Teaching Human Reasoning to Artificial Intelligence in a Maritime Context: the convoy method

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Master's thesis

Master of Engineering, Autonomous Maritime Operations

Turku 2021

MASTER'S THESIS

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Degree Programme: Autonomous Maritime Operations
Specialization:
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Title: Teaching Human Reasoning to Artificial Intelligence in a Maritime Context: the convoy method

Date May 28th, 2021 Number of pages 61 Appendices 1

Abstract

Artificial intelligence (AI) is a complex system that requires the right approach for education. This thesis aims to propose a new idea of a learning environment for autonomous vessels. In other words, developing the convoy method based on the "mother" and "daughter" relationship inside the safe transit corridor. The purpose of the thesis is to research how suitable is the combination of convoy method approach inside the safe transit corridor. In other words, is a safe transit corridor a good option for the learning environment of AI, and in which regions this could be implemented.

Qualitative research and interviews were selected as the method for this thesis. Participants were interviewed individually via Teams. Firstly, a description of the proposed learning method was presented to them. The object was to familiarize them with the components, elements, and techniques of the proposed learning environment. Then all interviewees were asked the same questions, and they had the freedom to express their own opinion about the presented method.

The idea of this kind of learning environment received positive feedback. As a result, it was discovered that participants support the further development of the concept and would be glad to see it happening. Some aspects regarding the advantages and disadvantages of implementing the convoy method approach inside the safe transit corridor as the learning environment for AI were discussed. In conclusion, this idea of the learning method approach could become a starting point or provide the readers with new ideas.

Language: English
Key words: autonomous vessel, convoy method, artificial intelligence, mother, daughter, safe transit corridor

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1 Introduction

The shipping industry has seen many changes over the years. The discovery of new lands, migrations, technical revolutions, and other issues made the maritime sector an area requiring broad skills and knowledge. The ability to learn fast and adapt to a constantly changing situation is also essential for supporting technical development. The maritime industry has witnessed the ups and downs of world economics, but the need for highly qualified specialists with colossal experience has always been a top subject.

The idea of autonomous shipping is the future, but it will take time for society to accept the changes brought by automation. Shipping is becoming more automated, and celestial navigation is not the only method to define the position and course of the ship. Appliances like Automatic Identification System (AIS), Global Maritime Distress and Safety System (GMDSS), and Electronic Chart Display and Information System (ECDIS) have been accepted within an industry and the society. The ongoing digitalization will also impact the maritime sector. Autonomous shipping is one example of digitalization and will be obtained when all the systems are tested and verified as support tools. There is a necessity to find the best solution for developing this area, and artificial intelligence (AI) plays a significant part in autonomous projects. New technology will also bring questions on how to teach AI and define possible decision parameters to implement.

Technology development and constant changes are part of our everyday life. This is why the International Maritime Organization (IMO) has foreseen the fact that autonomous shipping coming is inevitable, and Marine autonomous surface ships (MASS) became a subject of the IMO agenda in 2017 (IMO, Autonomous shipping, 2020). The technology is developing much faster than the legislation, but both need to be aligned. Ships with different degrees of autonomy already exist and bring gradual change to the maritime industry.

Numbers cannot measure the meaning of good seamanship, and this is much more complicated to explain. In this Master's thesis, the goal is to analyze whether teaching artificial intelligence features of human behavior by a convoy method inside a safe transit corridor could become a successful idea. Humans are not so successful in multi-tasking, but it is possible to use their knowledge where machines are not so competent (Porathe & Rødseth, 2019). Furthermore, seafarers with great experience are sometimes unable to define the proper definition for good seamanship. Sailing of a vessel is most of the time improvisation, and seamen believe that "a well-run ship is a silent ship."

1.1 History of the shipping industry/premise

People always have travelled by sea for a long time. Goods have been regularly transferred, new continents have been explored, and a search for better living places conducted. The world has seen few major shipping revolutions. The first one was a conversion from sail to steam, which had a significant global impact on the industry. The second was changing the power source from steam to engines powered by diesel oil, which made it possible to create fixed schedules and timetables. (Miller, 2012)

From that moment, the shipping could be divided into two: liner and tramp. Liner shipping is a process when goods are transported by ships, mostly containerships and Ro-Ro's, that operate on regular routes on fixed schedules (World Shipping Council, 2021). Tramp shipping vice versa are operating without a fixed schedule or while visiting ports picking up cargoes as they become available and usually carry low-value materials for which inexpensive transportation is required (The National Archives, 2021).

The third change was containerization which could be called a revolution of standardization (Miller, 2012). In the 1960s, this was a huge step forward, and this change impacted our life until the present. Many goods are transported within the containers, they are simple and easy, and the standard containers are 20- and 40-feet long. Nowadays, the transportation of containers is considered to be the most common way to transport cargoes by sea. Undoubtedly, shipping has changed from national to international with a worldwide perspective.

'*The standards of construction of ships are supervised internationally on behalf of governments (flag states) and shipowners by classification societies. Other commercial organizations that exert influence and have rules binding on their members are the many Protection and Indemnity (P&I) clubs. In addition to international bodies, there are regional organizations, including the European Union (EU). Finally, there are several non-governmental organizations (NGOs) which act as pressure groups in, for example, marine environmental protection and human rights'* (Couper, Walsh, Stanberry, & Boerne, 1999).

The capacity of cargo was growing, and the types of goods started to vary. Ship sizes are changing, and bigger and bigger ships are being built. In the last few years, the tendency has changed, and the capacity has become more important than the ship size. The changing of the ship types of ports and infrastructure have also been revised and restructured.

Ships have been designed for various purposes and therefore are capable of carrying different cargoes. Mainly ships are used for the transportation of passengers, cargoes, and other particular purposes. The more detailed view within this thesis is to be put on the cargo transportation possibilities.

The process of digitalization is also known as a fourth or, by some assumptions, fifth revolution. It may seem unbelievable, but still, the reality shows that a lot of processes and actions could be done more appropriately. Because optimizing port operations are much more than just reducing human fatigue. Shipping routes and speed may be optimized to not to wait at the anchorage area or to burn a large amount of fuel and pollute the environment etc. The just-in-time principle could have its point because at present it is not working well in the shipping. (Alop, 2019) Not speaking of other systems and areas which had a significant impact on digitalization, like the opportunity to use only the positive and effective processes of digitalization. Sometimes decisions may be complex, and it takes time to adapt them for use.

Since 2020 the times have been challenging due to COVID-19. Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered coronavirus (WHO, 2020). The pandemic situation created a hole in the maritime industry. The disease is dangerous and spreading too quickly within the crew and passengers in an enclosed system. The largest known outbreak took place on a cruise vessel Diamond Princess (Dahl, 2020).

Asymptomatic crew members or passengers could still infect others without knowing it. To eliminate the spread of the virus, lockdown is the best possible option. Thinking positively, showing the world the need for an alternative approach. Difficulties with crew changes due to travel restrictions, long time at anchorage before entering to port, self-isolation, and even quarantine because of the infected persons. All these problems had their issues starting from the beginning of the 2020 year in the Asia region and spreading worldwide.

Problem-solving is located next to us: autonomous ship implementation in our everyday life could also become an appropriate solution in epidemic and pandemic cases. Goods will still be delivered to the port of destination, and the cargo could have been loaded or discharged without human interference. Viruses that affect humankind's health do not have a direct impact on the technologies.

Technology discussions lead us to the autonomous ship concept. The term ‘autonomy’ means the ability to make various decisions without being controlled by anyone else.

(Cambridge Dictionary, 2020) We can train AI through mathematical calculations using complicated equations, but the more significant challenge is to make it understand the human's way of thinking. As long as seafarers are onboard vessels, it is hard to predict when the vessels will be fully prepared for completely unmanned voyages and in which regions.

Thus, levels of autonomy are subject to disputes and different options. There are various proposals from IMO (see Table 1), Gard, Lloyds Register, Norwegian Forum for Autonomous Ships (NFAS), etc. They all have their point, but it would be beneficial to agree on the only version that others will use. Certain autonomy levels must be standardized before these vessels are going to sail in global terms. It needs to be kept in mind that autonomous is not the same as unmanned. Still, shipping can also include, e.g., a vessel with automated operations, remotely controlled with or without seafarers, and as a final result, it could also be unmanned. Taking this opportunity, the IMO version of autonomy levels for Maritime Autonomous Surface Ships (MASS) is presented below as an example of possible agreement in implementation (see Table 1).

Just to be clear, at this point, we do have conventional vessels operating as per degree one, and even degree two was tested under the Project SVAN (Safer Vessel with Autonomous Navigation) with the use of car ferry *Falco*. Moreover, in 2018 the Rolls-Royce, in cooperation with Finferries, also presented automatic course alterations to test the collision-avoiding system, and the automatic docking was performed without any human intervention (Rolls-Royce, 2018).

There are more plans in Norway regarding the ship *Yara Birkeland*. Initially to be the first-degree vessel and then proceed to the fourth-degree level. Conventional ships could be divided into two major sub-groups: with increased automation/autonomy and the second one with increased digitalization. As a result, the ships of the future likely to be autonomous or either smart ones. (World Maritime University, 2019)

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

Table 1. Proposed levels of autonomy according to IMO (IMO, Autonomous shipping, 2020).

Smart vessels exist already now with a crew on board, including aids for handling the ship. In particular, ECDIS, radar, 'elephant ears' (sound reception device), electronic logbook used by navigation officers. These technologies make a life of a seafarer simpler, and he/she monitors the information available. In other words, human-machine interaction is present. Moreover, more complex methods are used by shipping companies or ports such as Light Detection and Ranging (LIDAR) equipment or even vacuum/magnet auto-mooring systems shown in Figure 1. Examples of present technologies are confirmation that a long voyage is ahead, and preliminary ideas are done so as technologies are ready for future development.

To perform testing of unusual autonomous ships, special operation areas are created already or planned for future testing. Areas are a must to check the correct functioning of the systems and technology. Safety aspects and the reliability aforementioned have to be guaranteed. "Jaakonmeri" test area is located in the coastal area of Finland and can be used by all organizations and companies to test MASS. The area is operated by DIMECC Ltd. (One Sea. Autonomous Maritime Ecosystem., 2020) There is a second planned area in Norway probably to be used for *Yara Birkeland* voyages. It is located between Herøya, Brevik, and Larvik, but the maritime transport route does not yet exist (World Maritime University, 2019). There are more areas in the other countries available for specific test matters (International Network for Autonomous Ships, 2019).

Figure 1. Vacuum automated mooring application in use, Megastar (owned by AS Tallink Grupp) alongside in Helsinki West Harbour, Terminal 2. (Cavotec, 2018)

Maritime education has been one of the most discussable topics over the last few years in transportation services. Training and courses have always been a part of a seafarer's life. The program of maritime universities all around the world needs to be reviewed and adapted into a new reality. Still, it must be done following the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW). The older generation may be having difficulties, but the younger ones are in complete readiness for life-long learning. As time goes on, it is more time-consuming for older people to adapt, accept and keep up with innovations.

The life-long learning method has been identified as an essential element for success in the era of the fourth industrial revolution (Gleason, 2018). People have to make co-operation with machines, and this is one of the examples of human-machine interactions of the future. This feature can make people suffer from technostress. This is the condition resulting from having to adapt to the introduction and operation of new technology, mainly when equipment, support, or the technology itself is inadequate (Davis-Millis, 1998). It is a fact that technostress is a severe disease which has to be dealt with. Good training and sufficient rest time could become an option for how to deal with this disease.

1.2 Statement of purpose, research questions, and work

For the past few years, autonomous vessels' subjects became popular, and various research, thoughts, and ideas had their place for existence. Technology is developing faster than legislative aspects. Trials were planned and held in different countries, e.g., Finland, Norway, the People's Republic of China. Confirmation that the autonomous vessel concept has its spot in the future of shipping became apparent. It is worth noting, though, that not all challenges have been solved. Therefore, it is necessary to make an effort and continue offering new learning opportunities based on the human experience. In this case, it applies to AI-based technologies.

At the present point, it is crucial to mention that this particular thesis's economic point of view will not be considered. It could nevertheless become a starting point for someone's future thesis. Further, at this stage, the question and economic feasibility aspects are excluded from this thesis.

This is why this thesis does not contain information regarding digital twin technology. Digital twin technology is not only using human theory and knowledge to build virtual models. Still, it can also use virtual model simulation technology to explore and predict the unknown world and constantly inspire innovative human thinking (Wang, 2020). It is an entirely different approach, and the idea involves into consideration only one way of teaching an autonomous vessel that can be used further for the development of AI technology.

The initial purpose of the thesis is to create a new approach to prepare AI for future training. Demonstration of the "mother-daughter" relationship combines few methods that are currently used to train vessels using the convoy method. Moreover, the special focus will consider the concept of 'good seamanship' and not only be guided by the numbers and mathematical calculations, but this is also a different kind of approach for teaching AI.

To find out how efficient this idea is it is essential to conduct interviews with qualified experts with maritime backgrounds amongst seafarers, Vessel Traffic Service (VTS) operators, and maritime administration personnel. A certain number of persons have been involved in interviews to get feedback from various angles.

Implementation of convoy method inside the safe transit corridor requires close cooperation with various parties, e.g., the crew of 'mother' and 'daughter' vessels and other ones in traffic, local VTS, and remote operation center team. The convoy's movement will be monitored by different people, which allows analyzing the situation thoroughly, and in case of danger actions will be taken immediately. Moreover, the convoy will proceed in a safe transit corridor, which prevents it from deviating from the planned route. The VTS will transmit a schedule for convoy passing on channel 16 in advance, and additional information will be transferred to whom it may concern. All of these topics will be reviewed more accurately in the following chapters of the thesis.

Investigation of this idea by using the convoy method to train a vessel human behavior at the same time is a challenge. The possible implementation of this thesis idea could protect the shipping industry. This may be the best way to perform practical training of autonomous ships in the open sea in a safe manner to achieve future goals.

The research questions for the thesis are the following:

1. How suitable is the implementation of the convoy method approach inside the safe transit corridor for the training of AI?

2. Which locations could be chosen for the safe transit corridor application?

1.3 Structure of the Thesis

This thesis consists of seven main chapters with subchapters. It is divided logically to familiarize the reader with the subject in the most convenient way, clarify the difficulties and present a new learning method.

