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INCREASING THE LEVEL OF MOORING SAFETY THROUGH THE INTRODUCTION OF MODERN TECHNOLOGIES

Hotsulska A.I., assistant (NU "OMA")

The elements of the vessel's route in the concept of E-navigation are becoming the most relevant in the field of maritime transport management. The mooring process is one of the most complecated in this process, but modern technology makes it easier.

Artificial Intelligence (AI) ship control systems are being developed based on existing Dynamic Positioning (DP) technology. DP consoles connect to advanced software / devices that can analyze and predict the future position of the vessel.

At the end of 2018, the 85m ferry Folgefonn successfully completed tests of the Wärtsilä automatic mooring system. The vessel made three calls to the port, maneuvered in narrow Norwegian fjords, approached the beartg and moored without the help of the crew. The voyage was controlled by radar paths and points that led the ship to the next destination. Meanwhile, an autonomous controller based on the existing DP system monitored the vessel's speed, position on a given track and heading [1].

MSL automatic mooring systems use vacuum pads instead of ropes to keep the vessel at the berth. Each cushion has a controlled workload, ensuring a reliable physical connection between the vessel and the berth. The vacuum cushions were tested and categorized under the supervision of the international classification society DetNorskeVeritas, the results of which, combined with modern 3D hardware, showed the range and elasticity of automatic systems at the level of mooring with ropes. Since the automatic system keeps the vessel closer to the quay wall than the crossed ropes, it has greater mooring efficiency. Holding load information is obtained from measuring vacuum levels and lateral forces in the bow and stern bollards. Having information about all conditions of mooring at any time, the operator has full understanding and control over the condition of the mooring of the vessel [2].

FLIR announced in 2019 the new Raymarine DockSense mooring assist system, the industry's first docking solution for pleasure boats using intelligent object and motion recognition. Using FLIR CCTV cameras and video analytics, DockSense combines information from surrounding objects with the ship's propulsion and steering system to help the boat owners maneuver while docking.

Raymarine DockSense is designed to enhance the captain's handling skills with Virtual Bumper technology that surrounds the vessel's perimeter. If an object enters the range of the Virtual Bumper, FLIR's DockSense will automatically enter commands that will adjust steering to avoid a collision and help the captain correctly steer the boat to dock.

Using GPS and AHRS, DockSense negates the effects of wind and currents and allows the boat to moor without collisions or problems. The technology includes high-performance FLIR vision cameras, a central processing unit, DockSense app running on a Raymarine Axiom touchscreen display. Also integrated into the DockSense is a modern controller that provides auxiliary steering and throttle commands so that the captain can dock as smoothly as possible [3].

The European Maritime Safety Agency reports that over the past decade, there have been 16,539 accidents and incidents on board of maritime vessels, in which 600 people died and 5,607 were injured.

At the 5th session of the Subcommittee on the design and construction of ships, the working group on mooring and towing equipment, which included specialists from Denmark and Japan, presented proposals to the Maritime Safety Committee on introducing further amendments to SOLAS regulation II-1/3-8 on towing and mooring equipment and significant additional requirements of MSC / Circ. 1175.

The new circulaire draft offers a modern functional approach to the design of towing and mooring devices, which should provide the following:

- unimpeded access and operation of the mooring equipment;
- simplification of the configuration of the mooring lines;
- compliance with the peculiarities of the operation of the vessel;
- unobstructed view in the area of mooring operations;
- minimum exposure of crew members to rope-tension hazards and dynamic loads;
- consistency of characteristics of the mooring lines with the characteristics of the mooring equipment;
- constant visibility of the mooring area and control;
- adequate lighting and visibility for workers;
- sufficient work space;
- minimization of the mooring line rupture risk;
- exclusion of the possibility of injury by mooring lines;
- unobstracted communication during mooring operations;
- minimizing the risk of slip and fall injuries under any weather conditions;
- minimization of the mooring lines wear and tear;
- proper service and maintenance in operational readiness;
- versatility under extreme conditions.

To achieve functional objectives, all mooring equipment must comply with the revised chapter 5 of the circulaire. Among the measures to simplify the configuration of the winding of the mooring lines, it is proposed to think well of the position of the haws and rollers; to improve the means of communication - reduce the noise of mechanisms and not to obstruct the view; at least two people must be granted access to the mooring equipment at all times, also manual labor is minimized, etc.

Three new characteristics have been introduced for the choice of mooring lines and equipment strength:

- SDMBL (Ship Design Minimum Break Load) - the minimum breaking load of a new dry mooring line, for which a mooring system has been designed that meets the requirements;
- WLL (Working Load Limit) - the maximum load which the mooring line is subjected to during operation, shown in percentage, as a limit that should not be exceeded. For the steel mooring line it is 55% of the MBLSD, for the synthetic mooring line it is 50%;
- LDBF (Line Design Break Force) - the minimum force sufficient to the destruction of a new dry mooring line with the eye splice attached. Accepted from 100 to 105% of SDMBL.

The specified values should be indicated in the Mooring and towing equipment plan both during normal mooring and in high wind and current conditions [4].

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FEATURES OF TECHNICAL IMPLEMENTATION OF THE CONCEPTS OF BALLAST-FREE SHIPS

Kyrylo Onischuk, cadet of group 1103, scientific supervisor Kateryna Shumilova, assistant of the "Ship Theory and Structure" department (NU «OMA»)

Oceanic plants and creatures are known to be endangered by human actions. Oceanic life forms are also threatened by various activities of the shipping industry, which is a constraint on the existence and development of organisms [1]. An urgent problem that has become even more serious is invasive marine species. These species live in certain parts of the ocean, where rocks and winds act as natural barriers and prevent them from penetrating and expanding their negative growth. But due to the constant movement of vessels, they get into different ocean areas through the ballast waters of ships [2]. This complicates the problem on a huge scale. According to statistics, these problem organisms are part of a quartet of ocean pollutants, which also includes:

1) ocean pollution caused by land-based activities;
2) extensive use of ocean resources;
3) unnecessary changes to the ocean environment and ecosystem.

In connection with the entry into force of the International Maritime Organization (IMO) "International Convention for the Control and Management of Ships' Ballast Water and Precipitation" (adopted on 13 February 2004, entered into force on 8 September 2017), the topic of free-ballast vessels is regulated under very strict requirements for ballast water treatment [3, 4].

