Automatization of the maritime transport versus job availability

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Abstract

The shipping industry is one of the main employers globally. Wide use of the unmanned autonomous vessels in the future will change this role of the maritime transport. The study applies scenario analysis at company level to estimate how the availability of working places for navigational and deck crews will change due to transition from conventional vessels to autonomous one. Four scenarios were elaborated to estimate the number of people required to navigate and maintain a fleet of 10 vessels. Three future scenarios which assumed ships with certain degree of automatization were compared with the baseline scenario which considered the conventional vessels. In the Baseline scenario the fleet of 10 conventional vessels required 190 people. The ships with reduced crew in Scenario 1 required 121 people or 36% less compared to the Baseline scenario. In Scenario 2 the fleet of remotely controlled vessels needed 96 people or 49% less than in the Baseline scenario. The most technically advanced fully autonomous unmanned vessels in Scenario 3 could be operated with 90 people that is 50% less compared to the Baseline scenario. This study showed that automatization of commercial ships can lead to reduction of jobs available for seafarers with traditional maritime education.

Language: English
Key words: autonomous ships, scenario analysis, availability of jobs

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1 Introduction

The maritime transport is one of the pillars supporting world trade. About 90% of all goods traded in the world are transported by ships. In 2018 global maritime trade account for more than 11 billion tons (UNCTAD, 2019). Bulk raw materials, agricultural products, industrial equipment, and consumer goods are transported over oceans. There are over 50 000 merchant ships and more than 1 million seafarers sailing on international routes. The annual income from operation of the merchant fleet is over $500 billion (ICS, 2020).

Merchant vessels are technically complex and expensive assets. This type of transport uses the latest technological achievements to be competitive and safe. Technological complicity of the maritime transport is the result of thousand years of technical progress when centuries of slow development of shipbuilding technologies are followed by rapid technical revolutions.

1.1 Development of the maritime transport

Thousand years ago, the history of ships began from the single tree stem hauled into water by one of our ancestors. This first watercraft was only able to float on water surface and carry very limited load. Slow and unstable, these tree watercrafts did not make possible crossing of large water areas nor transport of cargo. Some improvements in terms of stability and carrying capacity were only achieved when people learned to build rafts connecting several stems side by side using plant or animal fibres. Unfortunately, until now no archaeological artefacts were discovered which would help us to understand how these ancient rafts were bult, how they look like and how they were used. We can only assume that these rafts were able to cross relatively large water areas such as big lakes and inner seas. However due to very limited manoeuvrability and poor weather resistance they became a "dead-end technology" in shipbuilding.

No one can say exactly how many years passed from the very first rafts made of round wood until someone removed inner part of tree stem to build the first boat. This was the first technological revolution in shipbuilding. Even the very first boats were more manoeuvrable and faster than the rafts. One of ancient boats, known as Pesse canoe, can be seen in the Drents Museum in Assen, Netherlands (Figure 1).

Figure 1. Pesse canoe

The Pesse canoe is 298 cm long and 44 cm wide and was found in 1955 during the construction of road in Holland. According to radiocarbon dating the boat was made during the early Mesolithic period or 10 000 years ago (Drents Museum, 2020). This archaeological discovery demonstrates that a boat type watercraft was known at least for 10 000 years.

The second technological revolution happened when sails were invented. The time of the invention is not known. The sail combined with oars added wind power to human's muscles extending the range of vessels, their speed and safety. Probably the very first sails were made of animal skin or plant fibres. These sails were likely stretched between poles installed on ancient rafts and boats to utilise wind power. It is not known who and when began to use cloth sails. There are archaeological evidences showing that already 5 500 years ago, in Egypt, boats equipped with cloth sails and oars were used to transport obelisks on the Nile (Encyclopædia Britannica, 2020).

Figure 2. A wall painting from ancient Egypt shows a boat on the Nile River (Orti, n. a.)

The invention of the sail became the most important technical achievement in the maritime transport for the next several thousand years. Sails were the main ship's propulsion system for centuries. The great geographical discoveries, intercontinental trade and trips around the globe became possible owing to sails. Supremacy of sail ships lasted for thousand years until the era of steam engine.

The first commercially applicable steam engine was built in 1712. More than 60 years passed before a boat was equipped with a steam engine. With invention of a steamboat ships became independent from winds and currents. Steamboats were actively developed in Europe and in the United States. Figure 3 shows one of the first steamboats built in 1787 by John Fitch in the United States.