In Chapter 2, the previous research is presented to track down similarities or the elements of the future idea. Moreover, the area with a suitable location regarding this thesis is presented in subchapter 2.1.

Chapter 3 presents the new learning environment and a possible method for teaching vessels AI. Components and the elements of the feature of the idea presented in subchapters 3.1 to 3.9.

Chapter 4 takes us back to the theory, in this case, the methodology. In this chapter, the method chosen is explained as well as the data collection, selection, and processing procedures. Moreover, ethical issues are mentioned.

Chapter 5 presents the empirical study part. The preparation process for the interviews described along with the basic information about the participants is described. Some interesting answers are shared, and the analysis of the other responses is presented after them.

Chapter 6 takes us to discussions with a summary and recommendation regarding the presented idea. Further research part makes it possible to share the most probably actual subjects for extended studies in the future.

Chapter 7 presents the conclusions where the author is answering the questions posed in chapter 1 and sums it up by analyzing the research process and thesis writing.

The references and abbreviations are available after, and the thesis is concluded by the annex.

1.4 Suggestions on the possible implementation of the idea

The idea is to use a conventional vessel as the ‘mother’ vessel and an autonomous vessel as ‘daughter’. These two vessels are not going to be connected in one unit in a conventional way. Their connection to be performed in a digital way; cameras will be used to observe the situation around them and sensors for assessment of situational awareness. Both vessels in convoy are going to be sisterships, built as per one project, which will give us a possibility to standardize them as it is the aviation industry. The ‘mother’ vessel is manned with a qualified crew on board. Responsibility area is familiar to crew members: bridge and engine teams know exactly how to do their work safely and where is a “no go area” for particular cases.

However, the ‘daughter’ vessel is to be autonomous and will remember/save all the actions performed by the first vessel to navigate safely. The ‘daughter’ vessel will have a crew on board at the beginning and later possibly controlled by the remote operation center team member who will only monitor actions and take over control if necessary. The vessel can become autonomous after a certain period of testing, but it must be approved by the appropriate organization. The “daughter” vessel will learn from the first one – this means that she is going to perform the same maneuvers and other actions as the “mother” vessel. In other words, she will act precisely as the Officer of the Watch (OOW) or Master of the “mother” vessel does.

Both vessels will use a safe transit corridor which has to be marked in ECDIS and on paper charts. The Local VTS will assist in maintaining communication between the convoy and other sea traffic participants. Actions to avoid collisions according to COLREGs must be taken into account, and the data can also be used later to perform the teaching of AI. The latter will show the ability of the system to make decisions remembering the previous experience.

2 Previous research

To define a new safe transit corridor, the area should be thoroughly explored. When it comes to research, respect should be shown for nature and the environment. Moreover, various cultures living in that environment must also be respected. Their opinions must be heard to come to a consensus. A similar approach is used for exploring the possibility of new shipping corridors in the Canadian Arctic. Inuit living there have a better understanding of natural behavior and animals' migration. They are aware of the chokepoints in the archipelago. This culture not considering ice as an obstacle but, on the contrary, uses it for a benefit as a road between two lands or even as a place for living. (Aporta, Kane, & Chircop, 2020) This case shows how important is the analysis of the area when changes are planned to be made, e.g., the corridor for shipping use.

The corridor can be seen as a transport road that connects cities and other settlements. Transport units are driving along a certain lane in a given direction. They are allowed to change the lane and perform an overtaking maneuver. They must also keep a distance when they are following someone or driving in a row. In this case, the concept of platooning. This concept is defined as a collection of vehicles that are travelling together and being actively coordinated in a formation on public motorways without making any modification to the infrastructure. Communication technology between vehicles (V2V) is used in platooning operations allows sharing of local vehicle signals, e.g., speed and data from sensors among the vehicles in the platoon. These signals are used further in the control algorithms of the platoon. The platoon is a system that senses something, then controls the algorithm, and shares the data for the communication of all vehicles. (Bergenhem, et al., 2012)

All this started with PATH research on automated platoons. PATH is a California traffic automation program that includes platooning. The first test took place in 1994; a four-car platoon with 4m distances between them was tested on highway speeds. Recently the PATH is focusing on heavy trucks. (Bergenhem, et al., 2012) The experiments are showing that even the fuel consumption for the first truck and other ones could be saved, for 5% and 10 to 15%, respectively (Browand, McArthur, & Radovich, 2004). Experiments and tests performed on land could be helpful when implementing a similar approach at sea.

The MAXCMAS (MAchine eXecutable Collision regulations for Marine Autonomous Systems) project started in 2015. The intention of this project was the demonstration of the navigation concept of an autonomous vessel. As stated by Varas et al. (2017), this concept will allow the maritime industry to introduce this project as a business case. For this matter, COLREGs had to be interpreted into specific collision-avoiding algorithms that will be understood by the machine. Machines are not capable of behaving like human beings. Still, after the project, there are more future directions to work on. For example, the interaction of manned and unmanned vessels has to be studied further. Nevertheless, this is one of the projects which took the phenomena of autonomous shipping in the manned shipping environment close enough to assume it like a business case. (Varas, et al., 2017)

The vessel train (VT) concept is developed and takes its idea also from the platooning method already mentioned in this chapter. This is planned to become a semi-autonomous one and consist of Leader Vessel (LV) and Follower Vessels (FV). (Meersman, et al., 2020) According to Meersman et al. (2020), the concept is taking into account inland navigation on a route Antwerp-Rotterdam-Duisburg.

After research, the results vary from positive to negative. Some scenarios have a positive impact on society; moreover, the costs are reduced due to shifting the transportation from road and rail to the inland waterways' environment. On the contrary, for some negative economic cost scenarios, VT is found a more expensive transportation type in comparison to conventional sailing (ordinary conditions). Nevertheless, there are still other challenges to deal with, for example, legislation. (Meersman, et al., 2020) The research performed by Meersman, et al (2020) did not focus on the open sea or ocean traffic cases.

One fascinating research was done by Hynnekleiv, et al (2019) on the human-machine relationship. In the material they presented, the machine is known as Robotic, Intelligent, Autonomous (RIA) technology. Changes in technologies are already performed by new kinds of colleagues or teammates because human-machine interaction is an everyday feature nowadays. There are different types of interaction or design approaches between human and machine (Hynnekleiv, Lützhöft, & Earthy, 2019): 1) augmentation, 2) replacement, 3) remoting, 4) teaming, 5) symbiosis, 6) parasitic, 7) influence, 8) unknown and 9) benevolent (governance). Within some interactions, humans are controlling the system, but there is also a possibility when the machine with the AI takes it over. According to Hynnekleiv, et al (2019), the best option for future cooperation between humans and machines that they are 'partners' and achieving aims together. This is because technology is yet not ready to be 'in charge' or 'in command', and some of the approaches presented above are new ones for the maritime industry (Hynnekleiv, Lützhöft, & Earthy, 2019). The process of future changes will take time, and as Hynnekleiv, et al (2019) mentioned, the prediction could be made only to a limited extent. This means that the future is not a constant value and can be changed under the influence of various factors, e.g., technology and legislation.

Unfortunately, the shipping industry is not capable of using different altitude corridor features which are a must in aviation. Corridors are located at various altitudes which gives a possibility to see them as a 3D model. Shipping cannot do that and could be presented only in 2D models. Air corridors are used by aircraft to separate the traffic and avoid possible collisions (Campos & Marques, 2021). Air and shipping industries have much in common like the phenomena of the corridors or the technologies. Prewarning systems like TCAS for aviation and ARPA for shipping show their similarity. Though ships are not using a third-dimensional system for navigation, they could still be found by the geographic coordinate system. Knowledge of φ (Lat. phi) and λ (Lat. lambda) will detect the position of the vessel. By implementing this method of position identification, the path of the vessel could be supervised. Hereby, the vessel could freely proceed within the Traffic Separation Scheme (TSS) or the fairway. A TSS could be described as a road for cars or corridors for aircraft, but in this case, it will be only related to shipping.

A TSS is considered to be a special system in the specific shipping region where it divides the traffic flow into various directions. Vessels are not allowed to break the rules and take an inappropriate lane or to join at the wrong position at the wrong angle. (International Maritime Organization, 2003) But, the TSS has one disadvantage that the vessel proceeding inside the TSS has no additional right of the way which means that she is still obliged to give way to others (The North of England P&I Association Limited). The idea of TSS could be used to perform a different kind of environment for autonomous vessels.

The "route exchange" feature could be used to inform another vessel regarding the next amount of the waypoints that are placed in the same manner as the route planning of the vessel itself in the ECDIS. Proposal to share the route with the shore-based Ship Traffic Coordination Center (STCC) could be named as a successful step further because the route is being checked by the system as well as the obstacles on the way and other crossing or meeting routes. STCC can propose the changes along the route which could be agreed upon or rejected. (Porathe, et al., 2014)

In addition, winter navigation of vessels is similar to the convoy method inside the corridor. Vessels are proceeding after an icebreaker to pass a dangerous and challenging part of the sea covered with ice. For this purpose, they have only one way which is known as the ice channel. According to Valdez Banda et al (2016), ice navigation within a convoy has a high-risk potential and professional navigational experience is a must. Moreover, the consequences of an accident could become fatal for the environment (Valdez Banda, et al., 2016).

2.1 Safe transit corridor characteristics and appropriate location

As the 2nd research question stated in the beginning, we will in this subchapter deal with the introduction of one of the possible areas where the safe transit corridor could have been implemented. According to previously mentioned facts, various places in the world are used for testing autonomous vessel technologies (International Network for Autonomous Ships, 2019). Here, in this case, the familiar region between Estonia and Finland was chosen. It comes from the authors' personal seafarer's experience where the sailing area was between Muuga, Estonia, and Vuosaari, Finland. Ports are cargo ones and situated quite near both country capitals, Tallinn and Helsinki.

Close location and well-organized cargo turnover allow performing international voyages between Northern Estonia and Southern Finland. Moreover, the large amount of cargo will not overload capital roads. Circle roads are not leading cargo transport units through the city center. Furthermore, this has a beneficial effect on the environment and makes the city free of exhaust gases.

Future projects have to be also borne in mind, e.g., Rail Baltica. This is a greenfield rail transport infrastructure project to integrate the Baltic States into the European rail network (Rail Baltica, 2021). A common link between the Rail Baltica project and the suggested idea may represent a good interconnection as well as precise cargo transportation schedules.

Crossing west and eastbound traffic makes this area an acceptable option for sea trials which is in the open sea. It is free from any navigational hazards, other than ships, and other obstacles. There is plenty of space to choose a maneuver to solve an emergency. Choosing this place for a trial will give reliable results based on the tests performed. The amount of traffic varies during the year. This is most noticeable during the summer months when a lot of cruise ships are visiting Tallinn, Helsinki, and Saint Petersburg.

The distance between the two ports is approximately 48 nautical miles, and the distance only inside the "green" zone is 15,1 nautical miles. The distance inside the "green" zone was measured on the British Admiralty (BA) #2248 paper chart and then checked in ECDIS. The time of the voyage depends on the speed of the vessel. The important fact to mention is that if the vessel will be fitted with 4G/5G antennas, then the area of signal between Muuga and Vuosaari is fully covered. This comes again from the authors' personal experience when working between Tallinn and Helsinki.

The ports and harbour areas, VTS area, fairway, and open sea area between Vuosaari and Muuga are shown in Figure 2. The route between Vuosaari and Muuga has been divided into red, yellow, and green zones. Red zones indicate ports and harbour areas, yellow zones archipelago and fairway areas, and green zone open sea areas. (Irla, et al., 2020)

Figure 2. Areas (red, yellow, green) between Vuosaari, Finland, and Muuga (Port of Tallinn, 2017).

Finland has a mandatory ship reporting system, together with Estonia and Russia, in the Gulf of Finland, the Gulf of Finland Reporting System (GOFREP). The system covers the area of international waters of the Gulf of Finland. Besides, Estonia and Finland have implemented this mandatory ship reporting system in their territorial waters outside their VTS areas. Finland is responsible for the northern part of the GOFREP area. Helsinki Traffic monitors the area, operating in the Gulf of Finland VTS Centre. Tallinn Traffic is responsible for the southern area of the GOFREP in Estonia. (Monitoring international waters, 2021)

Criteria for location choice is a matter of interest. Mostly short sea voyages are to be taken into account where the distances between two ports are not so far. One of the options is to pick up the short paths between islands or the mainland and island, e.g., archipelagos or the routes between Saaremaa and Hiiumaa islands. According to the idea, appropriate places are mostly there where it is possible to monitor the situation 24/7. Furthermore, the fewer navigational hazards there are in the vicinity, the better. The most preferable will be those regions where will be almost no proximity of navigational hazards. This means that the risk of running aground or getting into a close-quarters situation in a region with heavy traffic will be minimized.

Sea trial areas could be of open or closed type, but these still are not implemented in the international waters. The location of these areas depends on the safety aspects inside this zone: for other traffic participants (manned vessels) and autonomous vessels within the convoy itself. Moreover, countries have to agree whether these areas are completely closed and to be used only by appropriate companies and organizations. On the other hand, partnerships with other countries could be formalized in the name of new technology development.

2.1.1 The impact of COVID-19 on the maritime industry

To avoid the spreading of viruses like COVID-19 onboard special and strict procedures are needed. It includes hand washing and disinfection, usage of face masks, or any other additional disinfection. In this case, these measures can prevent virus spreading, but this works only for short voyages and the idea is to decrease the spreading on the vessels. For longer voyages, other steps have to be performed depending on the number of passengers or crew members on board. If we have approximately 800 passengers and a short boarding period then only passengers who carried out self-diagnose (the evening before the boarding), without temperature or symptoms (during check-in), or after the rapid test (during check-in), can board the vessel. When 2400 passengers are planning a voyage, then add to already mentioned measures tracing applications (1-2 days before boarding) could provide a piece of information regarding possible close contacts with COVID-19 positive patients.