The creation of vessels with an alternative non-ballast solution means that they are no longer bound by ballast water treatment standards. Exemptions from pumps, pipes and valves associated with ballast tanks can reduce maintenance costs, free up electricity normally required for ballasting, and make ballast water treatment systems unnecessary, making them the cheapest way to comply with IMO rules.

One of the well-known project of a ballastless vessel is the University of Michigan project, in which the ship's ballast tanks are replaced by a longitudinal structural ballast line, through which a constant flow of local seawater is created, which reduces the potential danger of contaminated water (Fig. 1, 2).

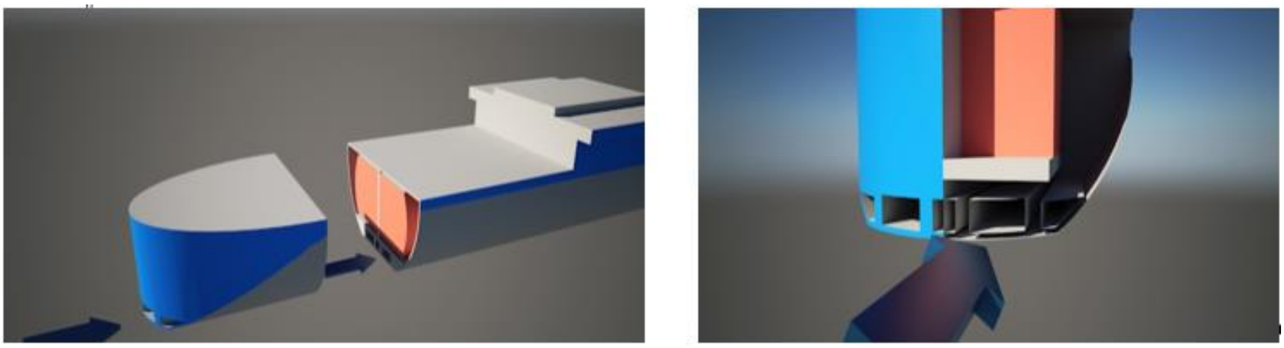

Fig. 1. Tunnels for the flow of ballast water in the hull

When the vessel moves in the area of the bow is forming of high pressure, and in the area of the stern is forming an area of low pressure. This pressure difference is used to create a flow of water through the tunnels, without the use of pumps. Although this slightly increases the resistance of the vessel, the flow to the upper half of the propeller provides a stable flow of water that attacks the propeller, increasing its efficiency and compensating to some extent for the increase in resistance.

A number of projects have also been developed that do not completely abandon the use of ballast water, but reduce its quantity to a minimum (low-ballast).

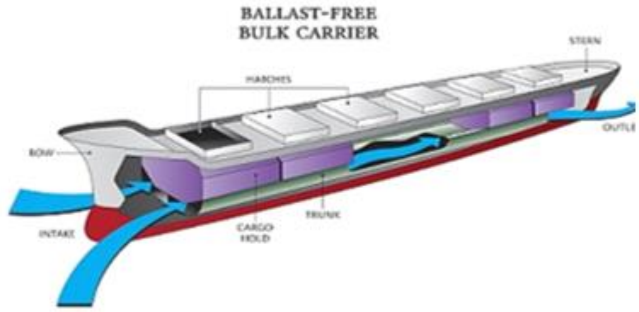

Fig. 2. Bulk with ballastless system of sea water flow through tunnels. "Electric Blue"

Fig. 3. Project of a modern ballastless container vessel

Another project worth mentioning is the Rolls-Royce Marine's Electric Blue feeder container project with modular components that can be replaced or upgraded to adapt to changing needs, which is a significant step towards building ships without ballast water (Fig. 3).

Conclusions

In the implementation of the ballastless vessels' concept, it is important that in addition to the costs associated with regulatory benefits, ballastless vessels can have an extended service life without the risk of corrosion caused by the accumulation of sediment in ballast tanks. Elimination of this problem will also reduce inspection and cleaning time, making life easier for crew members. The vessel's ability to hold course will also improve, and movement without heavy ballast tanks will reduce impacts during collisions in severe weather. Therefore, the creation of a vessel that does not carry ballast will prevent the transportation of microorganisms without the installation of expensive cleaning equipment, such as filters, installation of ultraviolet radiation, the use of chemical biocidal additives and other solutions.

Among the disadvantages we note the following:

1) loss of load capacity due to the limitation of the volume of ballast water, as it is difficult to maintain the load capacity and the same volume of ballast water;

2) loss of strength of the vessel – complete processing of the double bottom will be required;

3) increasing the flow rate of ballast water at the point of discharge, i.e., increasing the resistance, as shown experimentally.

Despite all the costs and some shortcomings, we will get much more – clean seas, oceans and progress that may open our eyes to new ideas and discoveries.

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DRONE VESELS ‒PROBLEMS OF AUTONOMY IMPLEMENTATION

Oleksandr Shelestiuk, cadet of group 1103, scientific supervisor Kateryna Shumilova, assistant of the "Ship Theory and Structure" department (NU «OMA»)

A logical continuation of the development of maritime transport is automation and reducing the dependence of the transportation process on people on board. Creation of autonomous (unmanned) vessels for commercial operation is not far off [1]. At the same time, there are security and safety concerns, alongside with issues including cybersecurity, in maritime transport, as well as concerns about the negative employment consequences of seafarers, most of whom are from developing countries.

The term "autonomous vessel" differs from the term "unmanned vessel". The former can operate at different levels of autonomy, including a partially autonomous regime (with human participation) and a fully autonomous regime (which does not require human intervention). The use of autonomous vessels opens up significant opportunities for shipping companies. The operation of autonomous vessels can also be made more environmentally friendly, as such vessels will run on alternative fuel sources, without ballast and with zero emissions. In addition, if there is less or no crew on board, there will be less debris and wastewater to be treated [2].

Autonomous vessels can potentially be used for a variety of purposes, including rescue operations, emergency oil spill response, passenger ferry services, towing, cargo transportation and as vessels providing offshore platforms (Fig. 1) The new vessel are going to commence their first voyage appear by 2030 or earlier.