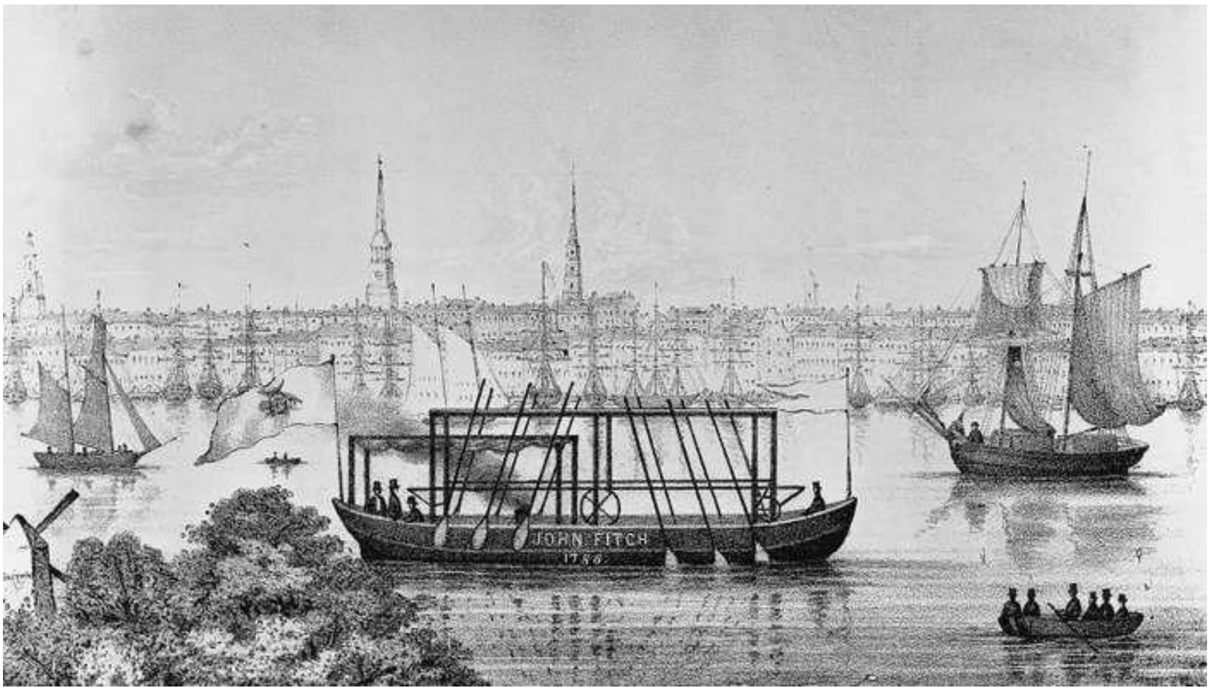

Figure 3. Steamboat (Encyclopædia Britannica, 2020)

In the beginning (1776 – 1807) the steam engines were used only on vessels for inner waters. It took more than 100 years of technology development until the first sea going steamboat Experiment (former French lugger) made voyage from Leeds to Yarmouth in 1813. Already 6 years later, in 1819, an American coastal packet Savannah equipped with an auxiliary steam engine crossed the Atlantic Ocean in less than 28 days (Encyclopædia Britannica, 2020).

After the steam engine revolution, the maritime transport passed through more than 100 years of steady technical evolution. During these years merchant vessels became bigger and safer, paddle wheels were substituted with propellers, diesel engines took over steam engines, navigational computers, gyrocompasses, and GPS replaced paper charts and magnetic compasses. However, the basic definition of ships, a surface watercraft with a crew on board, has not changed for thousands of years.

1.2 The new era

Now the maritime transport is in the beginning of a new technical revolution which will bring into practice new types of merchant vessels. These new vessels will not differ much from the existing merchant ships in many aspects, but still they are expected to make remarkable changes in economics of the maritime transport and to affect the human society. This will happen owing to the only one feature which differs these new vessels from the existing one – the upcoming types of merchant vessels will require onboard a very small or even no crew at all.

In 2018 the International Maritime Organisation (IMO) adopted new term to describe these vessels: "Maritime Autonomous Surface Ship (MASS) - …is a ship which, to a varying degree, can operate independently of human interaction" (IMO, 2018). Degrees of ship automatization are shown in Table 1.

Table 1. Ship types according to the degrees of automatization (IMO, 2018)

Ship type	Degree of automatization	
Conventional ship	Ship with automated processes and decision support	Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated
Reduced crew ship	Remotely controlled	The ship is controlled and operated from another location, but seafarers are on board
Remotely controlled ship	Remotely controlled	The ship is controlled and operated from another location. There are no seafarers on board
Fully autonomous ship	Fully autonomous	The operating system of the ship is able to make decisions and determine actions by itself

The main drivers for the development of MASS are to promote efficiency of the maritime transport and improve safety of navigation by minimising the probability of human errors. Also, automatization of the maritime transport will decrease operational costs by reducing labour costs. According to the Review of Maritime Transport 2019 (UNCTAD, 2019) labour costs account globally for more than 22 % of revenue of the maritime transport.

Another important driver for upcoming technical revolution is mitigation of human errors. The study carried out by the Allianz Global Corporate & Specialty, a global corporate insurance carrier, analysed maritime accidents occurred during 1912 – 2012. The findings demonstrated that human error was involved in most (75 – 96%) of the studied marine accidents (AGCS, 2012). In the follow up study almost 15 000 marine liability insurance claims between 2011 and 2016 were analysed. The results of the study (AGCS, 2019) showed that human factor was a primary reason for 75% of the value of all claims analysed – equivalent to over $1.6 billion of losses. The annual study of marine accidents done by European Maritime Safety Agency (EMSA, 2019) found out that about 66 % of maritime accidents occurred due to inappropriate manoeuvring or fatigue. Special emphasis is put on safety of navigation because remote controlled and autonomous vessels need to be at least same safe as the existing conventional vessels to fulfil the industry standards, legislation and to be accepted by the professional community and the society (DNV GL, 2018).