Furthermore, when 6000 passengers are planning a voyage on a vessel in addition to previously mentioned, they have provided the operator with a negative PCR test or be vaccinated. All these measures are in force for ships with a maximum of 80% capacity to get 0% of diseased persons onboard. (Niemelä, et al., 2021) All in all, this is one of the challenges which society is facing nowadays with different travel restrictions. This is one of the possible decisions of the future when even a much smaller crew can suffer from viruses and diseases. Procedures presented above can be used not only on the vessels but also in the VTS and ROC where people have to cooperate in a close environment with each other during their working time closely.

3 Proposal of the learning environment idea

The theoretical part consists of the integration of existing methods into the new approach. The idea of the thesis is to train the autonomous vessel applying the convoy method inside a safe transit corridor. The autonomous vessel is to be an understudy of the manned or "mother" vessel. The mother will assist the daughter in performing a voyage from port of departure to its destination. In this particular case, two ports are chosen and located in Muuga, Estonia, and Vuosaari, Finland. The method is considered to be applied only in the open sea area which is also be named as 'green' zone.

The method chosen for AI training is called a convoy and it is based and supplemented by conventional towing principle. The convoy with "mother" and "daughter" vessels will proceed inside the safe transit corridor. This aspect is highly important because the future locations of these spots have to be chosen carefully. Before selecting the area, a thorough analysis is needed depending on various factors.

3.1 Components for the proposed idea

Existing methods are divided into subtopics to present independent parts which are tied together. As it is already presented in Figure 3, the scheme consists of several components:

1. Safe transit corridor available for use in both directions,
2. "Mother" (M) and "daughter" (D) vessels,
3. Special purpose buoys (virtual aids to navigation, visible on ECDIS),
4. Crossing traffic navigating in both directions,

5. Precautionary area of the convoy,
6. Connection/bond between the “mother” and “daughter” vessels.

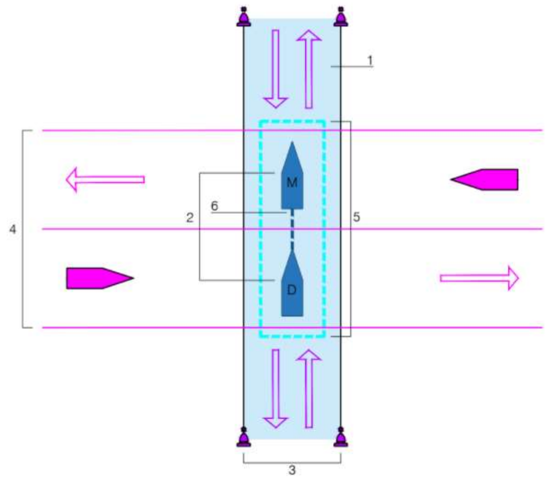

Figure 3. Presentation of the teaching autonomous vessel using a convoy method (author’s illustration).

Further details will be explored more thoroughly in this chapter with a more precise explanation of the components and method itself.

3.2 Safe transit corridor, convoy method, and towing operations principle

Keeping it simple and easy for all of the traffic participants is a huge aim of the idea. There is no need to invent elaborate schemes. A safe transit corridor is similar to the Traffic Separation Scheme (TSS) where vessels can navigate in accordance with Rule 10 of the COLREGs (International Maritime Organization, 2003). Moreover, it is quite important not to forget to use some paragraphs from Rule 9 of COLREGs (International Maritime Organization, 2003). This means that each vessel shall keep to the starboard side of the corridor when proceeding in traffic (International Maritime Organization, 2003).

A safe transit corridor is a specially designated area for autonomous ships to navigate either in convoy or not. The first option is used when the ship is being taught by her sistership according to convoy method and the second to be implemented at the time “daughter” vessel to be ready for independent voyage alone.

The convoy method means a group of ships that travel together, especially for protection, and behind one another in a row (Cambridge Dictionary, 2021). The convoy method in this thesis is where a conventional vessel is used as a “mother“ vessel and an autonomous vessel is the “daughter“ navigating in convoy as sisterships, where the “daughter“ learns from the navigational behavior of the “mother“. Both vessels will navigate within a safe transit corridor following one another. The implementation of the convoy method inside the corridor must be thoroughly checked along with risk assessment before implementation; this is one of the issues requiring attention to answer the 1st research question.

Inspiration for further research came from the Scania automated platooning approach which is similar to the vision of four levels of autonomous shipping (Scania, 2018). Moreover, testing the platooning method performed by Volvo Trucks and FedEx confirmed that fuel consumption could be improved (Volvo Group, 2018). Undoubtedly, the way of thinking in the interpretation of this method into maritime one has to be re-thought. Platooning became a convoy in this Master’s thesis and vehicles are the “mother” and “daughter” vessels.

Furthermore, another important part is always safety as well as the influence of fatigue on decision-making and the human factor issues. In this case, the autonomous mode of any equipment could be a great support. Besides the fatigue, the weather condition also plays a role. The convoy method in the rough condition is the individual topic because the sea is not calm all the time. The research on the critical weather conditions performed by Russians was helpful. This reflects the KamAZ company and its intention to start operations on the Far North by using the new autonomous approach. The prototype of the truck which is capable of driving on planned routes without the driver was presented in 2015. The AI system of the truck can distinguish road markings and signs, and even pedestrians. (TASS, 2019)

According to 2nd research question, the safe transit corridor is the active learning environment for the convoy with the autonomous vessel. This feature also dictates where and how it could be implemented. Various transit corridors are used, and different types are known, e.g., Traffic Separation Scheme (TSS) implemented by IMO and being used worldwide or even Internationally Recommended Transit Corridor (IRTC) actively used in the Gulf of Aden to reduce the number of pirate attacks (Combined Maritime Forces, 2017).

The Traffic Separation Scheme (TSS) idea is taken as a starting point in the development of the corridor. In the case of autonomous vessels, a safe transit corridor will be established to decrease the complexity of maritime traffic and to be marked in ECDIS. Moreover, appropriate corrections to be made on the paper charts and the new editions of them. The safe transit corridor will be highlighted with a light blue color, the same as in ECDIS. In addition to that special purpose, buoys are going to be placed at the terminations of the corridor.

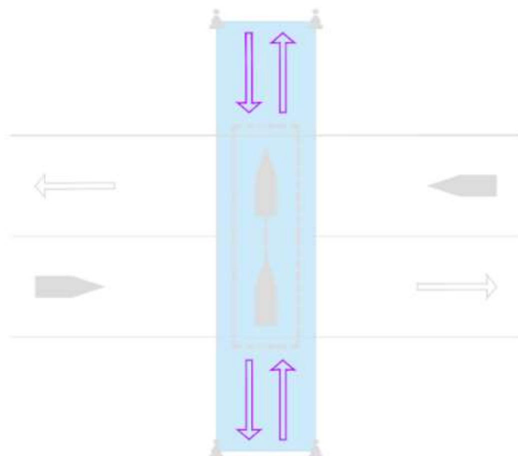

Figure 4. Safe transit corridor and possible traffic directions inside it (author's illustration).

Two vessels are intended to travel between the ports through the safe transit corridor marked on the ECDIS and paper charts and stay strictly within its limits. As seen in Figure 4 that in this case, ships can travel north and southbound, but in another corridor the direction to be assigned as needed. Moreover, the precautionary notes are going to be included on all the navigational charts either electronic or paper.

'Mother' and 'daughter' vessels are going to perform a voyage by using a convoy method. This is a similar procedure that is used by tugs and their caravans but in this case, two vessels are not going to be connected in one unit. Tugs can push ahead another vessel or barge to make this procedure alongside or to pull the caravan astern. The third option is the closest to the method used in this thesis.

It is a fact that the caravan could be short or long and all of the units are interconnected. The length and width depending on the object being towed and the purpose. COLREGs divide caravans into more and less than 200 meters (International Maritime Organization, 2003). It only makes them different when nominating special lights and dayshapes when the towing operation concerns difficult or restricted maneuverability towing.

The idea of the thesis is to use the principle of towing operations in the convoy method case. ‘Mother’ and ‘daughter’ vessels planned to have a more digital type of connection than it is used nowadays by the tow and vessel behind it. Methods to “connect” two vessels to be explained later in this thesis.

3.3 “Mother” and “daughter” vessels and why new vessels are needed

The “mother” vessel (see Figure 5) is the first one in convoy and it is manned like a conventional vessel. This vessel has to be built as a cargo vessel, e.g., container or bulk carrier. For this matter, the coastal trading vessel type could become a good example. Smaller vessels can easily maneuver and it is more convenient to operate them in case of emergency.

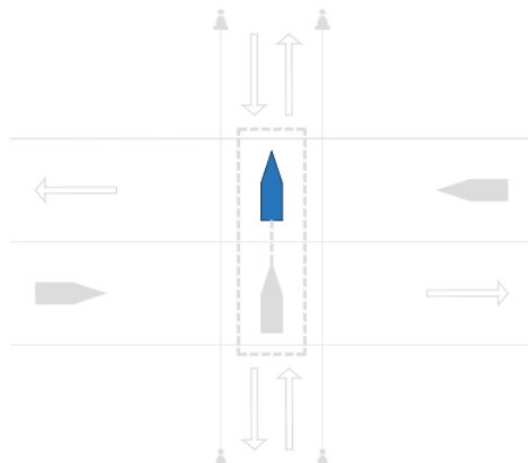

Figure 5. “Mother” vessel leading the convoy proceeding in the safe transit corridor (author’s illustration).

The “mother” vessel is the first in a row that has to be at least minimum manned and the design of the bridge is to be integrated with the „daughter“ one. Both vessels in convoy must be interconnected by technical means and their bridge design has to be alike. The initial idea is to project ships with “mother-daughter” relationship status by one design which is planned to be used on a long-term basis. This implies future projects where the same “mother” vessel could teach another “daughter” vessel. According to the idea, this approach is to be implemented in another region where the new safe transit corridor will be established.

The second vessel in the convoy to be a “daughter” vessel (see Figure 6) which will follow her “mother” all along the way. Two vessels are not directly connected; this will be explained in the following chapters. The vessel shall be the same type, even recommended if it could be a sistership, to maximally optimize maneuvering characteristics of both vessels.

There is a reason why it would be a better idea to build new vessels instead of converting old ones into autonomous ones. The first is an environmental fact; newer vessels are using more environmentally friendly fuel, e.g., LNG, Li-ion batteries, or even solar and wind energy. While the older vessels still use fuel oil. Moreover, the world cannot rely on these fuel sources because they come from non-renewable recourses. This means that in any case, the maritime industry needs an alternative.

The building of new vessels means a possibility to choose a source of energy for them. For the greener environment on short-sea shipping, the convoy vessels can use fuel alternatives. Undoubtedly ships are capable of using other means of energy, other than fuel or gas, e.g., wind, solar, sea currents, etc (Haugland, 2014). From an environmental point of view, the Liquified Natural Gas (LNG), solar panels, and Li-ion batteries-inside-container are more suitable as a power supply system for those vessels. Greenhouse gas emission may be reduced and all three methods could be easily accessible within the Gulf of Finland area. Meanwhile, the LNG bunker vessel Optimus, operated by Eesti Gaas business unit Elenger Marine is on the way to Europe and starts with bunkering operations at the end of this spring (Eesti Gaas, 2020).

On the other hand, using solar panels and Li-ion batteries-inside-container is quite a smart option as well. Solar panels may be charged wherever the ships are on a sunny day. Li-ion batteries can be charged in one of the ports between which “mother” and “daughter” vessels operate. If the system becomes integrated, then charging of the batteries-inside-containers could be possible right at sea.

Secondly, vessels being in use nowadays are built for years of operation and the life of each vessel to be longer than 20 years. According to this, it is not rational to re-build them and invest much more finance on that. The smartest way is to continue using them but bear in mind the future needs.

Thirdly, it is hard to find the same sisterships to use as the vessels under one project. The idea is to make the process similar to aviation and identically build vessels. In the future, the development of the autonomous industry may require larger vessels, but for this matter, it is necessary to successfully teach the smaller ones. Moreover, the idea of autonomous vessels needs to be accepted by society.

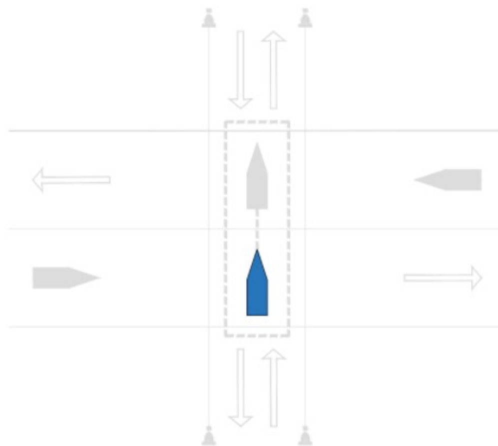

Figure 6. “Daughter” vessel following her “mother” in the convoy proceeding in the safe transit corridor (author’s illustration).

3.4 Identification of navigational lights, day shapes, AIS symbols, sound signals, and special purpose buoys

So far as autonomous ships are the new kind of vessels, there are no agreements about them yet. Moreover, guidelines in COLREGs are also missing. Still, special lights, daytime shapes, and their location on the masts of both vessels are an important part. Navigational light options can be borrowed from already existing ones, e.g., tug conducting towing operation for the manned vessel and carrying mine clearance operation for the second vessel in convoy (see Figure 7).

In case this option is accepted, for the “mother” vessel there would be only one change. Preferably one all-round purple flashing light on the mast, as Porathe (2019) suggests, is located above other all-round lights. With the „daughter“ vessel the solution is to show her autonomous mode by exhibiting three all-round purple lights in a way vessel carrying mine clearance operations do (International Maritime Organization, 2003). Purple light is not used for other purposes (Porathe, 2019). This could become a sign for other vessels that this particular one is in autonomous mode or being a part of an autonomous mode convoy. Towing light, in this case, is not necessary because both vessels have all-round purple navigational lights by which they could be identified.