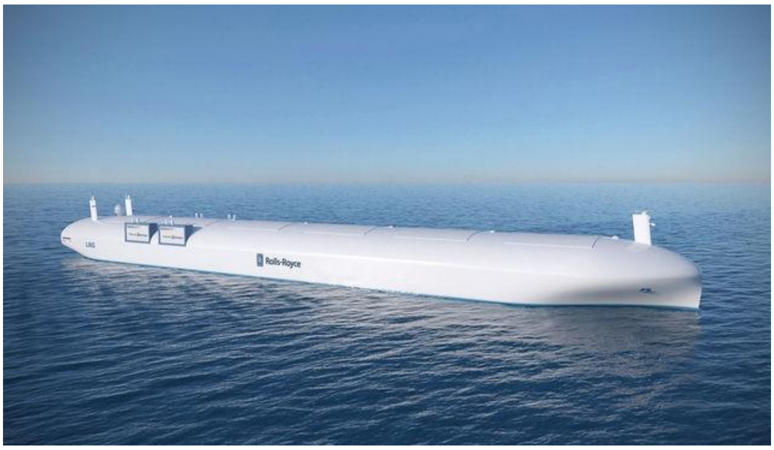

Fig. 1. Waste Shark ‒ autonomous robot for collecting plastic and garbage.

In September 2016, tests of the surface autonomous robot Waste Shark began to collect plastic debris from the water in the port waters. Such works can appear in various major ports around the world. In 2018, the Finnish company Finferries introduced the autonomous ferry Yara Birkeland (Fig. 2). Delivery by sea by means of an autonomous vessel should replace freight road transport in order to reduce pollution of the environment by the products of combustion of diesel fuel. The new vessel is provided by electric motors that are powered by batteries. The vessel does not use ballast. The Norwegian electric container ship Yara Birkeland was launched in 2020. The vessel will make its first autonomous voyage between the two cities by the end of 2021 ‒ a small team will remain on board to monitor the autonomous operation of the ship's systems.

Fig. 2. Norwegian electric container ship Yara Birkeland, 2020

Yara Birkeland is capable of carrying up to 103 containers at a speed of about 13 knots – the vehicle will transport fertilizers between three ports in southern Norway. Yara is confident that such cargo ships will have a positive impact on the environment. According to the developer's estimates, in a year the m/v Yara Birkeland will be able to replace about 40,000 road haulages, which will significantly reduce emissions. In addition, the developer is confident that this will reduce traffic congestion and play into human safety, as the vessel is completely unmanned.

Conclusions

Analyzing modern online forums and videos, it is obvious that seafarers and people involved in the maritime industry are skeptical of modern ship’s automation ideas, as the seafaring profession may become obsolete due to unmanned technology and telemetry development. According to superintendents and captains, in the next 50 years there will be no large-scale and crucial changes in shipping, and sailors will be just as in demand [4].

The reality is that the modern shipping industry cannot afford expensive vessels. It is much cheaper to hire people than to build vessels that will sail on their own without crews. In the open sea there are many emergency situations of technical and organizational nature, which can only be solved by human. Currently, the new fleet is mostly not in operation, which is gradually becoming obsolete. Replacing old ships with new ones is not a rapid process, modernization costs a lot of money. Paying for the services of a crew capable of solving all the problems that arise now is much more profitable.

It is worth noting that the full potential of unmanned vessels will be revealed only after a change in existing international law, which does not yet provide for their operation, and will take a long time.

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THE ENHANCEMENT OF SAFETY OF SHIPS NAVIGATION VIA DETERMINING OF DANGEROUS FACTORS IN CLOSE-QUARTER SITUATIONS UNDER EXTERNAL CONTROL

M. Kulakov, Ph.D., O. Petrychenko, PhD, V. Tolstikov, magister (NU «OMA»)

Safe and efficient operation of the vessel is the common point of interest of all parties concerned in shipping. These are shipowners, crew, shippers, consignees, insurance and many others. Nowadays it is impossible to reduce the number of marine incidents and accidents to absolute zero, but keeping this figure as low as possible is a direct responsibility of all the above mentioned. Safety of navigation, safety of human life at sea, health and well-being of crew and passengers, safety of cargo and environment protection is a main and prior task for the government.

The criteria of safety of navigation is a low incident statistic [1]. Global coordination is the function of the International maritime organization (IMO) which is a part of United nations (UN) [2, 3]. One of the brightest examples is a Ministry of Land, Infrastructure statistics (MLIT), published for the last years. There are 92 incidents of collision and 90 of grounding for 7 months only. Summary these are most common reasons of incidents on sea (Fig. 1) [4].