Automatization of the maritime transport is also called to balance shortage of professional seafarers. The global fleet of merchant vessels is continuously growing in numbers showing almost perfect correlation with the world's GDP growth (HSBA, 2018). The Manpower Report published by BIMCO & ICS (BIMCO & ICS, 2016) predicted by 2025 a shortage of near 150 000 officers that corresponds to more than 18% of the global demand for officers on ships.

Large green-field investments (Frost & Sullivan, 2019; Bajpai, 2020), first trials (Rolls-Royce and Svitzer, 2017) and new legislative initiatives (IMO, 2017) indicated that technical progress in field of MASS will soon result in the commercially applicable technology (DIMECC, 2018). Table 2 shows the expected development path for remote controlled and autonomous vessels.

Table 2. Expected development path for remote controlled and autonomous vessels (Rolls-Royce, 2016)

Timeline			
2020	2025	2030	2035
Reduced crew with remote control support, remotely controlled local vessels	Remote controlled unmanned coastal vessel	Remote controlled unmanned ocean-going ship	Autonomous unmanned ocean-going ship

Numerous research and development projects are going around the globe (Rolls-Royce, 2016; Haraldsen, 2018; BV, 2019). In 2017 in Copenhagen harbour, Denmark, Rolls-Royce and tug operator Svitzer demonstrated remote control of a commercial vessel. The 28 m long tug Svitzer Hermod conducted several manoeuvres being remotely controlled from the shore.

In Finland, the Rolls-Royce Marine together with several other companies and Finnish universities launched in 2016 a project “Advanced Autonomous Waterborne Applications”. The project funded by TEKES (Finnish Funding Agency for Technology and Innovation) has the aim “to develop the specification and preliminary designs for a proof of concept demonstrator by the end of 2017 and a remote controlled ship in commercial use by the end of the decade” (Rolls-Royce, 2016). First trials were done in 2018, when a conventional costal ferry was converted to a fully autonomous ferry vessel and made several voyages between Parainen and Nauvo in Finland (Rolls-Royce, 2018).

The beginning of commercial use of remotely controlled and autonomous vessels will change the shipping industry. The effect will spread over the maritime industry and affect also other sectors of the world’s economics. The shipping industry employing globally, provides more than 1 million people with solid income. Wide use of the unmanned vessels will change this role of shipping in the society. Considering the current input of the shipping industry into global employment the consequences of transition from the conventional ships to the remotely controlled and autonomous vessels must be investigated and clearly identified (DNV GL, 2018).

2 Aim of the study

The ongoing research and development activities related to the remotely controlled and autonomous vessels are focused mainly on technical and economic challenges, leaving aside social implications of the technology (Wariishi, 2019) . Among the industry players there is growing concern (ITF, 2017), (Rolls-Royce, 2016) about possible disruptive consequences of rapid transition from the conventional ships to the remotely controlled and autonomous vessels.

The main aim of the study is to provide an estimation for changes in the demand for seafarers at local level due to transition from conventional vessels to autonomous one. Due to limited resources of the study, it was not possible to build a comprehensive assessment model which will take into account numerous technical, economic and social factors affecting the demand for work force. Therefore, the study is called rather to demonstrate dynamics of the changes than to give an exact quantitative estimation which can be applied to any shipping company. The study also is to answer the following questions: which professions will be less required and how to mitigate the possible negative impact.

3 Materials and methods

This thesis was done in the form of a “What if-study” on company level. In the beginning it was planned to investigate how the availability of jobs at sea will change if an existing company will substitute her conventional vessels with remotely controlled or unmanned autonomous vessels. But latter, when preliminary results were obtained, it was decided to complete the study without direct references to existing shipping companies. The reason was the potential negative impact of the study’s results on the company’s social image.

The study considered an imaginary shipping company which operates a fleet of 10 RO-RO vessels. The RO-RO vessels were selected based on the author’s personal experience of these type of vessels. The company’s operational area covers the Baltic Sea, the North Sea, the Dover Strait, and the Golf of Biscay. The fleet is engaged in line shipping with the shortest route between Finland and Estonia, and the longest one between Finland and Spain.

The company's fleet consist of 10 RO-RO vessels. Due to the limitations of this study the analysis was done for the entire fleet without making the differences between the ships. For the same reason, the study covers only deck department. Consideration of engine room department is beyond the capabilities of this study. Table 3 shows the characteristics of the company's fleet considered in this study.