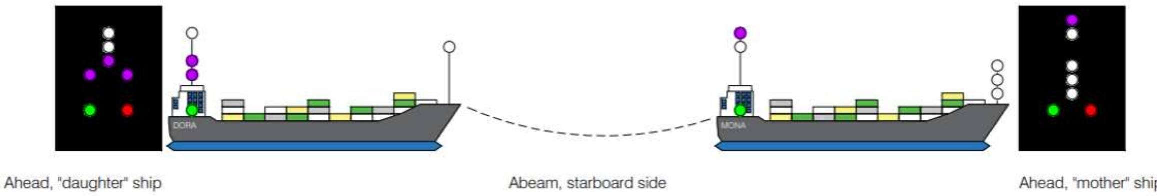

Figure 7. „Mother“ and „daughter“ vessels and their navigational lights, abeam, and ahead view (author's illustration).

Day shapes' perspectives must differ in comparison with the navigational lights. In this case, it is not possible to use the day shapes of a vessel carrying mine clearance operations for the „daughter“ vessel. For example, if the first vessel in convoy will add a cone with the apex upwards in addition to day shapes as described in the COLREGs (International Maritime Organization, 2003). This is the vessel engaged in towing operation such as severely restricts the towing vessel and her tow in their ability to deviate from their course but in this case with the additional shape (International Maritime Organization, 2003).

As per the „daughter“ vessel and her day shapes then another similar option could be proposed. Adding three cones with the apexes upwards instead of three balls of a vessel carrying mine clearance operations. This may force other vessels to pay extra attention to this category of vessels.

Bearing in mind specific equipment like radars and ECDIS, AIS symbols of autonomous ships have to be different. For that case, it is possible to add an extra A before AIS, e.g., A-AIS. Besides, the extra A could be visible right above the AIS symbol on radars and ECDIS. (Porathe, 2019) Other options are acceptable too, for example, the AIS symbol could be marked in purple and may also be a flashing one. This is the option used to show the dangerous target depending on the settings of your radar and ECDIS but colored in purple not red.

Sound signals in restricted visibility (such as snow, rain, sandstorms, etc.) also to be defined and agreed upon following COLREGs (International Maritime Organization, 2003). Signals could not be mistaken with already existing ones. The proposal is to use three prolonged blasts for the „mother“ vessel and the signal to be repeated by the „daughter“ vessel right after.

Entrances to and exits from safe transit corridors have to be appropriately marked (see Figure 8). The corridor could be marked with a more significant number of buoys, if necessary when it is possible in given circumstances. According to the plan, these are going to be the virtual aids to navigation (AtoN). They are *"entirely virtual in nature and exist only as a digital data object that resides within an electronic navigation chart for a display to mariners through an ECDIS"* (Wright & Baldauf, 2016). They are also defined as something that *"does not physically exist but is a digital information object promulgated by an authorized service provider that can be presented on navigational systems"* (IALA O143, 2013).

It will also be easier to move them to another position if the position of the corridor is changed or shifted. Special purpose buoys must differ, so there is no opportunity to confuse them with other ones. For that case, the buoy to be colored in purple, also, has a purple X as the top mark. Light characteristics of this buoy could be in any phase, this point can be agreed upon later. These category buoys are provided only to demonstrate that autonomous vessels are involved in the operation in the particular region or as an object to attract attention.

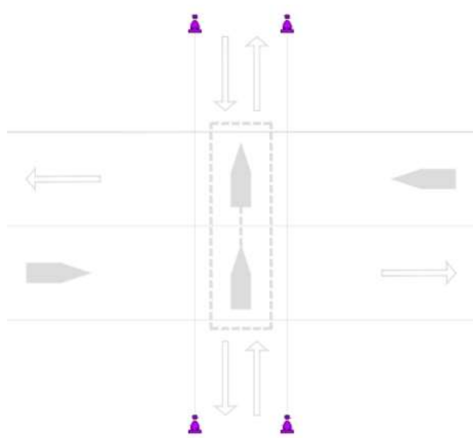

Figure 8. Special purpose buoys are located to show the beginning and the end of the safe transit corridor (author's illustration).

3.5 Communication aspects and possibilities

All the vessels in close vicinity of the safe transit corridor have to be informed about the convoy operations in advance. If the area is supervised by VTS, they should give vessels precautionary information. There are few options available for how this could be implemented in the future.

Updates coming from VTS via Very High Frequency (VHF) channel 16 to be transmitted at a particular time. Nowadays, this way is transmitted information about weather forecasts, navigational and gale warnings, ice reports, and ice breakers positions, e.g., in the GOFREP area, it is performed by Maritime Safety Radio - Turku and Tallinn Radio (Maritime Safety Radio, 2020), (RIKS, 2020). Moreover, in the same way, other vessels are informed about specific works and operations carried out in certain regions as well as regarding different positions requiring extra attention. In this case, VTS or, here is GOFREP, Tallinn, or Helsinki Traffic are direct contact organizations.

Besides VTS, there are also other options for how to transmit important information using various means. Here is the opportunity to rely on such a device as a navigational telex (NAVTEX). With the help of NAVTEX, information could be transmitted in text form without unaccompanied by the voice.

Practically the information sent contains the same what is transmitted by Maritime Safety Radio and VTS but available for a more extended period. Sent messages could be read through later on and (the most important) could be stored or also printed (for that printer is essential). Knowing the exact time when the messages will be transmitted, the ship's crew can predict the meeting point with the convoy and approximate time. Due to this action, manned ships will be able to calculate planned speed and course as well as possible maneuvers to give way to the convoy using the safe transit corridor, if needed.

Time schedules must be available 24/7 and updated in real-time. Information regarding a convoy must be visible on the radar or ECDIS screen if the *Safety Messages* will be chosen from the menu. Moreover, if the convoy already departed from the port, information has to be monitored via its AIS information. However, even though when passing in or near the area of the safe transit corridor the additional precautions have to be observed. Moreover, then the VTS or remote operation center team will have a closer look at the situation taking place near or inside the safe transit corridor.

Of course, in case of an emergency, none of the options should ever forget the implementation of new or improved technologies. For that reason, route re-planning requests should be available for all the vessels in the vicinity of the safe transit corridor. Logically thinking, if we cannot ask anyone on the autonomous vessel what maneuver she is planning to perform, then there must be some other option.

For example, if a manned vessel outside the safe transit corridor has lost its maneuverability and can not give way to the convoy or autonomous vessel, then there is an option for how to behave. The crew of the manned vessel is making contact with the convoy: it is simple with the „mother“ but more challenging to get in touch with the „daughter“. They could do this using the radar or ECDIS if both of them show the A-AIS signal of the „daughter“ vessel. Imagine that the message for the autonomous vessel could be transmitted in the form of a complete questionnaire. Another solution, to act accordingly to the prototype of the flowchart where the ship’s crew will select the options answering the most straightforward questions – yes or no.

In this case, the autonomous vessel or the whole convoy will implement the emergency procedures. It would be requested from them to re-plan their route and share it with the manned vessel being restricted in her maneuverability. The exact new route is significant for the manned vessel and necessary to resolve the situation if it can not be resolved by maneuver of the convoy or autonomous vessel alone. More detailed overview of the route planning to be presented in the following chapter.

3.6 Route planning, it's integrated sharing with other vessels, VTS and ROC

According to the guidelines, voyage planning must include an appraisal, the planning itself, execution, and monitoring (IMO, Guidelines for voyage planning, 2000). Route planning is an essential part of the navigational officer’s work. It has to be done in advance before departure, checked by the Master, and to be presented to other Officers of the Watch. On the vessels where paper charts are still being in use, the route planning must be drawn on them as well.

A manned vessel using a TSS for proceeding to her port of destination will do the same procedure of route planning as always. On the other hand, the second participant of the traffic is the convoy proceeding from port A to port B, using for that purpose the safe transit corridor. Here is to be mentioned that the convoy route is to be shared with the other vessels being close to the corridor.

The planned route to be prepared inside the safe transit corridor. In case of emergency, special procedures to be used for making any alterations from the pre-planned route. The route to be changed only in case of emergency according to special procedures. As an experiment, it would be a brilliant breakthrough if the convoy, VTS, or remote operation center team could see the routes of the manned vessels as well. In order not to create a mess on the radar or ECDIS screens, the route could be seen only if the operator would plot the target and select the *Route Preview* from the menu. The idea has already been tested and implemented in the Sea Traffic Management (STM) Validation Project (Sjöfartsverket, 2019).

According to the idea and guided by 1st research question, the route of the convoy will be planned inside the safe transit corridor. This means that the convoy will not leave the corridor in any case, except for the emergency, e.g., to avoid the collision. Moreover, the re-planned route will be updated on the radar and ECDIS screens in real-time without delay. Simple choices via menu can be helpful to inform the convoy or only an autonomous vessel regarding restricted maneuverability, not under command status or other cases requiring additional attention. These updates and their integrated sharing with manned vessels, VTS, and remote operation center team is essential for the safety of navigation.

Why is it important to share the new route with all of these units? The answer is safety. The "daughter" vessel will be taught how to act in the case of an emergency. It makes no difference whether this situation will be created by the actions of another vessel or in any other matter, e.g., when the failure will be detected on an autonomous vessel itself.

Emergency procedures could be explained to the manned vessel thoroughly. The convoy or only the "daughter" vessel can send a message to manned vessels in the vicinity as well as to VTS and the remote operation center team. The message will duplicate the error that occurred during the convoy procedure or on the autonomous vessel. All the information will be visible on the radar or ECDIS screens and then transmitted also by the VTS as a *Sécurité* type of message.

Another challenge is to explain the occurred failure to the convoy and the autonomous vessel proceeding within the safe transit corridor. When the failure on a manned vessel occurs, then strict procedures have to be agreed on.

One of the solutions is to implement additional menu functions of the radar and ECDIS. As it is seen in Figure 9, the information regarding the emergency case will be automatically transmitted to both. "Mother" and "daughter" vessels are going to receive identical data. After choosing the type of status and sending it to the convoy, the process of re-planning the route starts. Preparation for sharing it with other traffic participants will take some time because two vessels in convoy have to agree on the maneuvers.

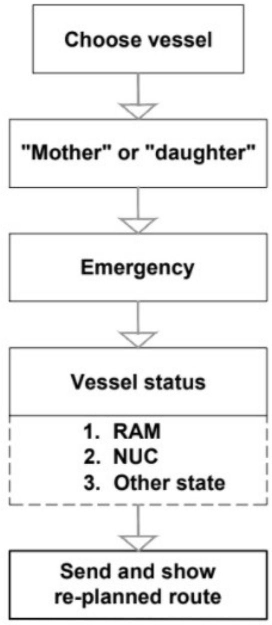

Figure 9. Example of decision-making sequence, manned vessel informing convoy on her emergency status (author's illustration).

The whole convoy, "mother" and "daughter" vessels, must decide whether both have to change course or speed to avoid the collision with the manned vessel. Here it is essential to add that the convoy and the autonomous vessel itself will try to avoid altering course to port. This decision is a reference to Rule 17 of COLREGs when the stand-on vessel to avoid collision with another power-driven vessel shall, if the circumstances of the case admit, not alter a course to port for a vessel on her port side (International Maritime Organization, 2003).

However, the maneuver of the "daughter" vessel alone could be enough during some of the situations. In this case, all the vessels in the vicinity will be informed about it. They will see a new planned course of the convoy or autonomous vessel alone. In theory, it has to be visible on the radar or ECDIS screens differently colored, other than is used for convoy initial route planning (see Figure 10).

Bridge design optimization for both vessels is a good topic for discussions and suggestions. Implementation of new technical solutions to simplify navigation procedures for other traffic participants have to be taken into account. Automatic Radar Plotting Aids (ARPA) has been a proven companion for calculating the closest point of approach (CPA) and time to the closest point of approach (TCPA). ARPA is similar to Traffic Collision Avoidance System

(TCAS) used in aviation. Based on this, ARPA could be improved and accompanied with a voice message. It may be used to duplicate actions of the convoy or the autonomous vessel, e.g., *altering course to port, altering course to starboard, decreasing speed, increasing speed,* etc. Then the manned vessel will also have an audible confirmation of the performed maneuver.

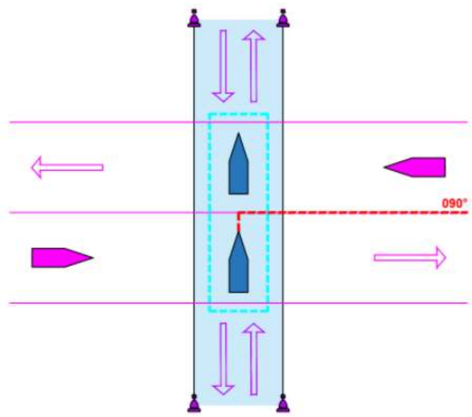

Figure 10. “Daughter” vessel sharing re-planned route with other traffic participants proceeding in the TSS, turn radius to be chosen appropriately (author’s illustration).

Trial Manoeuvre option-based system is being used widely on the vessels. With the assistance of this system crew of the ship can calculate possible changes in course and speed. It is necessary to plan further maneuvers to give way or avoid collision with another vessel. The system displays an image directly on the radar screen due to chosen period provided that other targets will not change their course and speed. If the system detects the close-quarters or collision situation corresponding warning will be displayed on the screen with a red color. According to this, minimum CPA and TCPA values must be selected in the settings in advance.

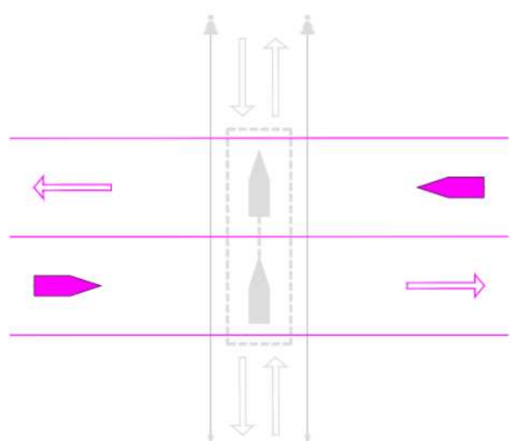

Figure 11. Manned vessels are proceeding via TSS and crossing the safe transit corridor (author’s illustration).

In other words, the area near the safe transit corridor is precautionary. It does not matter which vessel has a privilege, the convoy and the manned vessel (see Figure 11) must always proceed with extra caution.

