THE POTENTIAL IMPACTS OF THE DEPLOYMENT OF MARITIME AUTONOMOUS SURFACE SHIPS ON THE MARITIME FREIGHT TRANSPORT PROCESS

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Abstract

Different global processes affect all developments in our lives already today, most likely their influence in both the short and long term will continue to grow and force us to consider the challenges and consequences arising from them more and more. Digitalization is undoubtedly one of these global processes, and it affects all areas of human activity, including transportation of goods by sea. According to the general opinion, the digitalization of shipping is considered a completely positive phenomenon, it is often even believed that new digital technologies can stop any negative developments and to solve at least the main problems faced in this field. But is this obviously true? The authors of the paper take into consideration one of the important development directions of the transportation of goods by sea, namely the digitalization of ships and shipping, and try to point out some of its positive and negative sides, taking into consideration some important aspects of shipping, which the deployment of autonomous ships will inevitably influence. The authors go through the different stages of the process of shipping goods by sea and try to assess the possible problems and challenges, which arise due to the digitalization of it. As a result, the authors conclude that the interactions between the digitalization of shipping and various aspects of maritime freight transport, such as marine environmental protection and maritime safety, are not as unambiguous and one-way as it may seem at first glance, and in different situations they can affect each other in different ways, including possible amplifying of negative aspects. Developments and interactions in maritime transport should be viewed as a whole and approached realistically, digital solutions should be viewed with moderate optimism, constantly assessing possible risks and ways to mitigate them; the decisive influence of the human factor will not disappear anywhere, even if suppose that all ships become autonomous.

1 INTRODUCTION

In recent years, we have all witnessed the ever-accelerating global digitalization process. This process has a powerful influence on all areas of human activity, one of them is undoubtedly maritime, in the context of this paper, more precisely, the transportation of goods by sea. At the current stage of development, the prevailing opinion is that the impact of digitalization on the maritime shipping sector is most likely positive, considering most of the accompanying aspects. It is widely believed that the introduction of maritime autonomous surface ships (MASS) controlled by artificial intelligence (IMO, 2018), will significantly improve maritime safety by either greatly reducing or eliminating the influence of the so-called human factor (Porathe, 2021). It is also believed that digitalization will make all processes related to the maritime transport of goods faster and smoother both at sea and in ports, including helping to reduce the negative impact of maritime transport on the environment and through this to slow down the climate change process (Greencarrier, 2022).

In some ways, these views can be said to reflect a certain naivety inherent in people in general, they prefer to focus on the possible positive effect and hope that someone (or something) will come or arise from somewhere with a super-smart and super-powerful and solve all problems. This is a comfortable position that allows people to continue business-as-usual and not bother their heads with searching and finding difficult solutions. But there are two sides to the introduction of every new thing, in addition to the positive impacts, one must be aware and ready to anticipate and solve challenges. In recent years, the role of one such "lifeline" for humankind has been attributed to new, mainly digital, technologies, the possible positive effects of which may be overestimated, and the possible negative aspects remain unnoticed. Fig.1 (Senčila, Alop, 2019, pp. 574-577) illustrates the dynamics of the development of people's beliefs and expectations at different stages of development of new technologies.