Table 3. Fleet and the quantity of people onboard

Fleet	Average crew per a ship	Deck crew per a ship including master	Total deck crew		
			At sea	At home excluding cadets	Fleet crew
10 ships	18 seafarers + 4 cadets	8 seafarers + 3 cadets	110	80	190

The work at sea is a rotation type of work. This means that onboard fleet's deck crew including cadets consist of 110 people in total. The amount of crew members at home excluding cadets is 80 people (Table 3). Cadets are included in the crew at sea because they participate in deck maintenance, but they are excluded from the crew at home because cadets are not the company's employees. The deck crew is responsible for the wide range of duties. These duties shown in detail in Table 4 depending on the ranks.

Table 4. Duties and responsibilities of the deck crew onboard

Rank	Duties	Average working hours per day per person
Master	Overall command, arrival, and departure navigation	9
Chief officer	Cargo operation planning and supervising, ballast operation, deck maintenance planning, drills, and navigation	9
Second officer	Navigation, maintenance of navigational equipment, cargo operations, ballast operation, deck maintenance and moorings	9
Third officer	Navigation, maintenance of life saving and deck firefighting equipment, cargo operations, ballast operation deck maintenance and moorings	9
Boatswain	Deck maintenance, cargo operations and moorings	9
AB 1		9
AB 2		10
OS 1		10
Cadet 1	Navigation, deck maintenance, cargo operations and moorings	8
Cadet 2		8
Cadet 3		8

Total manhours per day	98

For the purposes of this study, it is of great importance to know when (during sea passages or at ports) ship maintenance is done and how much time and people it requires. In the considered case ship maintenance is done during sea passages. At ports, the deck crew supervises and assists with cargo operations. The needs for people and time required to maintain the fleet of 10 conventional vessels. will be estimated in the Baseline scenario (Chapter 4).

The study used demand driven approach and scenario analysis to address the research task. A demand driven approach was chosen because it could provide quantitative estimations of the demand for seafarers using the demand for ship maintenance as an input. A baseline and three potential scenarios were elaborated. The baseline scenario describes the business as usual – conventional vessels crewed according to their minimum manning certificates (Table 3). The scenarios follow the stages of technology development as showed in Figure 4.

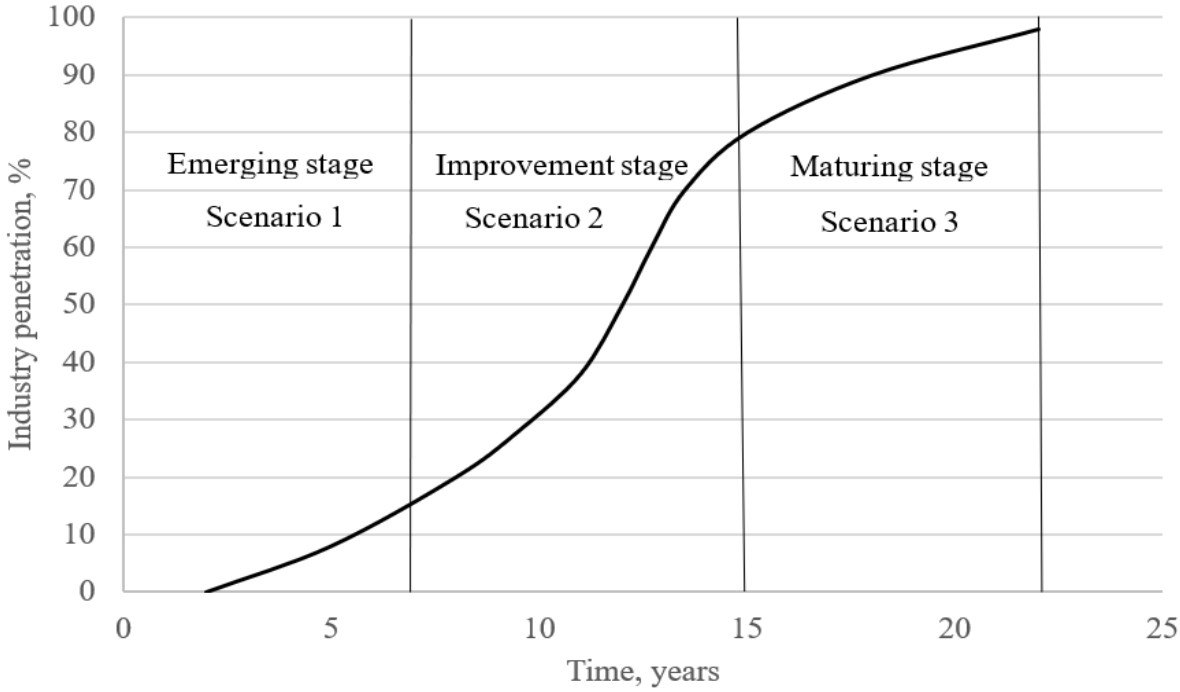

Figure 4. The stages of technological development and the scenarios (Barreca, 2020)

The scenarios analyse demand for seafarers under certain development stage of the technology (Figure 4), in other words, assuming different degrees of automatization. Currently, seafarers onboard have certain duties, and they are carrying out numerous operations (Table 4). The number of people onboard is defined by the necessity to do the required works. In order to estimate how the demand for seafarers will change in the future, it is required to calculate how many people will be needed to safely navigate and maintain the ship and her equipment in good state and working conditions for each of the scenarios. The starting point here is to calculate the amount of manhours required for ship navigation and maintenance depending on the degree of automatization (Table 1). This study assumes that automatization will not change much maintenance procedures and the amount of time required for maintenance. Therefore, in this study the remotely controlled and autonomous vessels required the same amount of maintenance as the conventional vessels.