3.7 Safety of navigation

Defining the safety issues of the safe transit corridor and convoy method is the most important subject in this idea to be. The safe transit corridor is the place where the convoy can proceed when being *en route* from one port to another. It could be named *safe* because it is monitored at all times from different locations when the convoy uses it. The idea is to define separated responsibilities of VTS and ROC to present a clearer picture.

How to ensure safety outside and inside the corridor? VTS observes the situation around the corridor, which essentially makes this organization a responsible contact with every vessel outside the safe transit corridor. Looking at the same issue from the other side, the remote operation center team will be responsible for monitoring the situation inside the safe transit corridor. If the ROC detects something uncertain or dangerous for the convoy inside the corridor, e.g., sailing or fishing vessel, the information will be transmitted to the VTS operator. He or she, respectively, will make contact with the vessel, which might pose a danger to the convoy.

If we assume that in the future, the autonomous vessels have to be integrated into the maritime traffic environment along with manned ones, then the safety aspects have to be agreed on. The safe transit corridor will provide a suitable alternative on how to involve both types but keep them separated at the same time. The area where autonomous vessels are going to operate must be under protection. This will provide safety at a higher level. Moreover, as long as two vessels are going to operate in one convoy, the situation will be monitored from the third spot, the "mother" vessel. The "daughter" vessel is an autonomous one, and she is never going to operate alone if the readiness is not confirmed during the testing period.

In the meanwhile, it is important to decide on how the convoy will behave to give way to another vessel. Undoubtedly, the convoy and the autonomous vessel itself should be considered as the vessel to which the manned ones have to give way. But the cases when the whole convoy or the "daughter" vessel only will perform an alteration, of course, have to be taken into account. These matters could be demonstrated on the example of flowcharts and other features.

Vessels other than convoy and autonomous one must not use the safe traffic corridor for proceeding inside it, this is strictly prohibited. If in an emergency matter, the manned vessel will have to use the safe traffic corridor even for a short time, then VTS and remote operation center team have to be informed immediately. For this matter, the level of danger will be considered depending on whether the convoy is on the way and how long it will have to reach the dangerous position.

In addition to already mentioned, the no-go areas for the convoy must be defined. This includes not only navigational hazards but also a distance between two vessels so as not to lose the signal between them. There are a few other cases when considering convoy with an autonomous vessel. This includes cyber attacks, possible blackouts of one of the convoy vessels and other traffic participants, navigation in ice, giving way in case of emergency, sensor failure, and losing command of the vessel itself.

In this case, this proposed method has to keep an eye on possible safety breaches. Not only to protect the autonomous vessel in a conventional vessel environment but also to ensure the protection of all traffic participants regarding all possible features. This method is better for maritime traffic because its implementation is divided into different parts, and each of them has a supervisor and persons to contact in case of an emergency. Integration of autonomous vessels is done in the most convenient way where various problems to be detected after conducting interviews with maritime experts.

3.8 The departure of the convoy

The departure of the convoy needs to be scheduled as per timetable, and the remote operation center team has to monitor this process from the beginning to the end. It means that their work starts with departure and ends with the arrival to the port of destination. They have to work closely with the convoy, „mother“ and „daughter“ vessels, VTS, and other manned traffic participants.

Before departure, safe transit corridors have to be checked and risk assessment performed. The density of traffic, possible obstructions on the way, dangerous targets which movements sometimes cannot be predicted, e.g., sailing and fishing vessels as well as warships. Moreover, unpredictable situations, e.g., restricted in her ability to maneuver (RAM) and not under command (NUC) vessels on the way of the convoy, have to be taken into account, and actions are needed from both sides. The one who is not able to maneuver at least has to inform another. This action is similar to obligation as per COLREGs that every vessel has to make an action to avoid a collision (International Maritime Organization, 2003).

When the convoy is ready to depart the port, the port authorities are the first organization who will be informed about this action. Pilots, agents, stevedores, and others must co-operate with the port representatives. The next step is to establish contact with VTS and the remote operation center team. They are the key to communication: from that moment, *Sécurité* type of message will be transmitted on VHF channel 16, Navtex messages to be sent to all the vessels in close vicinity and the planned route inside safe transit corridor will become active on the radar and ECDIS screens.

From this moment on, this is the starting point of convoy method operation between two ports. Information is going to be repeated in a certain interval of time. VTS will monitor the vessels in the close vicinity of the safe transit corridor and make contact if their position impedes the convoy. The remote operation center team will focus on the convoy consisting of “mother” and “daughter” vessels.

All participants have to monitor the situation having a closer look at the environment around the safe transit corridor. Each of them will have his or her area of responsibility. If any doubt or failure occurs, others have to be informed immediately.

3.9 Precautionary contour, the distance between vessels, and their interconnection in the convoy

„Mother“ and „daughter“ vessel precautionary contour (see Figure 12) is a distance of a certain amount. This could be based on the following values: the length and breadth, draft, speed of the vessel, and its maneuver characteristics. Moreover, various environmental facts have to be considered, e.g., traffic density, visibility, sea state, etc.

The testing area is planned in the open sea, so there are practically no natural obstructions that could impede convoy or other vessels from altering their course or speed. In the early stages, the precautionary contour has to be wider but not less than 1 nautical mile (1 nautical mile = 1852 meters). In some literature reviews, the precautionary contour is also known as a “safe haven” (Porathe, et al., 2014).

As per Master’s Standing Orders on different types of vessels, 1 nm is a usual distance for safe passing, especially during bad weather conditions, e.g., in fog. In this case, a vessel must use the appropriate sound signals and inform the Master correspondingly. On the other hand, precautionary contours could be agreed on and calculated lately if someone decides to make this his/her thesis idea.

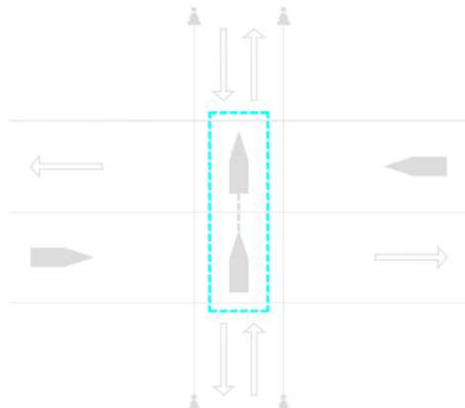

Figure 12. Precautionary contour around “mother” and “daughter” vessels (author’s illustration).

One more fact could be considered significant at this point. For collision avoidance, vessels could apply an early warning system. This could also be advanced ARPA or TCAS, which will be able to plot the convoy targets automatically at some point if it was not done by the ship’s crew. The principle is similar to ARPA settings which allow plotting the target when it enters the area of interest. It will give the vessel the possibility to plan course and speed when the convoy starts its movement.

Besides, the specific distance (see Figure 13) between “mother-daughter” vessels must also be agreed upon calculation. Some of the previous values are important here as well, but most of all – time of signal transmission, e.g., how quickly the second vessel will receive the signal from the first one in convoy. Moreover, the distance from receiving a signal to the full stop of the vessel is also a point of interest. For this purpose, maneuver characteristics are essential information and a starting point for a more detailed study on this topic.

The possible means of two vessels' interconnection are explained below. Firstly, cameras to show the “mother” vessel and remote operation center team a clear image of what the understudy vessel sees around itself. Besides, is the quality of the picture satisfactory enough to know the visibility is good or poor. The monitoring remote operation center team and the crew of the “mother” vessel must see the image in real-time without delay.

Figure 13. Specific distance between “mother” and “daughter” vessels, these two are not connected in a traditional way (author’s illustration).

Secondly, LIDARs have to be in an operational mode and not be disabled in case of heavy rains and snowstorms, high waves, fog, ice conditions, and in some regions, sandstorms or other weather states. Working of equipment in the night-time must also be tested and the results to be satisfactory. LIDARs should be working in 3D projection to allow all the participants, e.g., “mother” vessel and monitoring remote operation center team, to see the absolute available data. It is vital to observe on what basis the “daughter” vessel selects the decisions to memorize made by her “mother”. Besides, the second vessel in the convoy has to monitor the all-around traffic to keep the situation under constant surveillance.

Thirdly, sensors from all the equipment have to be installed and duplicated. If the malfunction of the system occurs, the sensor might be switched over automatically (like with the spare navigational lights). Moreover, a broken sensor could be replaced at the next port of destination. Information about the operational status of the sensor has to be visible on the specially designated equipment of the “mother” vessel and in the monitoring remote operation center team.

Although, the necessity to demonstrate ships' digital connection to be considered to avoid other vessels passing between “mother” and “daughter”. Here it is more important not to intend to exit the corridor. This will guarantee more accurate calculations for the meeting points with other ships and also protects other traffic participants.

Some of the existing risks have to be kept in mind, e.g., poor visibility when the cameras installed on the “daughter” vessel will not be able to see the “mother” vessel ahead. It means that interconnection between the vessels could not be agreed only on one factor, here the cameras, but on the information from different sensors and equipment. For example, data available from radars and LIDARs as well as AIS position confirmation incoming from GPS. Besides, other weather conditions such as high waves during storms and ice situations may require an increased distance between „mother“ and „daughter“ vessels.

All of the factors have a special role in combination performing a convoy method. The above mentioned is not a complete list; it could be continued further when additional measured to be defined. Together with the maritime experts from various fields of the same industry, the subject will be discussed in more detail to highlight the strengths and weaknesses of an overall idea.

4 Research methodology

Qualitative research, also known as interpretivism, was chosen as a means of data collection for this thesis. The research would be conducted in the form of interviews with qualified experts from different areas of the maritime industry. As Denzin and Lincoln (2000) state that "qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them".

According to Labuschange (2003), qualitative research is typically concerned with the characters and states, and the data received is not measured in quantities, amounts, and frequencies. This type of research is based on the experience, understandings, and beliefs of the interviewee.

Leavy (2014) claims that the approach of qualitative research to the inquiry is unique because of both philosophical and methodological diversity, in addition to the value system which guided the research practice.

Benefits of qualitative research are mentioned by Denzin (1989) in a way that this approach produces the thick description of feelings belonging to participants, opinions, experiences, and also their expressions. In addition to that, the qualitative research analyses behavior of the candidates, interviewers, interlocutors, and the influences on behavior during the interview (Lazaraton & Taylor, 2007). This research method also allows discovering participants' experiences in a deeper and broader way of the specific areas of interest (Rahman, 2017). Furthermore, qualitative research is the method where the data collecting process consists of observations, interviews, descriptions (Cohen, Manion, & Morrison, 2011). More to add, the design of the research has a flexible structure, and it could be corrected according to circumstances (Maxwell, 2012).

Each method of research has its strengths and weaknesses, and this one is not an exception. First of all, according to Rahman (2017), the qualitative research results may be low credible, smaller groups of participants taking part in research in comparison to the whole population raise the issue of generalizability (Harry & Lipsky, 2014; Thomson, 2011). Interpretation of data could become a complex barrier and time-consuming procedure. As Flick (2011) claims that even after performing the transcript of records, the results can be expressed in a limited way.

4.1 Method selection

Method choosing procedure depends on the needs of the author to get the desired result and answer to question posed. As it was already mentioned in the previous chapter, the qualitative research method was chosen for this matter. Instead of this, the approach for future research has to be selected in a way to support the qualitative method.

According to Trochim (2002), the inductive approach is more appropriate in this case. In this case, the approach (see Figure 14) takes its starts from specific observations, which move further to detect boundaries and patterns. After this, the idea, e.g., hypotheses explored, and then further research is carried out. Developing the idea is performed via a natural approach when using the data taken from people’s experience and their feelings. At the point when research is finished, the conclusion is sometimes presented along with the new theory.

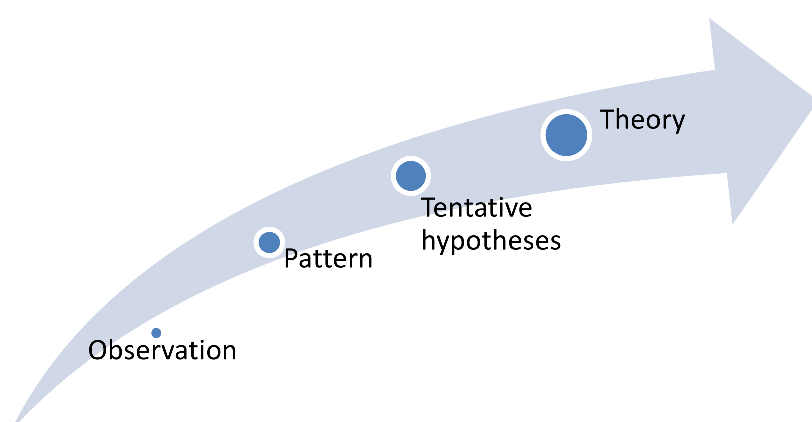

Figure 14. Scheme of inductive approach according to Trochim (2002).

As per Figure 14, it is clear that the inductive approach works as “bottom-up” (Trochim, 2002). Furthermore, according to Thomas (2003), the purpose of using this approach could be different, a) present a large amount of text information more compactly, b) link the research data to findings received after conducting the interviews, and c) create a theory which becomes the straightforward interpretation of the conducted research and processes.

4.1.1 Data collection procedure

The initial plan for data collection was dedicated to carrying out simulator exercises. Master Mariners' professional experience would allow having a numeric amount of data for future analysis of the maneuvers, distances, and time performed. Unfortunately, because of the COVID-19 and travel restrictions, there was a necessity to change the plans and take another research method regarding data collection.

Edwards and Holland (2013), like many others, define three categories of interviews: standardized (structured), semi-standardized (semi-structured), and unstandardized (unstructured). According to the intention to receive a particular result after collecting information, the semi-structured type is chosen because of no rigid attachment to the prepared questionnaire but more connected to the way how the interviewee responds and reflects (Adhabi & Anozie, 2017). For data collection intentions, the interviews could be performed in multiple ways, e.g., personally face-to-face, via audio or video call, etc.

There are a lot of advantages in respect of semi-structured interviews. Because of its flexibility, for example, it is easier to understand or have comments regarding a person's opinion after asking him or her a question during the interview. Moreover, this is a possibility to receive an honest answer when interviewing a person face-to-face; participants will share his or her opinion without fear of being misunderstood. (Adams, 2015) In addition, poorly researched areas require different thoughts, both positive and negative, as well as a fresh look at the topic from various angles.