Fig. 1 Gartner Hype Cycle diagram, adopted to autonomous shipping

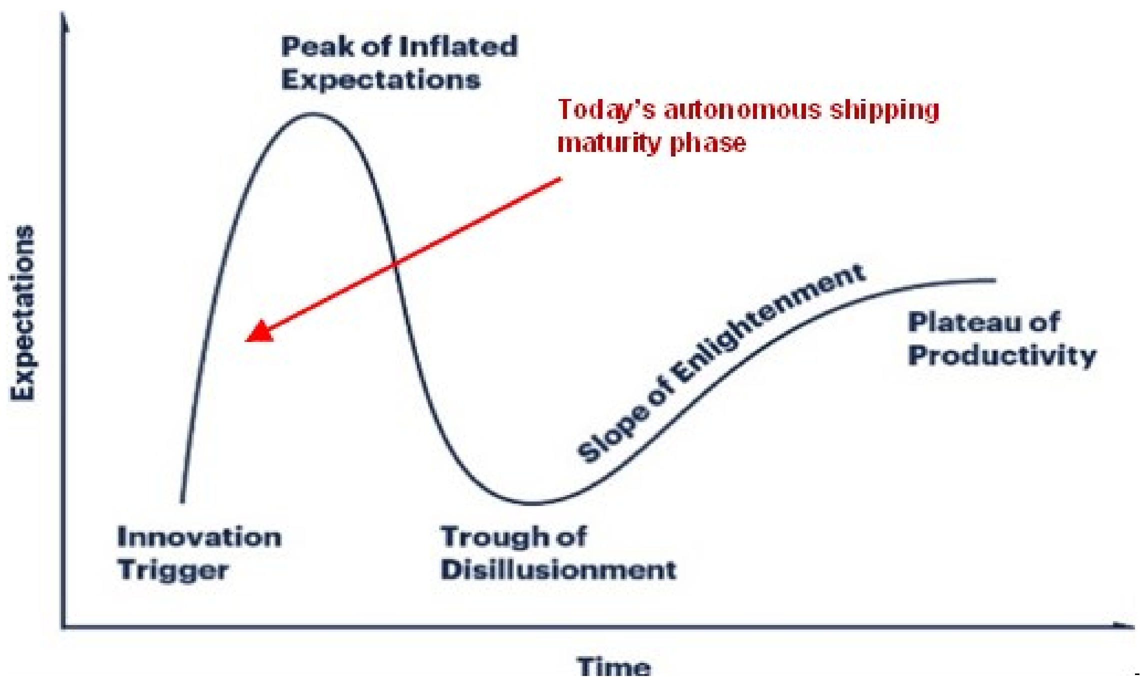

Fig.1 shows the so-called Gartner Hype Cycle diagram adapted to autonomous ships. In fact, the dynamics of change in expectations shown in the Fig.1 apply to any significant technological innovation. The diagram shows the five phases of the life cycle of each new technology. The first of them is called as *Innovation Trigger*, the authors of abovementioned article claim that the shipping industry's expectations for the digitalization of shipping are currently on this positively rising line. It can also be said that in the early stages of any significant achievement, including digital technologies, the certain "intoxication" may occur in society. Later, when it becomes clear that the technology cannot solve all the problems at once, or new, sometimes perhaps more serious problems arise in the process of solving existing problems, the tendency is often to go to the other extreme, i.e. the negative effects will be overestimated. Wouldn't it be more reasonable to take a sober and considerate approach to any new technologies, consider the risks associated with them and, if possible, proactively mitigate these risks and avoid negative consequences as much as possible, or at least accept and take into account those that cannot be avoided?

The authors of presence paper try to study the effects of the digitalization of shipping on two important aspects related to the maritime transport of goods, namely its impact on the environment and maritime safety, and to evaluate as objectively as possible the positive and negative consequences that the widespread adoption of digital technology, including artificial intelligence, can bring in the context of these aspects. The evaluated effects of digitalization on the environment are considered in terms of three types of effects: influencing the greenhouse effect, effects resulting from possible environmental pollution and qualitative and quantitative effects of the energy used, while considering both daily routine activities as well as dangerous situations at sea. When studying these effects, it is also unavoidable to address issues of maritime safety.

Although many different subjects are engaged in the maritime transport of goods, the main player in the maritime transport of goods is the ship. That is why the authors consider autonomous ships as the main object of survey. The second section of the paper is divided into two subsections, the first of which deals with the sailing of autonomous ships at sea, the second subsection examines some aspects related to the stay of such ships in the port.

2 ASPECTS AND EFFECTS

In this section, the term "autonomous ship" has a broad meaning, i.e. not only fully autonomous ships are considered, but also ships controlled by the shore operator, i.e. remote-controlled ships (IMO, 2018). The term "unmanned vessel" is also may be used for both. Only cargo ships are considered, but there are no restrictions when classified according to the type of cargo carried. Depending on the considered aspect of impact, some ship types may be studied in more detail, some may be left out of consideration in certain cases or only be briefly studied.