3.1 Baseline scenario

In the Baseline scenario the ships were manned according to their minimum safe manning certificates. The ships bridges must be manned 24 hours 7 days a week. Every ship had a master and 3 navigational officers: a chief mate, a second mate and a third mate (Table 4). The mates are navigation officers keeping watches on the bridges. The masters are not watch-keepers and under normal circumstances they are on the bridges navigating the ships only during arrivals and departures. The deck crew also included a boatswain, 3 deckhands and 3 cadets. In this scenario ship maintenance was done mainly during sea passages. At ports, the deck crew supervised and assisted with cargo operations.

3.2 Scenario 1

Scenario 1 considered the emerging stage when the technology is entering the market. In Scenario 1 early technology adopters implemented first commercial applications of the technology. Scenario 1 assumed that conventional RO-RO vessels are converted into reduced crew vessels with limited support of remote control. In this scenario the ships are remotely navigated in simple conditions. Mooring operations are automated and do not require assistance of the crew. However, the technology is imperfect because many technical challenges are not yet solved. In addition, elaboration of required legislation is going slower than the development of the technology that limits her application in practice. At this stage remotely controlled unmanned vessels are technically possible, but not applicable in practice due to legislative limits and lack of the infrastructure. Fully autonomous commercial vessels are not available for shipping companies due to the technical and legislative issues.

3.3 Scenario 2

Scenario 2 considered the improvement stage of the technology. During this stage, the technology is being rapidly improved further based on the results of first commercial applications. The legislation framework is being actively developed to meet the industry's needs regarding remotely controlled vessels. Purpose build unmanned remotely controlled vessels are widely used on local and international voyages. Fully autonomous unmanned ships still have limited commercial application.

In Scenario 2 the conventional RO-RO vessels converted into reduced crew vessels with limited support of remote control were substituted with purpose built unmanned remotely controlled vessels. Thereby, there was not a crew onboard and the duties and responsibilities of onboard crew were transferred from the ships to a shore-based control centre and a ship maintenance crew. The control centre is responsible for continues navigation of the remotely controlled vessels. The ship maintenance crew is responsible for maintenance and service of the ships and the equipment.

3.4 Scenario 3

Scenario 3 considered the maturing stage of the technology. The technology has reached its technical maturity. The fully autonomous unmanned vessels are widely used on local and international voyages, but their further technical improvements require significant efforts. Fast technical progress as in the improvement stage is not possible due to the fundamental reasons e.g., limited efficiency of propulsion systems.

Scenario 3 assumed that fully autonomous unmanned vessels most of the time do not require remote control. Therefore, in this scenario the shore-based control centre was substituted with the shore-based monitoring centre with a reduced crew.

4 Results

4.1 Baseline scenario

The annual number of sea and port days for the fleet were assumed based on the longest round route Finland – Spain – Finland. When estimating the annual number of sea and port days it was assumed that the average speed of vessels is 19 knot and the duration of port stays is 48 hours per ship for ports in Finland and Spain and 12 hours per ship for transit ports in other countries. Unusual delays, e. g. due to breakdowns or congestion in ports, were not taken into account. Table 5shows sea and port days for the fleet.

Table 5. The annual number of sea and port days for the fleet

	At port		Sea passage		Total	
	Hours	Days	Hours	Days	Hours	Days
One voyage	204	8.5	300	12.5	504	21
Annually	3546	148	5214	217	8760	365

As it was mentioned earlier, ship maintenance is done during sea passages. Table 5 shows the total duration of sea passages in days or hours. Maintenance of the ships consumes less time than the total duration of sea passages due to deck crew’s rest hours and other duties. Table 6 shows working hours of deck crew members involved in ship maintenance during sea passages.

Table 6. Baseline scenario: working hours of deck crew members involved in ship maintenance during sea passages

Rank	Average ship maintenance working hours per day per person	
	Ship	Fleet
Second officer	1	10
Third officer	1	10
Boatswain	9	90
AB 1	9	90
AB 2	6	60
OS 1	8	80
Cadet 1	4	40
Cadet 2	4	40
Cadet 3	4	40
Total manhours per day	46	460

As can be seen from Table 6 ship maintenance required 9 people including cadets and 46 manhours per day per ship or 90 people and 460 manhours per day per fleet. The chief officer among other duties has the duty to maintain his ship in good conditions. However, in practice chief officers are only planning maintenance operations. In case of reduced crew and fully autonomous vessels ship maintenance, operations can be planned ashore, therefore the chief mate's working hours are not included in Table 6. The most time-consuming duty of 2nd and the 3rd mates during sea passages is ship navigation, therefore they spent in average 1 hour each for duties related to ship maintenance. Compared to the boatswain and AB 1, AB 2 and OS 1 had less time for ship maintenance because AB 2 and OS 1 conducted look-out duties during night-time. Three cadets spent half of the working time as co-pilots on bridges.