Semi-structured interviews also have disadvantages because of the time consumption and diligence of the interviewer. According to Adams (2015), the process of preparing the interview forces an interviewer to pass different stages: making the questionnaire ready, choosing participants, planning time schedules, actually conducting the interviews, reviewing questions and structure of the interview, and analyzing them. The transcript of records may also take hours of work.

4.1.2 Participant's selection procedure

Interviews are conducted to get to know other persons' life experiences in a subject he or she is being interviewed; there is nothing we can change about it (Van Manen, 1990). According to Seidman (2006), the aim of the interviewer is "to present the experience of the people he or she interviews in compelling enough detail and insufficient depth that those who read the study can connect to that experience, learn how it is constituted, and deepen their understanding of the issues it reflects".

Firstly, according to Seidman (2006), it is necessary to define connections among those who are going to be interviewed. In the context of thesis research, all of the participants had to represent the maritime industry or at least be familiar with the area of study through their working experience. Secondly, the personal experience of the interviewees will make a told story feel different in comparison with the experiment that could be carried out in life (Seidman, 2006).

Essential is the process of selecting participants because they cannot be chosen randomly; moreover, they have to accept their agreement of being interviewed (Seidman, 2006). Furthermore, Seidman (2006) believes that if the interviews have been deep enough, then the researcher has an opportunity to find similarities between participants and, more importantly, with the presented idea of the thesis. It is the way to find complexities and future challenges.

According to Taherdoost (2016), the best possible option in the case of this thesis is to use the non-probability sampling technique such as snowball sampling. This approach is quite popular in small environments with difficult access due to their closed nature, e.g., maritime industry (Taherdoost, 2016). Proceeding with this approach will define the inconspicuous characteristics but will also be time-consuming (Seidman, 2006). Although, this approach allows participants to propose others for further research (Bertaux, 1981).

Advantages are clear: a) working in the maritime industry gives a possibility to make new connections all the time, b) they can help you to get in touch with others whom you do not know, c) new connections via others give you a better analysis of the situation because then you are receiving a truthful and professional answer and, d) it may give you future perspectives in your career.

The disadvantages of the approach are a) this is a time-consuming process because b) it is necessary to be sure that you have interviewed enough participants (Seidman, 2006).

4.1.3 Data processing procedure

Thematic analysis is a flexible method of data processing in qualitative research. According to Braun & Clarke (2012), it is a method "for systematically identifying, organizing, and offering insight into, patterns of meaning (themes) across a dataset; it allows the researcher to identify the need to be important concerning the particular topic and research question being explored".

This analysis contains six phases (Braun & Clarke, Using thematic analysis in psychology, 2006): a) introduce data to yourself, b) generating codes, c) theme search, d) reviewing the themes, e) themes definition and naming and, f) preparing the report. To prepare a good analysis of the data, it is essential to follow all the guidelines of the phases presented above.

4.2 Ethical standards during thesis writing

According to Elsevier journal (2017), it is necessary to be aware of the importance of the following ethical issues during the research: a) authorship, b) competing interest, c) plagiarism, d) simultaneous submission, e) research fraud and, f) salami slicing. These are the paramount rules of every single researcher; it means that for writing a good thesis, you must not break any rules.

Novia University of Applied Sciences is taking care of these issues by using the particular anti-plagiarism system "Urkund". The analysis is performed to ensure that all writing rules were followed. Although, the student is responsible for presenting the thesis, which is written appropriately without any violations.

5 The Empirical Study

In this chapter of the thesis, the interview results will be presented. Questions to be showed along with the answers received. Participants were chosen carefully, and they represent various areas of the maritime industry. This gives the possibility to obtain results from different angles. Hereby is important to add that interviews were agreed to be confidential. The total number of interviewees is 5, and they represent seafarers (master mariners), VTS operators, lecturers from international universities and maritime academies, maritime administration, and IT spheres.

Chapter 4.1. will present the general data based on which the level of education, work experience in years, and current field of work could be defined.

In chapter 4.2. interview questions and answers of the interviewees will be demonstrated. Within some cases, additional leading questions were used to have a better understanding of the flow of thought.

5.1 Participants general data

Persons participating in the interview are working and representing various areas in the maritime industry. The level of experience was considered at the time the interviewees were chosen. Each participant has a confirmation that the interview is entirely confidential and no names neither organizations to be mentioned.

Participants mostly live in the European countries (Finland, Sweden, and Ireland), but concerning them here, it is essential to add that the cultures they belong to embrace a broader range which spreads outside Europe. All of them have been previously or now involved in international projects.

The introduction question group consisted of 3 questions. The age of participants is not an important aspect of this research. However, the level of their education, work experience, and current field of work was defined.

The level of participants' education is presented in Table 2, which demonstrates that 40% of persons have a bachelor's degree and the other 60% have received their master's degree. Master Mariners among them is 80% which makes it 4/5 in total. Moreover, one (1) of the respondents also expressed a desire to continue studies on a doctorate (Ph.D.) level.

Level of education	**№ of participants**	**%**
Bachelor level degree or similar	2	40%
Master's level degree	3	60%
Of which Master Mariners	4	80%

Table 2. Level of education of the interview participants.

The work experience of the participants (see Table 3) is quite impressive due to the number of years that they dedicated to the maritime industry and others. To give them tribute, it is highly important to list all the areas in which they have been part of: education (university and professional seafarers training) sector, seafaring, VTS operators, maritime administration, and Information Technology (IT) sphere. Their work experience is expressed in years and presented in Table 3. 80% of participants have work experience which exceeds 20 years which indicates how competent and qualified they are.

Work experience in years	№ of participants	%
More than 20	4	80%
Less than 20	1	20%

Table 3. Work experience presented in 20-year period and percentage.

The current field of participants' work shows a variety of possibilities that people have after graduation. Bearing in mind that 80% are previously graduated as Master Mariners and nobody among them not presently working at sea. This being a sign that the education received has been a good start for their future career. Figure 15 represents the current field of work of the participants according to sectors. For that matter were used following criteria:

1. Education – participant works in a university, taking part in additional training of seafarers or been a member of the educational sector in any other similar way,
2. Authorities – participant works in any department of the Maritime Administration,
3. IT sphere – participant works in any company related to IT support, cyber security, or any other similar.

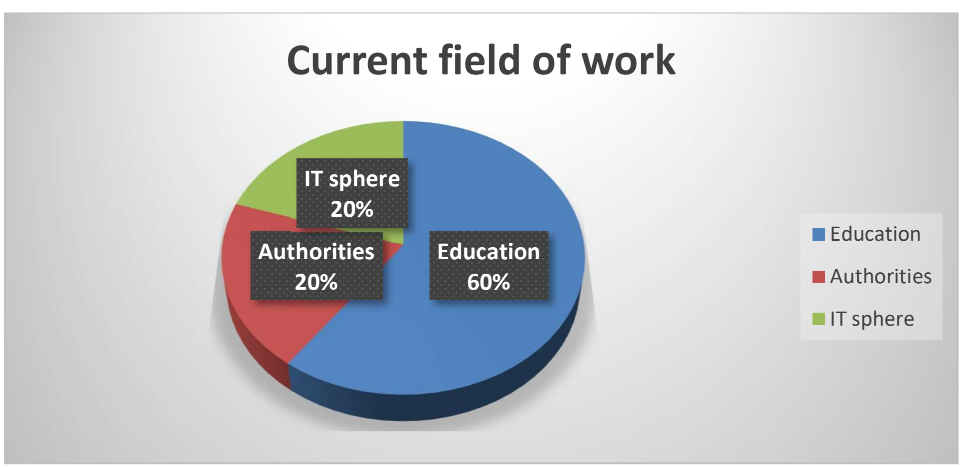

Figure 15. The current field of work of the participants according to the sector.

According to Figure 15, 60% of participants being a part of the educational system, 20% are engaged with various authority-related works, and the remaining 20% following their intended path in the IT sector.

5.2 Interviews

Preparation for the interviews was performed in advance, and a questionnaire was completed based on the idea presented to the interviewees. The date and time of the interviews were personally agreed upon with each participant individually. Meetings were conducted via Teams after lunch or during the evening time. Interviews were completed during the period from the 22nd of March and 2nd April 2021. There were no stressful facts or pressure, participants were informed about the structure of the meeting.

At the beginning of each interview, they were asked how they are feeling themselves and some other random questions to make them feel comfortable. Then participants were informed that the interview is planned to be recorded, and they were asked regarding the agreement. Each interview lasted from 1 to 2 hours, depending on the subjects discussed.

Discussions of the interviews were recorded, and the transcript of records was also performed later. Recordings and transcripts of records are saved to the author's hard disc drive (HDD), deleted from laptop and applications where the interviews were recorded. Location is safe and not accessible to anyone, excluding the author. Preparation of each transcript of records demanded from 3 to 5 hours.

The interview was divided into several parts, the first one, the introduction question group, was already mentioned in chapter 4.1. The next part started with the PowerPoint presentation in which the idea of the new approach of learning environment was introduced to participants, in this thesis is presented in chapter 2. And the third part consisted of 9 questions that were related to the subject introduced in the PowerPoint presentation.

5.2.1 Discussion with participants in Teams

Discussions with all participants took place in Teams environment. This was performed that way due to COVID-19 pandemic restrictions and their actual location abroad. All the questions asked from participants were according to the PowerPoint presentation, which included a shortened introduction of the idea represented in chapter 2. The topic with the idea of a new approach to the learning environment was presented to each individual and lasted about 25 minutes. After that, questions were asked, and participants were also welcomed to express their feelings on the presented subject.

In this chapter, each of the 9 questions will be introduced, and the purpose to be explained. Answers with high importance will be presented in the form of quotes. The analysis of the received information is carefully studied and available after each question-answer section.

1stQ. In your judgment, was this idea proposal a major, minor improvement, or not an improvement?

The purpose of this question was to understand how interviewees evaluate the approach to the idea of teaching AI by using the convoy method and implement it inside the safe transit corridor. Each of the persons asked answered this question based on their own experience and the potential of the action presented.

Three of five were convinced that the idea could become a major improvement in the maritime industry. One of the participants could not define whether this improvement is a major or minor one, but the improvement without any doubt. And one more of the interviewees thought that this is an improvement but with different parameters to consider.

1. *„The thing is to bring it to the real traffic, which is the big weakness of the most test sides... until that you can't really prove anything, you cannot build up trust".*
2. *"I do not see a problem as long as autonomous vessels and manned vessels stay apart, but so, therefore, it is pretty good that you have these corridors for ".*
3. *" The area where you want to traffic is new for me, but the idea development is something which has been quite a lot in the way of projects ongoing last 5 years".*
4. *"It could become an improvement if all the safety issues will be solved".*
5. *"In terms of the maritime industry and existing solutions that we have there because, in the end, it is all about creating a solution to solve the problem, at large scale extent".*

Interview participants made it clear that the idea is being an improvement. The biggest challenge here is no live traffic interaction because this is the only way to build up trust and prove the fundamental knowledge for the vessels. Moreover, ports may be concerned regarding the testing period and conditions in more open space areas rather than in port areas.

Here is also a question of data transmission possibilities and the amount to be transmitted from ship to shore via satellite.

One of the respondents thought that the perception of younger and older seafarers would be different, their understanding of the actions of the convoy. This is why the proposal to give a convoy and autonomous vessel a right to be a stand-on vessel could be reasonable.

Safety issues being a point of interest because the technology exists, but there is no total integration of the systems between all of them. But the future could be in combining AI equipment with sensors and teach it how to interpret the COLREGs. If we are going to be able to solve the more significant problem by teaching AI and using already existing means, it may become a road to success.

2nd Q. Have you heard anything similar to this idea before?

In this question, the purpose was to find out whether participants have seen, read, or heard anything similar to the presented idea. This was necessary to have a complete picture of the analysis performed in Chapter 3 regarding previous research. Interviewees answered differently because of their experience within various fields.

1. „This is the first time I heard this idea or anything similar to this. That's quite a unique idea".

2. „Not really. Maybe more we have been told about different shipping lanes for manned and unmanned vessels".

3. „We have been involved with the MonaLisa project and are still involved in the Sea4Value project where these types of ideas are a goal. I have heard about it but not the way precisely the area where this type of traffic should be started.".

4. „Only that there must be particular areas or traffic lanes for autonomous ships, in that sense connected".

5. „Not in terms of maritime industry".

Some of the participants stated that they have heard about the idea of the different shipping lanes for the manned and unmanned vessel but not in the way presented in this thesis. The consideration that this could be a good solution to move on having specific areas and then start to implement the autonomous ships into this environment. Undoubtedly, in combination with lights, shapes, signals.

One of the participants who have less experience in the maritime industry stated that nothing similar comes to his mind in connection with the maritime industry. But indeed, the aviation industry owns some knowledge.

3rdQ. What do you think is the maritime industry is ready for starting to consider such kind of idea?

We have all heard of quick technological solutions and slow work of the IMO. What does it really mean for the maritime industry? The readiness of shipowners and other organizations from different points of view was welcomed during the discussion of this question.

1. "Anything that could reduce the cost of implementation will be good. And I think it gives comfort that there is another vessel supervising it".

2. "Yes, I would say that especially ready to consider this idea, but in the maritime industry, it is also always a question of if there is something to win, moneywise in this case".

3. "Maritime industry and especially ship owners are always interested in the way how they can earn more money. The question is that what will be the cost...".

4. "Absolutely, the industry has created appliances to support different types of autonomous features".

5. "Maritime industry is far behind in many things, especially legislation. Right now, everything will stay on the experimental level".

The majority of the answers implying the financial aspect of the idea. In case shipping companies are interested in the development of autonomous vessel ideas and find this an opportunity of the business case to reduce costs, then it may become real.

Focus on the industry ideas needed because if one of the shipping players will be interested in the potential and become a leader, then the rest of the players will get after him eventually. Besides, the legislation is also moving forward but slower than the technology. There is a possibility to solve some of the problems regarding these vessels on the national level because we are not aware of when it may become an international issue. In the case of this idea, Finland and Estonia (referring to 2nd research question) may perform steps forward in their legislation to make the event happen.