2.1 Autonomous ships at sea

In terms of the possibility of a potential threat to the marine environment and the severity of the consequences, the cargo fleet can be divided into two large parts: first, ships that carry dangerous goods as cargo (crude oil and oil products, dangerous chemicals, etc.); secondly, ships that transport other types of goods (container ships, safe bulk cargo carriers, etc.), on which the goods transported do not pose a direct threat to the marine environment. At the same time, as of today, the fuel tanks of these ships contain a considerable amount of fuel, which, depending on the type of fuel, can be dangerous to the environment to one degree or another if it gets into the sea. A separate question is that cargo ships of any kind are a source of amplification of the greenhouse effect if they use fossil fuels as an energy source. However, based on research, it is also possible to reduce the environmental impact of such ships, the one solution is to choose a speed suitable for the type of ship based on the data (speed reduction) (IMO, 2021).

Keeping in mind the daily routine of seafaring, let us ask whether the digitalization of ships and maritime transport in general has any direct or indirect effect on the air pollution caused by substances transported on ships or used as fuel? The answer depends on several factors. Today, humanity still uses large amounts of fossil fuels as energy sources, and despite all plans and intentions to vigorously reduce these amounts and gradually transition to more environmentally friendly and safer energy sources, a significant reduction in these amounts may not be expected soon. This means that, according to all assumptions, the significant number of ships with larger or smaller quantities of environmentally hazardous substances in their cargo spaces and/or fuel tanks will be moving on the seas and oceans for at least decades. By IMO "In 2050, about 64% of the total amount of CO2 reduction is contributed to by use of alternative fuels" (IMO, 2021, 53).

Digitalization of ships as such does not make hazardous substances carried in holds or fuel tanks of vessels any less dangerous. At the same time, with the help of smart algorithms and advanced AI, fuel consumption on ships can be reduced to a minimum, as well as other energy-intensive processes in the engine room and other ship's equipment can be optimized, which should lead to a reduction of environmental, above all air pollution. The introduction of new, more environmentally friendly fuels does not directly depend on the degree of digitalization of the ship, but the digitalization of all processes contributes to the maximally economical and environmentally sustainable use of these fuels. From the point of view of the effectiveness of the results achieved in this context, it does not make much difference whether it is manned or unmanned ships, because in the ideal case, neither the ship's crew nor the shore operator must interfere with the operation of the smart programs if they are functioning in an optimal way.

However, we can see the difference between manned and unmanned, i.e. ships controlled by AI ore shore operator, considering the effects of ship systems and equipment related to the presence of people on board. An unmanned ship has no need for living spaces and most service spaces, as well as their heating, cooling, and ventilation systems. No need to worry about cooking, food storage and preservation; energy costs related to cooking and the generation of garbage and pollutants related to people's life processes are avoided. Of course, we cannot talk about bringing all these costs to a completely zero level, because from the point of view of the ship owner, it would be logical that on an unmanned ship of the same size, living and service spaces are replaced by additional cargo spaces, which in turn, depending on the type of cargo, may require cooling, ventilation, etc. energy costs. Also, it would probably not be the right thing to build ships that are completely unfit for living or even temporarily for people to stay on board, because in certain situations it may be essential to have people on ship, so some such spaces should be on the ship, although they may be in a canned state in fully autonomous sailing mode.

All this is correct if the ships are operating in a daily routine mode and in the controlled environment without any real danger situation arising. Since seafaring is still a high-risks activity, it is highly likely that dangerous situations will continue to occur in the future. The causes or the persons who cause the occurrence of these dangerous situations may change over time. According to various sources, 85-90% of incidents at sea today are caused by the human factor (Galierikova, 2019).

In the case of unmanned ships, dangerous situations caused by the human factor will most likely be avoided, but only speaking about the lack of people on the unmanned ship itself. It is hard to imagine that all ships on the seas and oceans will become unmanned in the near or even not so near future; it is clear that a considerable, even a large number of manned ships will continue to participate in maritime traffic, so in the case of these ships, the human factor will not disappear anywhere, also endangering unmanned ships that meet them at sea or are in contact with them in some other way. The mistakes of the crew members on the unmanned ships will be avoided, but the human factor, which plays an important role in the movement of the ship, will remain. Reducing the errors made under the influence of the human factor is possible only if this challenge is considered during the entire transition and development process. According to a recent study, there is a need to focus on the infrastructure, operational procedures, and human factors of autonomous (MASS) and remote-controlled (ROC) ships for the effective management and operation of autonomous marine systems (EMSA, 2023-2024). A separate question is whether the AI will make its own errors, which are unique to artificial intelligence; we must not forget the dangers arising from cyber-piracy, but dealing with these issues is not the topic of this paper.