The total number of ship maintenance manhours for the fleet is:

$$TMH = SD \times MND = 217 \times 460 = 99\,820 \text{ manhours per annum} \quad (1)$$

Where:

SD – sea passage days, annually

MND – manhours spent for fleet maintenance per day.

Table 7 shows the total number of people in the fleet's deck crew.

Table 7. Baseline scenario: the number of people in the fleet's deck crew

Unit	Crew, people	Duties
Deck crew at sea including cadets	110	Ship maintenance at sea, navigation
Deck crew at home excluding cadets	80	
Total	190	

4.2 Scenario 1

Scenario 1 assumed that conventional RO-RO vessels were converted into reduced crew vessels with limited support of remote control. The vessels are sailing the same route as in the Baseline scenario, with the same number of sea passage and port days (Table 5). In Scenario 1 responsibilities of crew members changed due to the reduced number of people as well as allocation of working hours for different duties. The main duty of the deck crews was ship maintenance. Now masters are responsible for planning of ship maintenance operations and chief mates are involved in ship maintenance. Thereby, the available during sea passages human resources are used more efficiently compared to the Baseline scenario.

Table 8 shows working hours of deck crew members involved in ship maintenance during sea passages.

Table 8. Scenario 1: working hours of deck crew members involved in ship maintenance during sea passages

Rank	Duties	Average working hours per day per person	
		Ship	Fleet
Master	Overall command, navigation during arrivals, departures and emergency, deck maintenance planning	-	
Chief officer	Cargo operation planning and supervising, ballast operation, deck maintenance, drills, navigation	9	90
boatswain	Deck maintenance, cargo operations and moorings	9	90
AB 1	Deck maintenance, cargo operations and moorings	9	90
OS 1	Deck maintenance, cargo operations and moorings	9	90
Total manhours per day		36	360

The ships are remotely controlled in open waters under good weather conditions. Navigation control is given to the ships' bridges in confined waters and under bad weather. Remote control functions are carried out by a shore-based remote-control centre. Due to the lack of information regarding abilities of a human operator to control numerous surface vessels the number of pilots in fleet control centre was set based on Porat et al. (2016) who found out that an experienced operator can control up to three unmanned aircrafts. In Scenario 1 the control centre's watch crew consists of a pilot and 2 co-pilots which are working 8 hours followed by 16 hours of rest, 12 people in total. Scenario 1 assumed that in case of emergency the onboard, the crew will take the required actions with assistance of national emergency bodies.

During sea passages available manhours for ship maintenance is:

$$AMH = SD \times MND = 217 \times 360 = 78\ 120 \text{ manhours per annum} \quad (2)$$

Where:

SD – sea passage days, annually

MND – manhours spent for maintenance per day for the fleet.

Considering the same amount of ship maintenance operations annually as in the Baseline scenario, some of the maintenance operations must be done when the ships stay at a port. The annual amount of manhours for ship maintenance to be done during port stays is:

$$MHPMa = TMH - AMH = 99\ 820 - 78\ 120 = 21\ 700 \text{ manhours per annum} \quad (3)$$

Where:

MPHMa - the amount of manhours for ship maintenance in ports annually;

Annually the ships stay at ports for 148 days and ship maintenance will require:

$$MHPMd = MHPMa / PD = 21\ 700 / 148 \approx 147 \text{ manhours per day} \quad (4)$$

Where:

MPHMd – the amount of manhours for ship maintenance in ports per day

Taking into account 8 hours long working day, the number of people required for ship maintenance in ports is:

$$P = MHPMd / 8 = 147 / 8 \approx 19 \text{ people} \quad (5)$$

Where:

P - the number of people required for ship maintenance in ports

Table 9 shows the number of people in the fleet's deck crew, the control center, and the shore maintenance crew.

Table 9. Scenario 1: the number of people in the fleet's deck crew, the control center and ship maintenance crews

Unit	Crew, people	Duties
Deck crew at sea	50	Ship maintenance at sea, navigation
Deck crew at home	50	
Control center	12	Remote navigation
Shore maintenance crews	19	Ship maintenance at ports
Total	131	

4.3 Scenario 2

In Scenario 2 the conventional RO-RO vessels converted earlier into reduced crew vessels with limited support of remote control were substituted with purpose build unmanned remotely controlled vessels. The vessels are sailing the same route like in the Baseline scenario, with the same number of sea passage and port days (Table 5). Therefore, all maintenance has to be done when the ships stay at a port. Annually the ships stay at ports for 148 days and ship maintenance will require:

$$MHPMd = TMH / PD = 99\,820 / 148 \approx 674 \text{ manhours per day} \quad (6)$$

Taking into account 8 hours long working day, the number of people required for ship maintenance in ports is:

$$P = MHPMd / 8 = 674 / 8 \approx 84 \text{ people} \quad (7)$$

Table 10 shows the number of people in fleet control centre and shore maintenance crew.