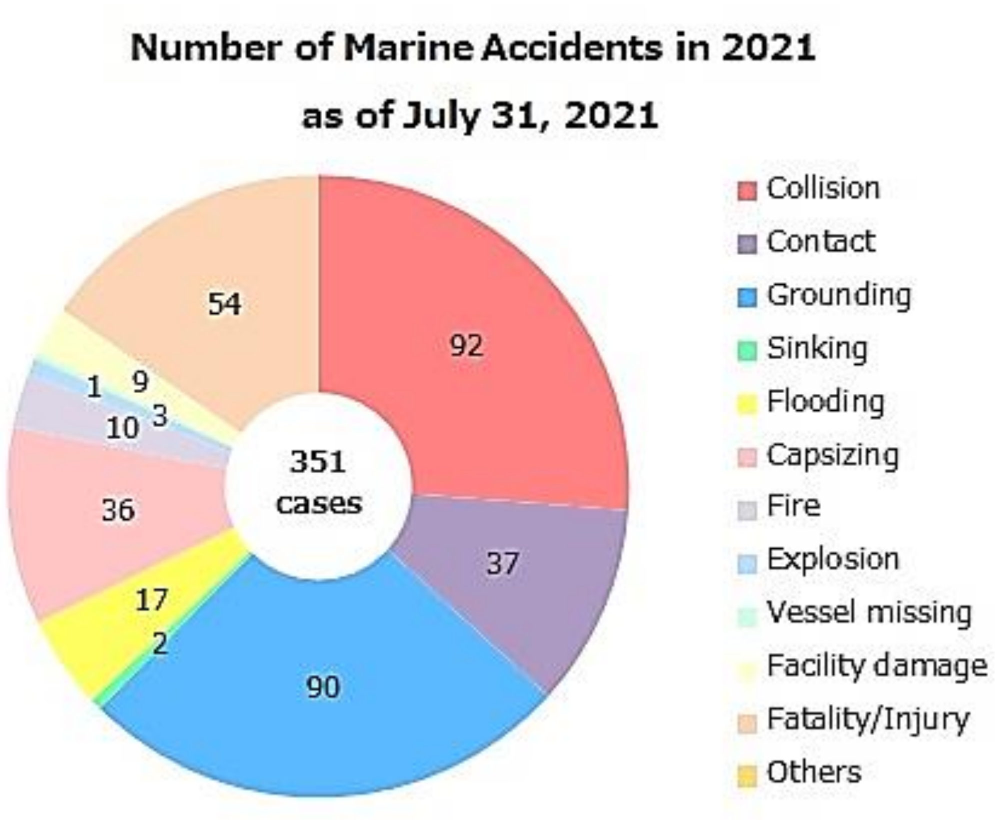

Fig. 1. MLIT statistics

Nowadays the most common practice is usage of AI-based system in different tasks even for road traffic control, incident analysis and prevention. There are some types of data exchange between vehicles and infrastructure, fitted with AI systems (Fig. 2).

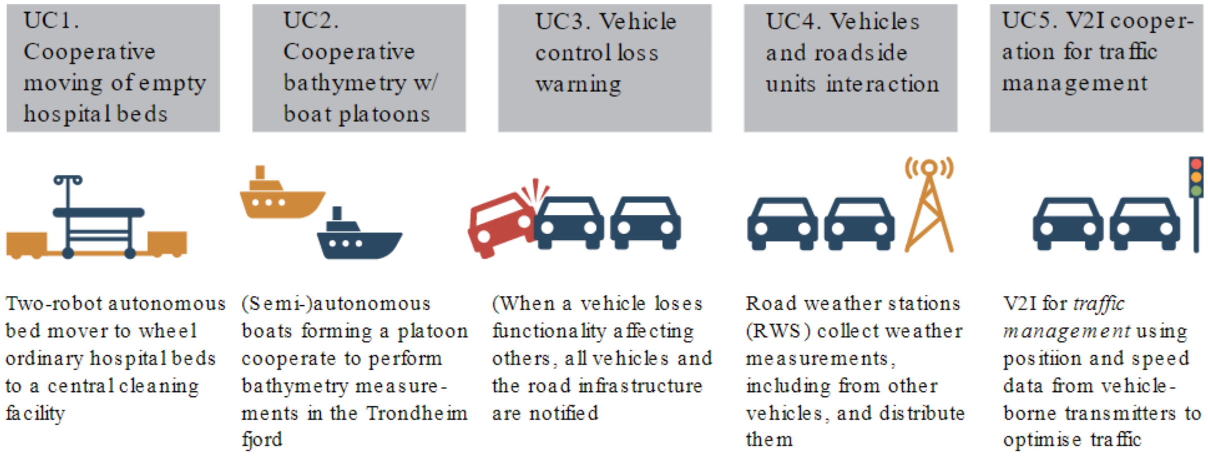

Fig. 2. Usage scenarios of data exchange

One of the most common scenarios is vehicle to vehicle (V2V). Data exchange is held between vehicles on safety related matters. This connection is helpful while maneuvering to avoid immediate danger.

Another one is group vehicle to vehicle (V2V) connection. This type of connection is established between vehicles which proceed in a line. The main intention for the use of the system is enabling vessels to pass narrow channels and straits, traffic separation schemes, which are the most dangerous parts of the route.

The newest scenario is vehicle to infrastructure (V2I). It is used during external con with feedback. This technology significantly reduces the risk of mistake because VTS operators have local knowledge and are aware of situation in complex. This type of connection is first of all required for passing through narrow channel and fairways, sea areas with high traffic, areas with special circumstances and condition. Another useful scenario is pilotage and mooring the vessel. Introducing +V2I reduces negative impact on environment, fuel consumption, seatime and wear and tear of the vessel and its machinery [5].

One more technology which is needed on the vessels all over the world in order to improve the safety and effeciency is night cams and thermal imagers systems. These appliances significantly enhance lookout options in night or fog conditions. The example of this equipment in complex with classic ship's systems is ORCA AI (Fig. 3) [6].

Fig. 3. ORCA AI system

This system provides constant monitoring and analysis on base of ready patterns of surrounding which includes ships course and speed, position of the vessel, reaction in critical and dangerous situation. It reduces a number of incidents, enhances safety, saves lives of people and preserves the environment.

There are some researches conducted into air traffic control via Artificial Intelligence- based systems. They are based on Machine Learning Patterns and are continuously developed and improved to reduce the decision-making time and to improve the quality of decisions taken. These systems are easy to learn on operating. The algorithm is drawn at the Fig. 4 [7].

Fig. 4. Ship – shore communication pattern

One of the most known companies introducing AI-based technologies for collision avoidance is a CMA CGM, which established a partnership with Fujitsu Laboratories Ltd. As a part of Digital Transformation Program wide testing of Fujitsu Human Centric AI Zinrai was held in cooperation with Japan Coast Guard and Tokyo VTS. The main objective is to reduce a close-quarter alarm latency for about 2 minutes and achieve a twofold increase of the number of alarms. There is c clear evidence that this system works in advance as a matter of safety of navigation [8].

The same partnership is established with the Shone start-up located in San-Francisco. Some prototypes are used as auxiliary aids to navigation and collision avoidance tools during passing heavy traffic areas, narrow channels and straits.

AI based system conducts a thorough analysis of accidents including collisions, groundings, strandings with gathering all data including, but not limited to heading, speed, position of the vessels involved. AI tries to predict the accident possibility based on the known patterns. Usage of this technology can significantly reduce number of accidents, keep people alive, protect the environment from negative impact, improves safety of navigation on a basic new level. Cooperation of seamen and IT sector is vital for the development of this branch onboard ships.