Consequently, the replacement of only some manned vessels with autonomous vessels on conventional waterways may not have a significant effect on improving maritime safety. Two possible variants of future developments can start to change the situation for the better if they are realized. One of them assumes a significant increase in the number of unmanned ships in shipping to numbers where the interaction of ships with each other is increasingly an interaction between autonomous ships; provided that the intelligent systems controlling these ships are sufficiently perfect and reliable, it can be hoped that there will be fewer and fewer dangerous situations during the navigation and operation of such ships, and maritime safety will improve significantly. While manned ships still sail along with these ships, even though they may be in the minority, it is not possible to eliminate completely the influence of the human factor; also, the human factor continues to affect the situation in the case of remote-controlled ships through the shore operators, who can also make so-called human errors, especially in dangerous situations requiring a quick response.

Another development option could be that autonomous ships start to travel along special shipping lanes, meant only for them, and conventional ships sail along their own roads. Of course, this option does not seem to be very realistic for several reasons: firstly, for this option to achieve even a minimal effect of economic profitability, the number of these ships would have to be enough large, so that the scale effect would start working; secondly, such an option can be implemented in the open sea or other relatively open sea areas. In entrances and other channels, areas with heavy traffic, near ports areas such a distribution is not conceivable due to the lack of space and/or the unreasonably high costs needed for creating additional space for separate shipping lanes.

How well and as free of human error as possible the navigation of autonomous ships would not have been organized, the possibility of a dangerous situations at sea will never disappears, if not for human-caused reasons, then due to *force majeure*, e.g. extreme weather conditions and so on. Now let's look at the potential problems and bottlenecks that may arise if a collision, grounding, or other marine accident involving autonomous ships does occur. In the classic sense, a maritime search and rescue situation arises; in the case of the conventional fleet, it is regulated by the so-called SAR Convention (International Convention on Maritime Search and Rescue, 1979), the Convention on Salvage (International Convention on Salvage, 1989) and other international and national regulations. The main feature of all these regulations and good maritime practices is now that rescue operations at sea require the active participation of the distressed ship's crew, in many cases they are the only ones at the initial stage of the accident who can take any measures immediately and thereby prevent the worst, until the help of either professional or volunteer rescuers arrives.

There should be no problem with the possibility that the AI of the autonomous ship is programmed to detect possible problems and dangers that may arise during the voyage and to decide when the moment has arrived when the ship needs external help, for example the arrival of a rescue team. The AI also informs the shore operator, who then decides when and which rescue operation to launch and takes the necessary measures to launch it. However, it is difficult to imagine that artificial intelligence has the same opportunities, tools and abilities as a ship crew consisting of real seamen to implement effective rescue measures even before the arrival of the external rescue team. Probably AI can handle the localization and extinguishing of a fire in a closed spaces but, for example, detecting a leak in a damaged hull or cargo/fuel tanks at any location, and especially the initial elimination of it, seems to be an "impossible mission" for a ship controlled by AI.

Since the speed of response and arrival of the rescue team and a good knowledge of the specifics of rescue operations are of critical importance in the case of autonomous ships, special training of these rescue teams is necessary. It also seems that the rescue teams of unmanned ships must be more numerous than the rescuers of conventional ships because they have no one to count on for help when they arrive at a ship in distress. Although the participation of volunteer rescuers, i.e. crews of conventional manned ships, in sea rescues is one of the oldest and most common maritime practices, the practicality of such participation becomes questionable in the case of unmanned ships. For this to be of real benefit, the crews of all conventional or manned ships should undergo the corresponding special training (you never know at what moment and to whom it will be necessary to go for rescue), but this does not seem to be very reasonable, first from the point of view of economic expediency. It is difficult if not impossible to predict an optimally functioning plan of action for unpredictable situations. Even using technological means, they are developed and planned by a person. Similarly, in the training of seafarers, no matter how well it is done, it is not possible to provide ready-made solutions for every situation, but the ability to think critically and solve problems can be developed. As mentioned above, in the case of digitalization, all existing processes must be re-evaluated. This is also the case with the existing rescue system and processes, since success is not only in direct cooperation with people, but the participants are people and technology.