Table 10. Scenario 2: the number of people in control centre, ship maintenance and emergency response crews

Unit	Crew, people	Duties
Control centre	12	Navigation
Ship maintenance	84	Maintenance of the ship and deck equipment
Total	96	

4.4 Scenario 3

Scenario 3 considered the maturing stage of the technology when fully autonomous unmanned vessels most of the time do not require remote control. This allow the number of pilots in the monitoring centre be reduced from 12 to 6 people. Table 11 shows the number of people in the monitoring centre and ship maintenance crews. Because in this scenario the ships are unmanned, the total number of people required for ship maintenance is the same as in Scenario 2

Table 11. Scenario 3: the number of people in the monitoring center and ship maintenance crews

Unit	Crew, people	Duties
Monitoring centre	6	Monitoring
Ship maintenance	84	Maintenance of the ship and deck equipment
Total	90	

4.5 Scenario comparison

Four scenarios were elaborated to analyze how demand for seafarers will change with development of the technology of remotely controlled and unmanned vessels. The baseline scenario describes business as usual. Scenario 1 assumed that conventional RO-RO vessels are converted into reduced crew vessels with limited support of remote control. In Scenario 2 the fleet consisted of the purpose built unmanned remotely controlled vessels. Fully autonomous unmanned vessels were considered in Scenario 3. When elaborating the scenarios, it was assumed that the degree of automatization does affect the amount of time needed for ships maintenance. This means that all the considered types of vessels – conventional, reduced crew, remotely controlled and fully autonomous ships required the same amount of maintenance work. In every scenario 10 RO-RO vessels sailed voyages between Finland and Spain. The round trip took 21 day. Annually the ships made about 17 voyages spending at sea 217 days and at ports 148 days.

The scenarios showed that the number of people required for navigation and maintenance of the fleet is decreasing when the degree of automatization grows. Figure 5 shows the number of people required for the fleet of 10 vessels according to the scenarios.

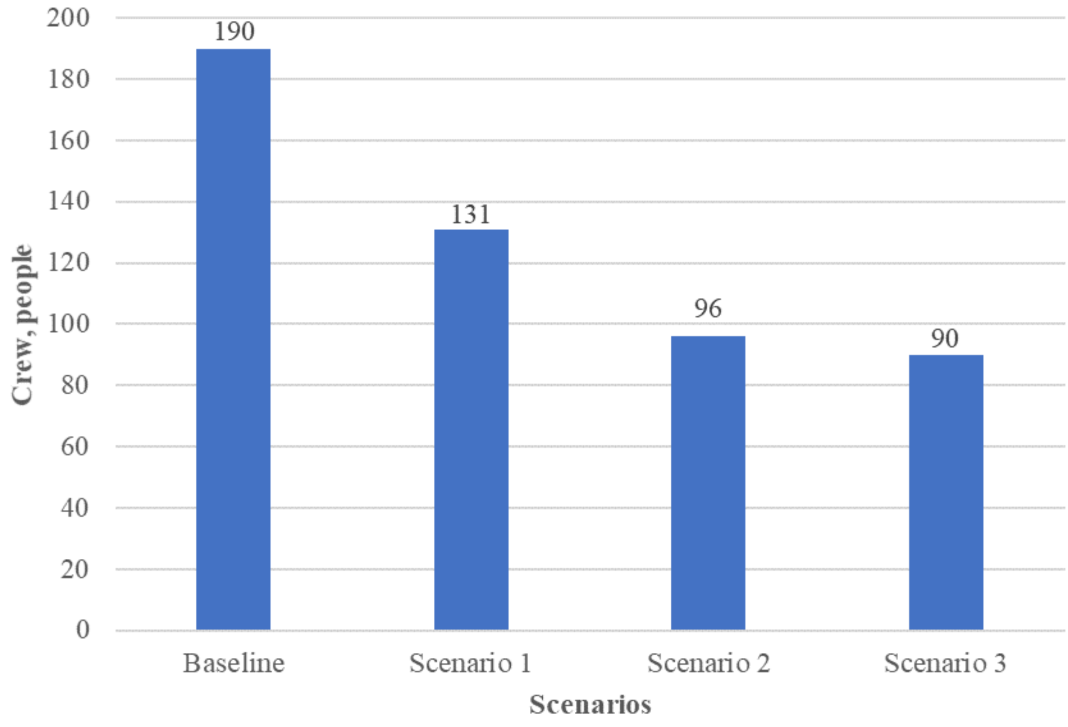

Figure 5. The number of people required for the fleet of 10 vessels according to the scenarios

As it can be seen from Figure 5 in the Baseline scenario the fleet of 10 conventional vessels required 190 people, more than in other scenarios. The ships with reduced crew in Scenario 1 required 131 people or 31% less compared to the Baseline scenario. The higher degree of automatization in Scenario 2 leaded to the smaller number of people required to operate the fleet of remotely controlled vessels. In this scenario, the fleet needed 96 people or 49% less than in the Baseline scenario. The most technically advanced fleet of fully autonomous unmanned vessels in Scenario 3 could be operated with 90 people that is 50% less compared to the fleet of conventional vessels in the Baseline scenario.