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SAFETY OF NAVIGATION IN DEEP-WATER FAIRWAY DANUBE – BLACK SEA IN THE CONTEXT OF THE INTERNATIONAL TRANSPORTATION DEVELOPMENT

Konon N., **PhD student (NU «OMA»)**

Deep-water fairway Danube – Black sea (DWF) is a complex area for navigation. The fairways established by the regulations due to administrative, navigational, hydrographic and meteorological reasons pose a danger to navigation and are subject to review and change. Ensuring the safety of navigation is a necessary condition for the development of international transport on inland waterways of Ukraine. The DWF passes through the estuaries of Bystre, Starostambulske and Kiliyske in the Danube Delta as well as through the Danube Biosphere Reserve. The length of the fairway in natural channels is 172.36 km, the length of the artificial sea approach channel is 3.4 km. The width of the canal is from 85 m to 100 m, depending on the area. The maximum design draft for ships is 5.85 m and depends on the regularity of dredging works. The canal route consists of sections: Reni port - Cape Izmail Chatal (44.1 km), Cape Izmail Chatal - Vilkove port (98 km), Vilkovo port - Black Sea (17 km) [4].

The project "Construction of deep-water fairway of the Danube - Black Sea on the Ukrainian section of the delta. Phase I was approved by the order of the Cabinet of Ministers of Ukraine dated 12.05.2004 №83-P. The Ministry of Infrastructure of Ukraine has identified the Delta-Pilot branch of the AMPU State Enterprise as the customer for the design and construction of the Danube-Black Sea GSC through the Bystre estuary, with a total budget value of UAH 543.5 million. The transport project for the development of the canal is essential for the creation of a national network of international transport corridors and its integration into the transport system of Europe, Asia, the Baltic and Black Sea regions. The project includes optimizing the capacity of the Ukrainian part of the Danube Delta, reducing costs as well as improving the safety of navigation when passing vessels on the Danube-Black Sea connection. The main advantages would include:

- competitive tariffs;
- two-way vessel traffic 24/7 all year round (unlike Romanian canals, where traffic is one-way and during daylight hours).
- condition of compliance of maritime safety management systems with international EU standards and other international norms.
- development of navigation on the Ukrainian section of the Danube as one of the measures of the European integration course announced by Ukraine.

The development of DWF contributes to the expansion of logistics capabilities and strategies for the direction of cargo flows in the vector "East - West" Full development " developed in 2004 by the order of "Delta-pilot" design and survey and construction and technological institute of river transport "Richtransproekt" on the basis of:

- Tasks for the development of a working project approved by the State Enterprise "Delta Pilot";
- Decree of the President of Ukraine of June 10, 2003 №502 / 2003;
- Order of the Cabinet of Ministers of Ukraine dated 13.10.2003 № 598-R "On approval of the working design and title of the GSC structure;
- Decree of the President of Ukraine of February 2, 2004 № 117/2004 "On the expansion of the Danube Biosphere Reserve";
- Architectural and planning task, approved by the Department of Urban Planning and Architecture of the Odessa Regional State Administration on August 25, 2004 [1].

The following parts took part in the development of the working project: Delta Pilot Branch, Danube Hydrometeorological Observatory, NOOSPHERE Research Center, Ukrrybproekt Institute, State Hydrography State Enterprise, Institute of Hydromechanics of the National Academy of Sciences of Ukraine, Ukrainian Research Institute of Environmental Problems.

Construction on this project lasted from May 2004 to May 2005 (with breaks during storms and fish spawning periods). The project was considered by the state ecological examination from August 10, 2004 to April 19, 2006, which was the reason for the delay in preparing the project for approval. Despite the fact that in July 2005 the ban of the Ministry of Environment was lifted, the construction of the first stage of the ship's course did not continue. Due to the cessation of construction works, as well as hydrometeorological conditions in July-September 2005, there was intensive siltation of the incomplete fairway, which made it impossible to navigate [2].

In 2007, according to the first stage of the project, DFW managed to permit vessels with a draft of up to 5.85 m. The construction of a dam in 2008-2009, which provided a complete closure of the north-eastern ravine, increased the flow velocity through the sea approach channel and reduced soil subsidence on it. In other words, this fact relieved the canal from storm silt and sand, which helped to preserve the sediment. The second stage (by the Order of the Cabinet of Ministers of 31.05.2007 №351-r - for full development.) Aims to increase the draft of vessels to 7.20 m.

In November 2007, Ukraine made the final decision on the implementation of the project "Creation of GSC Danube - Black Sea in the Ukrainian part of the delta. Full development. ". The second stage (by the Order of the Cabinet of Ministers of 31.05.2007 №351-r - for full development.) Aims to increase the throughput of vessels to 7.20 m. alternative to the Sulina Canal in Romania. Vessels with such a draft make up about 80% of the total number of seagoing vessels and vessels of mixed (river-sea) navigation, which enter the ports of the lower Danube.

This decision was taken with an incomplete implementation of a number of procedures provided by the Espoo Convention (Convention on Environmental Impact Assessment in a Transboundary Context). As a result, it became the main reason for the adoption at the 4th meeting of the parties to the Espoo Convention (19-21.05.2008, Bucharest) certain recommendations to limit the implementation of Phase II (Decision IV / 2), which remains in force today. In addition to these restrictions, the obstacle to development is the position of the Romanian side, which prevents dredging in border areas. Romanian side is adamant in its decision and refuses to jointly monitor the Danube Delta.

In 2019, the Minister of Infrastructure of Ukraine announced the active work on the restoration of DWF, emphasizing the importance of the Danube for the economic and transport infrastructure of Europe.

In the context of the development of international transportation on the inland waterways of Ukraine, DWF "Danube - Black Sea" is a very important artery of international economic relations and maritime transport infrastructure of our country. There are such Ukrainian ports on the Danube as Reni, Izmail and Ust-Dunaisk, the development of which contributes to the development of Ukraine's economy by strengthening cargo turnover and strengthening international trade. The EU strategy for the Danube region is a significant project in the implementation of which Ukraine is strengthening its participation. All countries participating in the EU strategy benefit from the development of the Danube-Black Sea DWF, which is included in the List of Inland Waterways of international importance (category E 80-09) of the European Agreement on the Most Important Inland Waterways of International Importance. The creation of multimodal terminals at Danube ports is one of the main tasks of the EU strategy, so the country needs to focus on the most effective measures in terms of the DWF project [3].

The development of the Danube-Black Sea waterway includes appropriate modifications and construction works to increase the capacity of the canal, which also requires an analysis of the navigation system and safety of navigation.