The possible quick and efficient rescue of unmanned ships, including the prevention and/or rapid liquidation of large-scale pollution of the marine environment, seems to be realistic only in the case of short-sea transportation, if all the above prerequisites can be met. In this case, the unmanned ships must sail along more or less certain sea routes and be relatively quickly accessible by specialized rescue teams in case the need for rescue arises. However, this does not seem to be possible in the case of long-distance shipping, i.e. ocean transportation. It may take too much time for professional rescuers to reach such an ocean-going ship (if at all), so a successful rescue and prevention of pollution of the marine environment is unlikely in this case. Thus, it seems that the deployment of unmanned vessels on ocean lines become real only if two conditions are met: a) unmanned ships use only environmentally friendly and 100% environmentally safe fuel or other energy sources (sun, wind); b) humanity has abandoned the use of fossil fuels and tankers no longer travel by sea.

It seems that the fulfilment of point *a* is more realistic than the fulfilment of point *b*, i.e. if the condition of point *a* is met, the introduction of unmanned container ships, safe bulk cargo ships, etc. on ocean lines is possible. The prospects of these ships and goods carrying on them being saved will also be poorer than in the case of conventional ships, but at least in the case of unmanned ships, human lives are not at dangerous, and the risk of environmental pollution is not big. In this case, however, there is a high probability that the insurance premiums for such ships and goods will increase significantly, which may not please the owners of these ships and goods at all (Alop, 2023).

Such a specialized, fast-reacting, sufficiently capable unmanned vessel rescue and pollution clean-up system will require more resources than the current combination of professional and volunteer rescuers, even if we are only talking about short-sea unmanned vessels. Of course, rescuers specializing in unmanned vessels do not sit around and wait for something that matches their qualifications to happen, but go about their daily work as professional rescuers, while always being ready to organize an unmanned vessel rescue operation if necessary. This reduces the additional costs needed for their special training.

The environment, be it water or air, can be polluted not only by pollutants, but also by energy released into the environment, mostly in the form of excess heat. It is difficult to give an unequivocal answer to the question of whether the impact of this type of pollution on the environment decreases or increases in the case of unmanned vessels. On the one hand, this effect should decrease, firstly, due to the more efficient and economical use of fuel and other energy sources on a ship controlled by AI, and secondly, due to the absence or scarcity of ship equipment and systems necessary to keep people on board alive. On the other hand, smart systems, including the AI of the unmanned ship itself, require a large amount of energy, both to ensure the safe navigating of the ship itself and the efficient operation of the shore control centres. In the case of autonomous ships, we are dealing with the continuous processing of a very large amount of data, and the energy consumption required for this can be significant, possibly even greater than the energy requirement of a conventional ship sailing at sea. It does not change the fact that a large amount of this nature-polluting energy can be released somewhere very far from the location of the ship or the shore control centre, because today big data is stored and processed using a "cloud" service; assessing the effects of digitalization on any processes, we cannot ignore these kinds of effects.

The basic principles of data collection, use and storage that reduce the impact on the environment must also be followed in maritime transport. When collecting data, it is important to observe the principle of data reuse. If possible, use the possibility of reusing already existing, regularly collected data, instead of creating additional systems. For example, the data collected during the use of the ship is helpful in the design and construction of environmentally friendly ships and equipment (Sallivan et al, 2020). The next step beyond data reuse is to think about how to reduce the generation of data waste - in the case of automatically collected data, keep only the part that is necessary. Choose the data storage environment consciously, reducing the impact of the environment related to data collection and storage, choose energy-efficient storage devices - think about whether all data must be immediately available (cloud technology) or if passive storage devices are sufficient. The environmental footprint of data storage increases, it is necessary to make informed choices when choosing data storages as well. Sustainable data storages monitor the impact of their operations and strive to reduce their environmental footprint.

2.2 Autonomous ships in port

The effects of autonomous ships in ports on the environment and thus on climate change are broadly the same as those at sea. However, there are some differences. When arriving at a port, an autonomous ship generally must go through the same operations as a conventional or manned ship. Whether the effects of an unmanned ship on the environment during the performance of these activities are smaller or greater than that of a manned ship depends on many factors: the ship itself, the type, size, and level of development of the port, the regulations of the port state, etc.