Figure also showed that among all the scenarios the highest relative reduction in crew size was reached when the conventional vessels (the Baseline scenario) were converted into the reduced crew vessels with limited support for remote control (Scenario 1). The further technical advance which would result only in the increased degree of automatization did not significantly decrease the number of people needed to operate the fleet in Scenario 2 and 3. The difference between the number of people required for the fleet of remotely controlled vessels in Scenario 2 and the number of people needed to operate the fleet of fully autonomous vessels in Scenario 3 was only 6 persons.

5 Conclusions and discussion

When elaborating the scenarios, it was assumed that the degree of automatization does change the amount of time needed for ship maintenance. This means that all the considered types of vessels – conventional, reduced crew, remotely controlled and fully autonomous ships required the same amount of maintenance work. In case of the conventional vessels all maintenance is done during sea passages, while the reduced crews in Scenario 1 had not enough time at sea to do the required maintenance works. In Scenario 1 part of maintenance should be done when the ships are at ports. In Scenario 2 and 3 the ships did not carry any crew on board and all maintenance should be done at ports. These similar maintenance requirements explain why despite the higher degree of automatization, the fleet of remotely controlled vessels required just 35 people less than in Scenario 1 reduced crew. However, remotely controlled vessels are unmanned at sea, there are no one to repair and serve ships and their equipment. Therefore, it can be expected that these vessels will be bult in such way that will allow minimization of maintenance. If the shipbuilding industry will be able to offer more durable ships with less maintenance requirements this will respectively decrease the number of people in shore maintenance crews. Also shipping companies can reduce life span of their ships to minimize maintenance and to reduce shore crews.

However, there is one factor which could limit the potential of unmanned vessels to reduce the demand for work force in relation to ship maintenance. The absence of a crew onboard unmanned vessels makes impossible fast response actions on site in case of e.g. breakdown, loose cargo, or a fire. This means that an emergency situation cannot be stopped in the very beginning and it will continue to develop if remotely controlled or automatic response actions will not succeed. In this case follow-up repair will require much more resources compared to a ship where the onboard crew could prevent further development of an emergency.

A new era in history of the shipping industry is approaching. In the future remotely controlled and unmanned fully autonomous vessels are expected to substitute the conventional commercial vessels on local routs and ocean voyages (Wise, 2018). This transition will cause not only technical and economic changes in the maritime transport but also will affect social role of the shipping industry as one of the world's global employer. Among the industry players there is growing concern (Rolls-Royce, 2016; ITF, 2017; Nautilus, 2018) regarding possible disruptive consequences of rapid transition from conventional ships to unmanned remotely controlled and autonomous vessels. In 2018 Nautilus, a Federation of Maritime Professionals, (Nautilus, 2018) asked almost 900 maritime professionals from 13 countries about their attitude to automatization of the maritime transport. The survey showed that majority of respondents (84%) consider automatization as negative factor in relation to job availability.

Recently, several studies (HSBA, 2018; WMU, 2019; Kooij, 2020) were conducted to predict how rapid automatization of the maritime transport will affect the availability of working places for seafarers. For example, Hamburg School of Business Administration (HSBA, 2018) predicted that according to the most optimistic scenario by 2025 about 3 000 vessels will be fully or partly autonomous that will cut off about 50 000 onboard working places. Taking into account the predicted shortage of near 150 000 officers in 2025 (BIMCO & ICS, 2016) HSBA concluded that in the near future autonomous ships will not strongly affect the global demand for seafarers. For longer perspective HSBA assumes that automatization of the maritime transport will not eliminate jobs related to maritime transport, but shift working places ashore. This last conclusion of HSBA study (HSBA, 2018) is opposite to the results obtained in this case study. The scenario analysis showed that even taking into account the working places shifted ashore the number of people needed to operate the fleet of autonomous ships is 50% less compared to the fleet of conventional ships. The possible reason for this contradiction is different basic assumptions and study scales. The results of this case study are in line with the long-term predictions made by the World Maritime University (WMU, 2019) which expected a 22% reduction in the demand for seafarers by 2040.

This study conducted on company level showed that automatization of commercial ships can lead to reduction of jobs at sea available for seafarers with traditional maritime education. Already on early stage of the technology (Scenario 1) the ships with limited support for remote control would not require 2^{nd} and 3^{rd} mates. Further technical advance (Scenario 2 and 3) will lead to a situation when human presence on board a commercial cargo vessel would not be needed. In this situation masters and mates with traditional maritime education will need to go through professional re-education to get skills required to operate unmanned remotely controlled and autonomous vessels. This means that educational facilities which provide maritime education and training must adapt to the fast-developing technology to efficiently address these new challenges. At the same time deck hands are in a bit better position. Automatization of the maritime transport will not lead to completely maintenance-free ships. Deck hands will continue to do their job as members of shore-based maintenance crews.

It is not possible to say when automatization of the maritime transport will start causing the significant impact on the availability of jobs for seafarers. But obviously once it will happen. The maritime industry and the society should be respectively prepared for the changes to mitigate the potential negative effects of technical progress.

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