In the framework of consideration and analysis of the shortcomings of the current state of the shipping system in the region, it is necessary to indicate areas for improvement. Regarding cartographic support, it should be noted that it is insufficient and outdated and needs to be modernized. Modern ships use electronic navigational charts (ENC), which should be implemented and agreed with the Romanian counterparts, in order to eliminate discrepancies and errors.

The aids to navigation (AtoN), both floating and shore-based, should be upgraded, expanded and constantly monitored to ensure the safety of navigation at the current level, as well as for timely technical control.

Unlike the Romanian part of the canal, Ukraine does not have the satellite station differential correction (GPS) stations needed to improve its positioning accuracy. Signal coverage areas should be surveyed to install differential correction stations.

Vessel traffic control systems with AIS need to be improved to increase efficiency. It is necessary to draw up rules in accordance with the regular reports of vessels while sailing in different areas, as well as advice from the operators of the vessel traffic control center, regarding the navigational safety of navigation.

It is necessary to establish emergency areas in case of emergencies, where vessels will be able to stay temporarily until the problem is resolved.

The rules on fishing vessels should be revised and amended to ensure safe navigation so as not to interfere with fishing in the water area.

The state of the river's water level is an important issue, as the required water supply under the keel (UKC) is a critical basis for maintaining seaworthiness and safety during the passage of the canal. For this purpose, it is advisable to install automatic depth measurement stations, with a permanent transfer to a single center of the vessel traffic control system.

The above-mentioned areas of improving the navigational safety of navigation at the DWF "Danube - Black Sea" have prospects for development and implementation. Thus, the Basic Provisions for Navigation on the Danube (OOPD) should be adapted accordingly.

Summarizing the information provided in the article, it is necessary to emphasize the importance of the Danube as a leading route for Ukraine's international trade. DWF "Danube - Black Sea" is subject to deep development, research and reforms. Furthermore, amendments should be adopted to the relevant regulatory framework by the responsible parts in order to publish an updated version of the "regime of navigation in the Black and Azov Seas". In addition, the same should be applied to the edition of the "Danube River Lotion", as well as to the introduction of educational programs in the preparation of the merchant staff in higher educational institutions of Ukraine.

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UDC 631.348.44:331.542

NAVIGATORS' TASKS IN FACILITATING SAFE TRANSPORTATION OF FUMIGATED CARGO IN NORMAL OPERATING CONDITIONS AND DURING EMERGENCIES

Sihal O.S., master, Torskiy V.G. PhD, professor (NU «OMA»)

Since the inception of the maritime craft, its fundamental goal, and the primary priority of mariners, has been safety - the safety of the structure of the vessel itself, the safety of the life of the crew members responsible for its operation, and the safety of goods transported on board. Any event related to the handling or storage of cargo inevitably entails additional risks for the aforementioned safety - in particular, here we will talk about fumigated cargo and the tasks of boatmasters to ensure the safety of their transportation.

The most common fumigants are phosphine and methyl bromide. Phosphine is incredibly toxic to humans, and poisoning with it often leads to painful death of the victims. Such cases are somewhat more common on old river-sea vessels, which had a 70-fold excess of pesticides delivered to the vessel compared to panamax bulk carriers, however, studies for 2006-2016 did not find an absolute correlation between characteristics of ships and the number of phosphine poisoning by seafarers.

In addition, it should be noted that often, despite the sufficient warning of the ship's crew about the presence of cargo fumigated with toxic phosphine on board, the officers are unable to correctly determine the diagnosis and conduct the first treatment of the victim. Studies show that in more than 45% of cases, phosphine poisoning is confused with food poisoning, due to the similarity of symptoms, namely:

- nausea;
- vomiting;
- diarrhea.

Other symptoms include headache, irregular heartbeat, severe dilated pupils, severe dry cough, dizziness, etc. The only way to clearly understand the possibility of phosphine poisoning and to distinguish it from food poisoning is to be aware of the presence of fumigated cargo on board and the principles of poison gas dynamics.

Additional risk factors associated with fumigated cargo include the use of fumigants - special fabric sleeves containing fumigants - which can lead to fires and fires in the holds and decks of grain carriers [1]. The combination of the danger of thermal injuries, acute poisoning and pyrolysis (combustion) products of fumisives and cargo makes the process of transporting fumigated cargo a serious test for boatmasters..

This fact compels attention to the careful observance of the procedures for fumigation and subsequent ventilation of the holds. The responsibility of shipping companies here can be expressed in the creation of well-thought-out procedures and checklists, which are included in the Ship Safety Management System; and the boatmasters themselves are responsible for the strict implementation of these procedures, compliance with all precautions and safety.

However, the safety procedures alone cannot be ensured - it is also necessary to provide for emergency measures in the event of a person being poisoned with phosphine on board. One of such measures may be the product "First-aid kit for medical care in case of fumigation phosphine poisoning", developed by scientists of the State Enterprise "Ukrainian Research Institute of Transport Medicine of the Ministry of Health of Ukraine" and ONMU of the Ministry of Health of Ukraine, taking into account the requirements of such international documents as IMDG Code, MLC-2006, MFAG etc. [2]

The aforementioned first-aid kit provides medicines for two possible types of assistance: pre-medical care by ship workers without special medical education, and full-fledged medical care provided by shore doctors or ship officers who have undergone appropriate training in accordance with the provisions of the STCW-78 Convention. In order to fully ensure safety on board the ship, boatmasters are required not only to undergo basic medical training in accordance with STCW, but also to take courses on the use of this "First Aid Kit", or other similar products..

It is also necessary to pay attention to the issue of sufficient sealing of cargo spaces with fumigated cargo. All phosphine hazards begin with the release of toxic gas from cargo spaces. The inability of the crew to identify these leaks in time and to take appropriate safety measures is unacceptable for the boatmasters responsible for the carriage of such cargo. The tightness of the covers of the hold can be checked in various ways: physical inspection, visual search, air pressure test by blowing, ultrasound test, etc. Studies have shown that regardless of the type of ships, their size or the amount of cargo in their holds, the last stage of loading namely, the closing of the covers of the hold - always takes place in an atmosphere of poisonous gas that accumulates in the over-grain space of the hold [3]. The results of such studies substantiated the patenting of the model "Methods for the control of airtightness with fumigated and phosphorous vantages before the ship goes on a voyage.» (№ UA 116604 U).