Emergency procedures for this type of learning should be thought out and provide more than one option. For example, if the “daughter” vessel is not being under command for some reason, then the crew must take over. The second option is to send the “mother” vessel crew by fast rescue boat (FRB), and for that case, a pilot ladder could be rigged during the operation as an additional safety precaution. Moreover, there is also a possibility to have an extra crew on land always ready for action. They could be transported to a “daughter” vessel with the help of a coast guard boat or by helicopter.

The maritime industry is having difficulties in being modern and revolutionary aspects take time to be adopted. For that time, technology could become outdated. Therefore, one of the interviewees points that out talking on the practical level. It also means that all the trials are performed in a closed environment in designated areas mentioned in Chapter 1.

4thQ. What are the good things about the principle of teaching AI using the convoy method? What are the strengths and opportunities?

AI could be taught using various techniques and measures. Mathematical calculations, repeatedly performed actions, trial and error method or with the help of the experienced experts. Human thinking cannot be presented to AI in the way of calculations because sometimes it cannot be defined in numbers. Some may say that human could perform non-logical actions which might be committed contrary to the rules.

1. “It is good to see how humans think; AI is getting to observe what the human-manned vessel can do and to learn from them. At the moment, nobody knows do we change the COLREGs, do we need an entirely separate Code for these vessels, do we separate them, do we mix them with the normal traffic and make them behave the same”.

2. “I would say that having so-said “mother” ship there gives quite a lot more safety. You are kind of combining, but you still have somebody there, kind of looking after it. Not totally unmanned, good starting point”.

3. “The good thing is that, from my point of view, is that it could be done in that way what you are planning”.

4. “You do not mix your feelings in the analysis when it is done by technology”.

5. “Continuous improvement, integration, development. That is the major trend in the development of AI”.

Following this idea, a new training tool will be created. It may consider not standard paths or actions but different human actions among different crew members with their views and opinions. They will decide when to alter the course and to what extent. This process will become an accessible learning environment on when to start maneuvers and to save that by AI. In this idea, everything is planned to be done in the open sea, natural environment with live traffic around not just planning it in the computer program-based environment. Avoidance of separation of two types of the traffic is not possible, even preparing for them different corridors, traffic will always stay mixed. This is an opportunity to show the reality of what ships will face in open seas and oceans. It could become the future of short sea shipping.

During the interviews, it was also clear that some of the proposals offer interest to participants. They have never heard before about the actual proposals of certain lights, shapes, or sound signals for the autonomous vessels. According to Porathe (2019), some basics were taken as a starting point for considering real ones in this thesis. Hard to tell whether it is a good proposal or not; it must be decided during the trials. It may be helpful to provide the industry with the answers. If the coastal states are not happy with the lights and shape proposed, then they can use their own.

The presence of the „mother“ vessel ensures safety which means that there will still be someone in the vicinity taking care of the „daughter“ vessel, and she will not be left on her own. And also the positive feedback about the time while the safe transit corridor will be used. It is planned to be limited: a short period „in action“ and to be under surveillance each time. The speed of the convoy must not be very slow; it must be higher than during the towing operations in order not to cause unnecessary inconvenience to cross traffic.

In the beginning, the AI could propose further actions during its learning process. As long as there would be an Officer of the Watch (OOW), he or she can accept the maneuver proposed or not (an idea similar to autopilot). Later it may be done by a remote operation center team member. This action will be a confirmation that all of the decisions AI is making are right and appropriate for the prevailing circumstances and conditions. From the IT point of view, the continuous integration and development of AI matter. For the learning process in the past, we used to wait for the result until we had all the desired outputs. Nowadays, it is possible to improve the failed input and apply it again right after it has been improved.

The phenomena of the digital twin are not used because, in the case of this idea, there would not be an aim achieved. The interviewees agreed that the digital twin phenomena work in a better way with the machinery features, and the „daughter" is always under the control of her „mother" escorting her.

Shipping can not take the same path as aviation and agree only on the different corridors. Here, in this case, we do not have a benefit of the third dimension; shipping corridors can not be located on different altitudes (see Chapter 2).

The strength and future opportunity of this idea could save the industry from the influence of the viruses such as COVID-19. Traffic will not be stopped because of the infected or sick crew member, which may pose a danger to the whole crew.

This idea has its strengths because of the clear vision and the limited number of features: the safe transit corridor and "mother" and "daughter" vessel proceeding in convoy. This is the supportive answer to 1st research question of this thesis. These features are not connected to one place but could be shifted and implemented in different regions where the traffic density and safe navigational situation will allow this. This is a continuous process that ends when the "daughter" and AI become mature enough to operate independently. Then the process will be completed.

There are many opportunities for this idea in the future perspective which involve such factors as safer navigation, faster traffic and transportation, fuel-saving, the next generation of identification systems, situational awareness.

5thQ. How do you feel about the implementation of a safe transit corridor into this idea?

The intention is to understand how safe this area becomes if autonomous vessels are going to operate there. For this purpose, the safe transit corridor is proposed as a potential safety measure.

1. "Easy way to ensure safety. It is charted, everyone is aware of this; you have your virtual AIS, which gives additional safety. It means you can test it in open seas with the traffic with additional safety measures in place".

2. "Implementing, it is a good idea. Clear from other traffic during the passage".

3. "I think it is quite a clear presentation of how it should be like. It should be clear and as simple as possible, that is about putting it on the map and in reality".

4. "Depends on the area. Virtual fairway and the buoys have to be frequently placed".

5. "Unless we do not have any validation and verification from the program, it is hard to define the safety of the safe corridor. But we have a vision; this is a good start".

The implementation of the safe transit corridor will compensate for the lack of confidence and show that the additional measures and checks are performed. Governments must have insurance that the operations with autonomous vessels could be performed safely; the safe transit corridor is the option for that. It is not going to be accessible in a legal way. But permitting them only in certain areas and specific routes could become an essential feature. Using the safe transit corridors could guarantee additional safety for leisure vessels because, for them, it is a confidence that they would be detected. It may become possible due to the constant monitoring of safe transit corridors when convoys and autonomous vessels operate inside.

There are those parts of the world where those corridors will never be implemented because of the heavy traffic. European Union (EU) prepared operational guidelines for safe trials performed by MASS where actions which should be considered by Administration are available (European Comission, 2020). The ship Safety Zone for MASS trials is quite similar to the vessel's precautionary contour described in Chapter 3.

The area where the safe transit corridor be will define safety. If there are less traffic and other moving variables, then it could become safe. But in the long run, it would be safe because of the development of technology. The situational awareness from other ships must be good when navigating near the area of the safe transit corridor. Fatigue and human factor can play an unexpected role at any time. But their attention may be attracted by the buoys or group of buoys on the radar which will embrace the safe transit corridor. In addition to this, the convoy indeed can send precautionary messages to the vessels being in close vicinity to the corridor.

A safe transit corridor has to be tested in the simulation environment first and then in the real one. As long as the concept of a safe transit corridor will be developed and improved, the risk mitigation feature will be there.

6^{th}Q. How it seems to you, is the plan on separated responsibilities between organizations that could simplify the implementation of the autonomous vessels' phenomena into life?

Separation of responsibilities is only one of the options. The purpose is to understand it is worth it. It may seem more straightforward to keep the monitoring on the one hand, but still, other options exist.

1. "I am not sure. There is the possibility that VTS will be concerned about it if somebody else will have an authority".

2. "Hard question. Maybe it is good, make it easier to implement this".

3. "If you are thinking about the risks, so my point of view that there are no options to give any responsibilities for the VTS station about the traffic. They are, of course, supervising it inside all areas for sure".

4. "When you have several parties or organizations which need to work closely together, it is necessary to define rules and boundaries very clearly. It is difficult because written information could be interpreted in many ways which create risk for mistakes".

5. "It could become more standardized; they will have fewer factors to consider with fewer variables (per person). Exact path and dimensions are known, areas of crossing".

Some of the interviewees were not sure whether it is a good idea to separate the responsibilities of VTS and ROC. VTS may be concerned that somebody else will have authority; they must be involved aside and be in direct contact. All in all, if they are still going to be divided into two organizations, then the direct contact and real-live communication or working from the same building or room to be highly appreciated. There are other possibilities for how to perform cooperation. One is the idea of route exchange which comes from the MonaLisa project (Swedish Maritime Administration, 2021). In this case, the VTS could ensure safety by monitoring any routes of the vessels approaching the area. There is also an agreed route plan exchange format S-421 proposed by the International Association for Marine Electronics Companies (CIRM) (CIRM, 2021). Adoption of a standardized data transfer format is essential.

Enhanced Navigation Support Information (ENSI) service was used in the GOFREP area for safety and to reduce any possibility of oil pollution accidents. For that, the planned route was sent to ENSI and checked there. In return, the crew could use other services, e.g., meteorological information and ice conditions. (Hänninen, Mazaheri, Kujala, Laaksonen, & Salmiovirta, 2012) This is the first route exchange procedure known used in the GOFREP area since 2009.

One of the participants also thinks that VTS will have a significant role in the future. In comparison to aviation, where dispatchers are monitoring various areas, and there is a certain amount of them in place.

7th Q. Which education and field experience are needed for people working on "mother" and "daughter" vessels and VTS and remote operation center team?

Future education is one of the pieces of the puzzle. The process has to be well-thought-out and improved. Due to this, some areas will be supplemented, and some will be removed from the educational program. New education plans and training will be created because of the appearance of new specialties and specifics of work. But in any case, it must be done under STCW.

1. "Training in situational awareness with the theory of making a decision about the vessel where you are not standing, on a vessel which is actually away. I think that the knowledge in sensor fusion is needed, as well as communication".

2. "I would say that maybe some extra training besides being OOW, a little bit more technical training, IT. VTS operators do not need that much training, a little bit of understanding a new system. Remote operation center – more training, IT, depends on their background for those who are going to be in the ROC".

3. "I don't exactly see that we should as a seafarer start huge studies for the programming software. The intelligence of the vessel should be in the level where it clear but not like the engineers want to see this".

4. "On the short run – the Master Mariner education, on the long run – more technical kind of information. Communication skills are essential. IT, Master Mariner and Electro-Technical Officer (ETO) would be a good combination".

5. "Combination of marine technology and maritime management with seafaring background".

Additional training in situational awareness means that training in latency of signals and potential delays must be carried out. Moreover, actions when the operator will lose the communication, e.g., performing a circulation of the vessel, making it stop automatically, going astern, choosing the anchor mode, or even dynamic position (DP) mode. But the understanding of the danger must be presented as for person in charge (PIC) standing on the "mother" vessel or even being onshore in ROC. Previous experience and further training needed for better decision-making in the key areas. Sea experience of the future is becoming a hot topic; some parts probably could be performed in the simulator class.

Extra training for OOW with a more specific technical and IT background is needed. VTS operators have to understand a new system and how the "mother" and "daughter" vessels are going to operate. This is essential to inform crossing traffic about the new feature, the convoy. With the ROC operators, their background, and also training, it is more complex; they have to represent seafarers and be qualified experts not only in navigation but also in understanding the maneuvering characteristics.

Seafarers and those who have worked at sea are preferred choices because they can make quick decisions based on experience and manage variables. Their knowledge in the field of technology will become a priority.

A mix of IT, Master Mariner education, and Electro-Technical Officer (ETO) knowledge could become a good combination for all the future experts, not only working on a ship but in VTS and ROC. It means that malfunctions could appear even in the shore center, and some basic knowledge of the systems could become a must-have condition.

8thQ. Does this idea need any improvements; how do you feel about it?

Anything which on the interviewees' point of view missing in this idea or they think that it could be even improved to suggest a higher level of safety.

1. „The digital connection between vessels must be shown in a way when other vessels will understand that two of them are virtually/digitally interconnected".

2. „Method for connecting a tow to the unmanned vessel, it has to be identified how to do this and then training and carrying out a practice".

3. „The only thing I'm thinking about are still those small vessels who don't have AIS. And keeping them away".

4. „Digital connection between the vessels in case of backup could also be substituted by rope/line".

5. „Making them behave as a normal vessel and implement it in traffic. And, of course, the COLREGs maybe are a topic of change.".

The line between vessels could be used as a backup option but in the case when it is essential. It is not rational to connect them because it will affect the maneuverability or speed of the „daughter" vessel. The connection between them is planned to be digital and could be seen virtually on the radar and ECDIS screens.

For future needs and other corridors may be used a more significant number of „daughter" per one „mother". This could be implemented in ocean voyages; during the short sea voyages, it will not be practicable because the safe transit corridor could be pretty short (between Muuga and Vuosaari only 15,1 nautical miles as mentioned in Chapter 2.1.

Like with every vessel, the autonomous vessel can break down as well. The coastal state will be interested in towing operations of these kinds of vessels. One of the ideas which came to mind during the interview is the automated mooring technology mentioned in Chapter 1 (Cavotec, 2018). An autonomous vessel's hull could be built in the way the vacuum and magnet mooring fenders work. Then the tow could quickly come alongside like to the berth, perform "mooring operation," and tow the autonomous vessel to the closest port. No extra lights or signals will be needed because it is an ordinary towing operation.

Besides, during an interview, one of the proposals was to implement these kinds of vessels into traffic and make them equal with manned ones. This means that autonomous vessels should behave as manned ones and make all the maneuvers according to COLREGs (International Maritime Organization, 2003). This is an idea that will have its approval only during the trials. This is the way to understand which approach will be suitable for the maritime industry and approved by society and various organizations. And the COLREGs in this case, to change or not to change them and which Rules. This depends on trials and the implementation of autonomous vessels into a manned traffic environment.

Regions where autonomous vessels operate, could be marked and known in the same way as the buoyage, IALA A, and B regions. For autonomous traffic, similar areas could be implemented. Information regarding this could be available from Nautical Publications (NP) of British Admiralty (BA) or other coastal states publications and sources.

From one of the points of view, it is hard to say what improvements are needed. Nowadays, everything is about implementation in comparison to the past when it was more about research and planning. As well as the intention and the idea are new, and it is something that is not yet existing, then it could not be improved.

9thQ. What are the biggest challenges and risks of teaching AI using the convoy method and corridor? What are the weaknesses and threats?

Risks have to be dealt with in any operation, and the challenges are still going to be there; it is an inevitable matter.