The first stage upon arrival at the port is piloting the ship into the port, if necessary, also the help of tugs. It is unknown whether the AI of an autonomous ship will be so smart that it can perfectly perform the task of piloting into the harbour and mooring to the quay. At the same time, taking into account that the pilotage area is usually quite dense with traffic, with difficult and narrowed navigation conditions, we also add here possible bad weather conditions, it can be thought that it will be much safer, confident and less expensive to use a classic pilot who comes on board an autonomous ship and takes over command of the ship and, very importantly, responsibility for the ship. The same applies for piloting the ship out of port. Of course, the shore control centre can also perform the piloting function if a control centre with the corresponding level and qualifications exists in the port or in the nearby area. However, the use of a pilot with the qualifications and experience of a Master seems reasonable, especially given that the ship does not have a captain and therefore the question "Who is responsible?" is very relevant. In (Alop, 2019) this universal person called as "Master-Pilot" (MP). In this case, the ship's AI helps the pilot in processing information and giving advice, which is why operations probably can take place faster, with less fuel and time consumption, and thus with less environmental impact.

Today, there is and probably will be for a long time (if not always) such a phenomenon as waiting for ships in the port roads or anchorage places, as a rule, due to the lack of a free berth when the ship arrives. While on a anchorage places, ships burn fuel, polluting the environment. Even unmanned vessels cannot avoid the waiting times. However, it is possible that the AI of the unmanned ship, being in constant contact and interaction with other ships, ports and other parties involved, will adjust its actions in such a way as to travel at the minimum speed necessary to arrive at the port just at the moment when the designated berth becomes available. In this case, it spends less fuel at sea and does not spend fuel and other resources waiting on the anchorage places; arriving at the port and mooring at the quay on time, the ship connects to the port's electrical grid and thus significantly reduces its impact on the environment.

We cannot leave out the loading-unloading operations in the port. In the case of a manned ship, there is no question of who ensures that the type, quantity, condition, etc. of the goods loaded on the ship meet the conditions declared by the shipper; this person is the ship's captain, who also takes responsibility for delivering the goods to the destination port in the same quantity, order and condition in which it was accepted for transport. The captain and his entire crew are also vitally interested that it is the right cargo, that its safety or danger is clearly determined, that the cargo is placed in the right place on the ship, stowed and secured in accordance with the requirements, and that it is completely ready and suitable for sea transport on the upcoming voyage. In the case of an unmanned ship, it is much more complicated. There is no such responsible person as the captain on the ship. The above-mentioned MP also does not completely replace him, because he does not navigate the ship to the destination port, but at best to the pilot station; the same applies to the shore control centre. In (Alop, 2023) is offered such a solution that the ship owner hires a separate universal crew, which is not the crew of one specific ship, but deals with organizing the loading and unloading of all the autonomous ships belonging to the ship owner in different ports where they arrive according to the ships' work schedule, using mainly air transport. In this case, the indirect impact on the environment can be considered as increase of the "footprint" resulting from the frequent use of these aircrafts.

3 CONCLUSIONS

In this paper, the authors mainly address one of the many potential impacts of maritime digitalization, namely its impact on the environment and, consequently, climate change. They also do this comprehensively, asking themselves questions that may not yet have very definite answers. At the same time, it should be mentioned that the connection between maritime digitalization and climate change is not unambiguous and one-way, which also came out during the writing of this paper. This problem should be placed in a wider context, i.e. many other aspects related to maritime digitalization should also be taken into consideration and their effects in interaction should be studied.

The development and impact of maritime transport must be viewed as a whole, and the impact of the human factor cannot be underestimated in the future, as the share of digitalization increases. The development of shipping and maritime transport so far shows that risks and ignorance in shipping can never be reduced to zero. It must also be prepared that all processes related to maritime transport today will have to be reevaluated during digitalization and developments. To be sure that the impact of the changes will ultimately be positive for the environment, it is necessary to evaluate the impact of the changes on the entire scale of the participants in the digital transformation and evaluate all acquired processes and their need to change.

The ships must be cost-effective in compliance with both international and national requirements. The ongoing question is how to find the best solution for this with less environmental impact. It is important to understand how the environmental footprint is measured. The measurement must not be more resource-intensive than the activity itself. For this, it is also necessary to be a smarter customer of digitalization solutions and to set the necessary restrictions to reduce environmental impacts already in the development phase. The other important aspects are the impact of maritime digitalization on maritime safety and the economic feasibility of introducing autonomous ships. One of the most important issues is ensuring cyber security at sea and on land; there is currently no very good solution to this problem.

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