The analysis of marine accidents (AMA) over the past 15 years, associated with fumigated cargo, showed that the main causes of such accidents are poor training of the ship's crew on the basics of marine fumigation, insufficient preparation of the vessel for the carriage of fumigated cargo, lack of knowledge of the symptoms of phosphine poisoning and methods of its treatment, as well as the lack of necessary medicines in the ship's first aid kit [4].

Based on this, we can highlight the main tasks of boatmasters to ensure the safety of transportation of fumigated cargo on board the vessel:

1. Familiarization and training with the basics of marine fumigation, the dynamics of the formation and movement of toxic gases in the hold space.
2. Paying special attention to the dangers of fumigants to human life, symptoms of poisoning by them and measures for the treatment of poisoned people.
3. Conducting appropriate training on the use of medicines from the ship's first-aid kit, as well as additions to this first-aid kit like "First-aid kits for fumigation with phosphine" - this training should go beyond the basic knowledge for boatmasters stipulated by the STCW-78 Convention;
4. After fumigation of cargo on board the vessel, make sure that there are no phosphine leaks from the holds and that they can be adequately ventilated (in particular, this can be done using a "phosphine test detector" [Patent of Ukraine UA 116604 U]).
5. 5. Compliance with the requirements specified in the international regulatory framework, in documents such as:
   - SOLAS-74;
   - IMSBC Code;
   - IMFO Code;
   - IMO Recommendations on the Safe Use of Pesticides on Ships.

Conclusions: Cargo fumigation is a life-threatening activity for ship's crew and requires careful training and competence in marine fumigation, treatment of phosphine-poisoned people and the use of medicines on board, while shipping companies are held accountable for making sound plans and fumigation procedures and related thematic briefing for the crew of a vessel with fumigated cargo.

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OBT IN TIME OF COVID 19 PANDEMIC

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Since the outbreak of COVID-19 in February 2020, the global maritime trade plunged by 9% in 2020, an unprecedented loss since the trade decrease triggered by the 2008 financial crisis. In addition to the disruptions of supply chains and decline of transportation sectors brought on by the pandemic, surging nationalism and protectionism, the retreat of globalization, and calls for more diversified global value chains and decoupling of economies have heightened the adverse impacts on survival and sustainable growth of the shipping industry. As a result, many people have adopted a more pessimistic view, and predicted that "the short-term outlook for maritime trade is grim, and that the industry's recovery is fraught with uncertainty," according to one UNCTAD report. Some even proclaimed to "wave goodbye to the greatest era of globalization," wrote The Economist in May of 2020 [1].

This article argues that the MET will have a strong and speedy recovery from the disruptions brought on by COVID-19. The adverse factors that the MET faces would be marginal rather than fundamental in nature.

The article provides recommendation for the **Simulator based training and evaluation by the consideration for sea time equivalence.**

1. Introduction

The direct comparing of cadet performance is rather tricky due to different reasons. The real efficiency assessors of training of prospective officers are acting ship's officers including masters and chief engineers. As they can offer the most competent opinion, their views should be taken into consideration as basic data for proposed research. As a result, we collect experts' views by elaborating the concise and targeted questionnaire, which can be distributed during STCW courses conducted by IAMU universities. The data collected and coupled with views of university assessors could serve to create the expert model of training efficiency. As the structured source for this activity the TRB for prospective deck officers could be used [2].

2. Simulator based training and evaluation – Consideration for sea time equivalence.

Do all the competencies need to be assessed on board the ship during the OBT time? If not, could it be reasonable to reduce the OBT time for prospective officers substituting it by more effective training ashore? It could raise the level of the OBT quality. This issue can be explained by drawing out inferences from STCW Sec A chapter II Table A-II.

Below is the table containing details for the knowledge, understanding and proficiency. The columns are the various methods for demonstrating competency and the rows are the competencies to be evaluated for First COC [3].

S.NO	Competence	Approved in service experience	Approved training ship experience	Approved simulator training where appropriate	Approved laboratory equipment traning	Practical training	Approved training on a manned scale ship model where appropriate
Function: Navigation at the Operational level							
01	Plan and conduct a passage and determine position	√	√	√	√		
02	Maintain a safe navigational watch	√	√	√	√		
03	Bridge Resource management	√	√	√			

04	Use of radar to maintain safety of navigation	√		√			
05	Use of ECDIS to maintain the safety of navigation		√	√			
06	Respond to emergencies	√	√	√		√	
07	Respond to a distress signal at sea			√		√	
08	Use of the IMO standard marine communication phrases and use of English in written and oral form					√	
09	Transmit and receive information by visual signalling			√		√	
10	Manoeuvre the ship	√	√	√	√		√
Function: Cargo handling and stowage at the operational level							
S.NO	Competence	Approved in service experience	Approved training ship experience	Approved simulator training where appropriate	Approved laboratory equipment traning	Practical training	Approved training on a manned scale ship model where appropriate
11	Monitor the loading, stowage, securing, care during the voyage and the unloading of cargoes	√	√	√			
12	Inspect and report defects and damage to cargo spaces, hatch covers and ballast tanks	√	√	√			
Function: Controlling the operation of ship and care for persons onboard at the operational level							
S.NO	Competence	Approved in service experience	Approved training ship experience	Approved simulator training where appropriate	Approved laboratory equipment traning	Practical training	Approved training on a manned scale ship model where appropriate
13	Ensure compliance with pollution prevention requirements	√	√				
14	Maintain seaworthiness of the ship	√	√	√	√		
15	Prevent, control and fight fires onboard	Section A-VI/3 Mandatory minimum training in advanced fire fighting					
16	Operate life-saving appliances	Section A – VI/2 Mandatory minimum requirements for issue of certificates of proficiency in survival craft, rescue boats and fast rescue boats					
17	Apply medical first aid onboard ship	Section A-VI/4 Standard of competence for seafarers designated to provide medical first aid onboard ship					

18	Monitor compliance with legislative requirements	Assessment of evidence obtained from examination or approved training				
19	Application of leadership and teamworking skills	Approved training	Approved in service	Practical demonstration		
20	Contribute to the safety of personnel and ship	Section A-VI/1 Mandatory minimum requirements for safety familiarization, basic training and instruction for all seafarers				