1. "Potentially limited learning, only from one vessel and a limited number of people. It may take time to build enough different types of operations".

2. "Threats, always when the AI learn too much. But also learning from manned vessel operator, it can be quite difficult. They are not always following the COLREGs".

3. "If we are thinking the market, there is no risk; it is coming anyhow. The only hope is that the IMO could be a little bit faster to put it in force and use. Then of course shipowners, whether they are interested in this, if it will exist".

4. "If you assume that this concept works technically and otherwise and this is safe then also assuming that one teaching, has all the skills and knowledge needed to teach, then, of course, the risk is on the receiver side".

5. "The bias is the biggest challenge; AI is highly biased towards different sources of data".

Algorithms may work well, but identical situations occur rarely, and even if the situation may seem similar, in this case, it has its distinctions. All the actions performed by the "mother" vessel have to be made at the right time to avoid any potential risk of collision. In other words, the 'daughter' vessel has to memorize only the right decisions and should be able to take into account the values of human behavior. For this matter, it could be an appropriate method how to teach her using that expert's knowledge and their experiences.

As a solution for the 1st comment, the simulator could be helpful in addition to the live testing. In this case, the data will be collected more quickly to build up a complete data system for autonomous vessels. It means that participants from different countries can come and take a test on an actual vessel, and before that, they will be able to train themselves on the simulators choosing for that the same area with the corridor where they will do the trial on the "mother" vessel lately. It could also be tested from different angles, vessels, traffic flows, and scenarios, and the test area could be shifted to another appropriate location in the simulator program for training purposes. This will give the participants a complete picture regarding various orientations to receive knowledge and get experience. Information on testing of potential areas for future corridors could be used from simulators to assess whether an area is an appropriate one to start conducting trials there. Moreover, information on European traffic density is available via EMODnet, which could become a planning tool for use (EMODnet, 2021).

In order to ensure safety, various interest groups should be included in the process of developing the new technology. Trial exercises must be prepared by an experienced seafarer who understands how the ship behaves.

6 Discussion

In summary, after proceeded the path from the idea proposal to the completed thesis, it is essential to say that maritime experts see a perspective in the development of autonomous vessels. Either earlier or later but this phenomenon will be integrated into the shipping industry. Still, there are many options to be dealt with before it happens.

The standard business case in the way of the pilot project could become a beginning. In case the idea becomes successful and pays for itself that other companies will agree to join, then the process may accelerate. This action could increase the number of autonomous vessels included in convoys and the possible implementation of new safe transit corridors.

The proposed idea of combining the convoys and safe transit corridors is a new approach and may become a problem-solving issue for future research. Wiser to implement the autonomous vessels into manned environment step by step but not to change the whole industry because of this. This implementation can only be achieved by conducting actual trials in a testing area with traffic where the other participants are actual vessels. But if the legislation will not accept this approach, then it will stay on the practical level.

The presence of a „mother“ ensures even maritime professionals that safety being an essential part of the idea. The second factor is the presence of the safe transit corridor where the convoy must stay in any case other than an emergency. It means that there are designated limits for this concept. VTS and ROC participation is a matter of discussion because experts' opinions divided whether these two organizations to be under one or separated. But at the same time, it is a fact that they must cooperate closely.

Type of education processes separates STCW module courses and other subjects taught in universities. Old and not relevant programs have to be replaced by new ones, which will include the concepts of autonomy, autonomous vessels, and the future vision of the maritime industry. Even if it is difficult to predict the future, the programs must change at the same pace as the technologies produced. For this reason, not only the students and seafarers who need to study and refresh their knowledge must be a part of this process. It is crucial to keep in mind teachers, lecturers, and instructors who are responsible for the education and training of the latter.

None of the ideas are perfect and require time and dedication. For this, risks and challenges have to be accepted and dealt with because it is the only way how the solution could be found. Not only does the AI part have to be developed, but the participation of real maritime experts with various backgrounds will give an additional advantage.

6.1 Recommendations

Recommended actions on the whole process on how to start implementing the idea in the chosen region:

- Find and choose the spot where the safe transit corridor is planned to be implemented.
- Identify risks, prepare a risk assessment to detect all the possible complexities.
- Traffic density analysis and availability of safe water to perform emergency maneuvers assess the proximity of navigational hazards, e.g., shallow waters, anchorages, other no-go areas, etc.
- 4G/5G coverage of the area to avoid losing signal or connection ship-to-ship and ship-to-shore.

- Governmental level agreements to be a part of work inside one country or between multiple ones.

- Building prototype "mother" and "daughter" vessels or using already existing ones, instructions, and additional training for involved parties to be performed at the same time.

- Starting to collect data by using simulator tests with different participants, scenarios, and situations.

- Agreement on the safe transit corridor design, location of virtual special purpose buoys, etc., electronic and paper chart corrections available to everyone proceeding near or in the area with safe transit corridor.

- Development of emergency procedures for all parties: convoy, VTS, and ROC operators and also for other manned vessels.

- Starting the trials with the "mother" and "daughter" vessels increased attention and the maximum number of participants in the first stages (this number could be reduced in the process of AI becoming more mature).

- Record all the results and perform constant analysis of the decisions taken by seafarers, which AI is learning. At this stage, it is necessary to eliminate all possible wrong decisions.

- When the AI becomes mature enough, another approach of testing is needed. The AI has to propose to the seafarer which maneuver the ship is going to perform next. This could be accepted or declined, and the result to be saved in the memory.

- The final testing stage is performed in a way when AI is operating under the surveillance of the "mother" and ROC operator and making its own decisions based on the assimilated learning material.

- When all the stages are successfully performed, and the results will be considered satisfactory and safe, the AI will be able to operate a vessel from port A to port B via a safe transit corridor to deliver goods.

6.2 Future research

Research work for this thesis highlighted many new approaches and ideas for further research. The following subjects may become a beginning or possible idea for another master's thesis and Ph.D.'s:

1. Share route planning in ECDIS (online or with ECDIS update), which could be performed in real-time.

2. Implementing more than one "daughter" vessel in the ocean voyage convoys and with safe transit corridors away from busy routes.

3. Corridors in a different location and using the same "mother" vessels for teaching other "daughters" for different routes.

4. Emergency towing by using vacuum or magnet mooring systems techniques.

5. Distances and speeds of manned and unmanned vessels when approaching the safe transit corridor.

6. Convoy ship domain: united or its own for "mother" and "daughter" vessel.

7. Implementation of safe transit corridor idea into COLREGs.

8. Space convoys and safe transit corridors to avoid collisions with asteroids etc.

9. Safe transit corridors in underwater environments and similarities with the aviation industry.

7 Conclusions

For proper teaching, the AI must be ready to undertake different challenges. Still, AI is not yet that mature and must be closely supervised by professionals (Hynnekleiv, Lützhöft, & Earthy, 2019). From this thesis point of view, the AI must be taught most likely by humans to let it act more like a human in the future. As per research, the teaching can be performed in the form of a convoy method. In this case, it is reasonable to avoid twofold situations which may lead to misunderstanding on the part of other vessels. Therefore, it is suitable to use the convoy method inside the safe transit corridor. However, the locations of the safe transit corridors must be agreed upon in advance.

Interview participants mostly agreed that the idea of the safe transit corridor could have a positive impact by limiting the convoys with „mother“ and „daughter“ vessels from other traffic. Although, even though they are located in the separated feature still they are a part of the traffic along with the other manned vessels. This cooperation is suitable in terms of the implementation of “daughter” vessels with AI into manned vessel traffic environments. The locations for these vessels could be different but primarily short sea voyages close to the shore. To define those spots, traffic analysis of potential routes have to be performed not only from the navigational side but taking from account business and environmental issues.

During the research, the idea was presented to maritime professionals from different sectors. They could share their thoughts even not all of them have heard something similar to this idea before in the maritime sector. Moreover, they mostly agreed that this could become an improvement and that the maritime industry may be interested in this kind of approach. Of course, there is always a risk that innovative ideas like this could be left apart due to complexity and proximity to the practical level. Each idea and its implementation have advantages and disadvantages as well as challenges but hard yet to tell about any improvements needed.

Maritime professionals believe that the safe transit corridor could solve many of the problems which may become a stumbling block in the development process. Opinions regarding separated responsibilities were divided: some think that only one organization, VTS or ROC, should be in charge of the monitoring of convoys inside the safe transit corridor; others tend to think the contrary. But they are all agreed that these organizations, together or not, should be located in one building or room. The educational aspect was more or less clear – professionals working on the vessels and the VTS or ROC should be Master Mariners. Although they may have additionally performed other training, the IT and ETO background will be appreciated

All the findings and new ideas that appeared during the interview and its analysis are valuable findings. They are significant for further research on the same subject or could be implemented as a new idea for already presented one.

This thesis is the first step of starting an authentic conversation on teaching AI in the natural vessels’ environment. Until today the autonomous vessels were tested only in close environments without any potentially dangerous targets. All the scenarios were planned appropriately in advance, and the test was run accordingly. This thesis is considering some special features of the structure of the learning environment. Moreover, it shows a new possible approach for teaching AI human behavior and is similar to imitation learning. The above research could become a starting point for further developments, and the concept itself had positive feedback from the interviewees.

The area of the sailing for vessels approaching in convoy inside the safe transit corridor is limited to the "green" zone, in this case between Finland and Estonia. This study does not include the "yellow" zone, also known as the pilotage area, and the "red" zone, which is the port area. Vessels in convoy are the cargo ones, and this thesis does not include any circumstances regarding passenger ones. In addition, the number of vessels in convoy is limited up to two and does not take into consideration longer convoys. Furthermore, the concept does not provide the financial part with the calculations and does not intends to be reviewed as the business idea. Here are not presented calculations or any distances, e.g., between the vessels or the CPA. Nevertheless, all the limitations could become someone else's research on a similar subject.

The autonomous vessels are the future, but there is no clear vision yet. Right now is a good time to propose various ideas which may find their place in the future of this industry. The concept combines already existing features and procedures and taking them to the next level of technological complexity. The process of teaching vessels using the convoy method based on the towing and different kinds of backup or emergency procedures could be implemented to the "mother" and "daughter" vessels. Moreover, the area of their sailing is strictly limited up to one safe transit corridor, and they are allowed to leave it only in the case of emergency. This is the principle that is followed by all the vessels proceeding via TSS. However, every situation must be assessed closely and carefully before the decision to be made.

Finally, this is the future that we want to take part in and see with our own eyes. Convoying autonomous vessels at sea inside the safe transit corridor may give us a chance to have a closer look at manned and autonomous vessel interaction. Hopefully, the maturity of AI and its ability to better understand humans and their actions will play a role here. The better the machine will understand human behavior, the easier it will be to teach and educate it in the appropriate direction.

7.1 Acknowledgments

In conclusion, performed research was a long way from one little idea into that colossal thesis. The idea came into mind in August 2020. This process took an enormous amount of time, but I enjoyed all the ups and downs, no matter what. Literature reviews, writing

process, conducting the interviews, transcript of records – this is a challenge (including COVID-19 issues and travel restrictions) what is worthy of being lived through.

I would like to thank each and everyone who performed this journey with me from the beginning to the end: my family, colleagues from work, and also the great AMO team from Novia UAS. People who supported me at any stage of my thesis by performing brainstorming activities, discussions, etc. I will not be here without any of you.

For those who are still working on their thesis: be strong and remember that there is nothing impossible. If you have an aim, then you will find your way, even if it will be long, complex, and full of obstacles. Start at the right time and constantly observe your progress. In addition, do not hesitate to ask for help because you may need it.

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Abbreviations

AI – Artificial intelligence

AIS - Automatic Identification System

ARPA - Automatic Radar Plotting Aids

AtoN - Aids to Navigation

BA – British Admiralty

CIRM - the International Association for Marine Electronics Companies

COLREGs - Convention on the International Regulations for Preventing Collisions at Sea

CPA – Closest Point of Approach

DP – Dynamic Position

ECDIS - Electronic Chart Display and Information System

ETO - Electro-Technical Officer

EU - European Union

FV – Following Vessels

FRB – Fast Rescue Boat

GMDSS - Global Maritime Distress and Safety System

GOFREP - Gulf of Finland Reporting System

HDD - Hard Disc Drive

IMO - International Maritime Organization

IRTC - Internationally Recommended Transit Corridor

IT - Information Technology

LIDAR - Light Detection and Ranging

LNG - Liquified Natural Gas

LV – Leader Vessel

MASS - Marine autonomous surface ships

MAXCMAS - MAchine eXecutable Collision regulations for Marine Autonomous Systems

NAVTEX - Navigational Telex

NFAS - Norwegian Forum for Autonomous Ships

NGOs - Non-Governmental Organizations

NP – Nautical Publication

NUC – Vessel Not Under Command

OOW - Officer of the Watch

PIC – Person in Charge

P&I - Protection and Indemnity

RAM – Vessel Restricted in her Ability to Manoeuvre

ROC – Remote Operation Center

RIA - Robotic, Intelligent, Autonomous

STCC - Ship Traffic Coordination Center

STCW - International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers

STM – Sea Traffic Management

SVAN - Safer Vessel with Autonomous Navigation

TCAS - Traffic Collision Avoidance System

TCPA – Time to Closest Point of Approach

TSS - Traffic Separation Scheme

VHF - Very High Frequency

VT – Vessel Train

VTS - Vessel Traffic Service

Annex 1. Questions for the interview

1stQ. In your judgment, was this idea proposal a major, minor improvement, or not an improvement?

2ndQ. Have you heard anything similar to this idea before?

3rdQ. What do you think is the maritime industry is ready for starting to consider such kind of idea?

4thQ. What are the good things about the principle of teaching AI using the convoy method? What are the strengths and opportunities?

5thQ. How do you feel about the implementation of a safe transit corridor into this idea?

6thQ. How it seems to you, is the plan on separated responsibilities between organizations that could simplify the implementation of the autonomous vessels' phenomena into life?

7thQ. Which education and field experience are needed for people working on "mother" and "daughter" vessels and VTS and remote operation center team?

8thQ. Does this idea need any improvements; how do you feel about it?

9thQ. What are the biggest challenges and risks of teaching AI using the convoy method and corridor? What are the weaknesses and threats?