shore Control Center will have an overview of those vessels. «I am quite sure that this will happen.» Sailing fully autonomously from for instance Singapore to Rotterdam is not considered to become a reality any time soon because of the maintenance needs on-board such vessels. «I believe that autonomy will happen but locally.»

Question 12

Regarding remote pilotage of vessels, do you see that happening in the future?

Answer

«I do not think that remote piloting will happen.» The vessel can be remotely controlled when sailing for instance overseas and when it enters a port a pilot can embark on the vessel and guide it in the port. It is considered challenging for a computer algorithm to guide a container vessel in and out of a port. It might happen in the future but it will not be the first thing that will happen.

INTERVIEW WITH EXPERT E – FULL TEXT

Question 1

Would you like to share your opinion on autonomous vessels with me?

Answer

The percentage of costs of having people on board compared to the costs of building a ship is a relative small amount. «I do not think that trying to automate something that has a marginal impact is a good approach. I struggle to find the business case for autonomous vessels.»

Question 2

So, you believe that they will not be an attractive option for the future of shipping companies?

Answer

«Yes.» Unless someone explains to him what the business case for autonomous vessels is, for instance how many millions per day can be saved on a containership, but if you look at the number of people on-board and compare it to the vessel's costs for their handling operations, the bunkering operations, the fuel, it is very difficult to define the business case for autonomous vessels.

Question 3

It is expected that smaller vessels will be the first to become autonomous, what is your opinion on that?

Answer

Smaller vessels operate in much more restricted areas than larger vessels and they sail from port to port quite fast and to be able to navigate an autonomous vessel through a crowded port is considered to be very challenging. From a technological point of view everything is considered possible and doable when you have enough sources like time and money, so that is not expected to be a challenge. The business case is what needs to be defined.

A number of activities on-board a vessel are connected to administrative tasks, such as providing documentation, carrying out physical inspection of cargo by authorities and for such activities you need to have people on-board the vessel. Therefore, it is not only the navigational aspect of a vessel that needs to be automated, but also the administrative operations in order to reduce 5the number of people needed on-board. Authorities request for certain documents in a paper form on-board the vessel and they will board the vessel in order to check that document, there is the possibility of digitalizing everything but the need for on-board crew still remains. So (he thinks) that for autonomous vessels every interaction that the

vessel has with the various parties has to be fully automated and that is the main complexity of employing an autonomous vessel.

The autonomous navigation of such vessels is being emphasized, but the question that arises is: «Can they administer themselves autonomously?». In barge shipping, there is a big amount of paperwork produced (he doubts) that the savings will be significant enough.

Question 4

There is a paper that discusses the use of Blockchain and Public Key Infrastructure technology for the document-related vessel operations? What are your thoughts on that?

Answer

They work on the electronic Bill of Lading with Blockchain. The amount of documents that are being produced in international and by authorities is «mind-bondling». «I think that in order to reach a point where we have autonomous vessel, everything surrounding the vessel's operation has to be digitalized in order to remove the crew.»

Question 5

Since you are, also, working on renewable sources of energy and the energy transformation of ports, do you believe that if there are autonomous vessels in the future they will contribute to that if, for instance, they are powered by electricity or LNG that have lower emissions?

Answer

«I think that electricity might be a solution for barges and the inland transport not for the deep-sea voyages, because in inland transport it is possible to change batteries quickly and use batteries that have the form of a shipping container and situated around the river in order to change batteries and not necessarily recharge.» There are possibilities, also, for deep-sea vessels to employ a hybrid energy system where thy use electricity when in the port and then switch to a combined propulsion system of diesel and electricity in the future. However, it is considered challenging for large deep-sea vessels to rely only on electricity because the amount of battery capacity that needs to be on-board is big. For example, if the vessel sails past the Cape of Good Hope then it has to have substantial amount of energy stored in the batteries. So, it is not foreseen that in the next 10-15 years deep-sea vessels will be powered by electricity solely, but a hybrid situation is considered possible.

Question 6

Is there anything else that you would like to add with respects to the technology of autonomous vessels?

Answer

«I think that the navigation aspect is the easiest to automate and there is a lot of researched carried out in this field, but this is not the real challenge.»