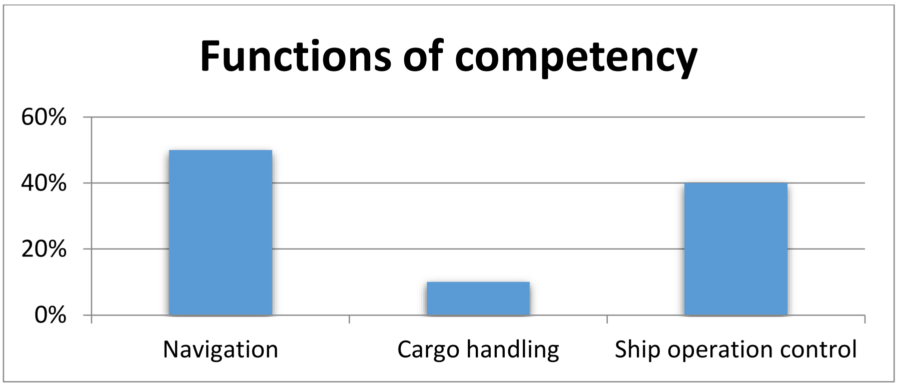

Fig. 1 The number in denominator indicates the number of competencies identified as per STCW for First COC for deck officer as per Table A II Sec A of the code. When such is the case, competencies that are learned and evaluated using simulator could be given a proportional sea time equivalence

Conclusion

Maritime industry is evergreen industry providing opportunities to the stakeholders by its varied possibilities. The entire world is suffering from the Covid-19 pandemic lockdown and is struggling to come out from the situation. The article highlights the present mentality and economic status of mariners and the future of the students. Mariners reported that they have fewer sailing opportunities compared to the past. Many of the respondents were worried that this economic slowdown due to the pandemic had a huge impact on the industry is terms of less Liner schedules and reduced employment opportunities and poor practical exposure. Maritime students pointed out that they were unable to get the practical exposures to face the challenges and virtual education system gave fewer chances to learn the practical aspects. Maritime educators mentioned that less interaction between students resulted in negative impact on their competences. Maritime education institutions have to revise their mandatory policies to meet the changing trends in education sector. It concludes that both positive and negative aspects of this pandemic resulted in the tremendous changes in the maritime sector hugely in reduced possibilities in the economies of the maritime business ventures. Future economic prosperity of the world purely depends on the maritime industry and is going to contribute to the maximum sustainability of the world.

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OPTIMIZATION OF PLANNING DURING PROCEEDING TO THE ANCHORAGE USING PATH POINTS

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Analysis of the voyage cycle of sea vessels shows that they spend about 20% of the sailing time in confined waters, but it accounts for about 80% of all emergency events.

Turning a ship in the open ocean, when sailing away from navigational hazards, is not difficult, and when using maps 1: 50,000 and smaller, its details are not expressed on the map at all. In confined waters, the water area for maneuvering is commensurate with the geometrical dimensions of the vessel and planning the trajectory of movement, and especially its curvilinear section, becomes of paramount importance.

The most dangerous section of the track, which determines the safety of the vessel's movement, is the curved one. The reasons for this are the speed of the process of moving the vessel when turning, the absence of the planned coordinates of the curved path and the necessary data on the turnability, which are required for their planning.

To eliminate such reasons, it is necessary: to carry out preliminary planning of the coordinates of curved track sections or to automate the process of their calculation, which can be performed while sailing; perform automated control of lateral displacement, relative to the planned coordinates, select a maneuver for divergence and use the maneuver in a timely manner to correct movement; use high-precision methods of determining the position of the vessel, including geodetic ones. Therefore, the purpose of this work is to produce a method for planning the specified coordinates of trajectory by waypoints (WP), based on determining the matrixes of coordinates of trajectory points (TP) of rectilinear and curved track sections through which the ship passes when maneuvering for anchoring. Another aspect of the problem is the lack of the necessary data on the maneuvering properties of braking and turnability of the vessel for all modes of using control actions. Therefore, such tasks are highly relevant.

Based on the contemporary shipbuilding science [1–7], the following navigation support systems can be offered, which produce information in the form sufficient for maritime operations:

1.A navigation device for calculating maneuverable characteristics for the current state of a vessel and its mode of movement and representing data on the characteristics of braking and maneuverability in the form of tables, as given in Table 1.

Table 1. MSC Canaberra *vessel circulation parameters*

The angle of the transfer steering wheel	Parameters	Legend	Laden		In ballast	
			Experimentally estimated, buildings	Experimentally estimated, cables	Experimentally estimated, buildings	Experimentally estimated, cables
5°	Advance	l_1	7,48	6,61	6,18	5,46
	Direct displacement	l_2	7,1	6,27	5,59	4,94
	Tactical diameter	$D_{т}$	13,62	12,03	10,83	9,56
	Constant diameter	D_y	14,36	14,36	11,26	9,95
	Advance	l_1	5,03	4,44	4,15	3,66

10°	Direct displacement	l_2	4,25	3,75	3,23	2,86
	Tactical diameter	$D_т$	8,34	7,36	6,46	5,70
	Constant diameter	D_y	8,57	7,57	6,47	5,72
15°	Advance	l_1	3,94	3,48	3,25	2,87
	Direct displacement	l_2	2,98	2,63	2,19	1,93
	Tactical diameter	$D_т$	6,00	5,30	4,52	3,99
	Constant diameter	D_y	6,00	5,30	4,35	3,84
20°	Advance	l_1	3,29	2,91	2,71	2,40
	Direct displacement	l_2	3,23	1,97	1,56	1,38
	Tactical diameter	$D_т$	4,60	4,07	3,37	2,97
	Constant diameter	D_y	4,47	3,95	3,08	2,73
25°	Advance	l_1	2,85	2,52	2,35	2,07
	Direct displacement	l_2	1,71	1,51	1,14	1,00
	Tactical diameter	$D_т$	3,65	3,22	2,58	2,28
	Constant diameter	D_y	3,43	3,03	2,22	1,96
30°	Advance	l_1	2,52	2,23	2,08	1,83
	Direct displacement	l_2	1,33	1,18	0,82	0,73
	Tactical diameter	$D_т$	2,95	2,60	2,00	1,77
	Constant diameter	D_y	2,66	2,35	1,58	1,40
35°	Advance	l_1	2,27	2,01	1,87	1,65
	Direct displacement	l_2	1,04	0,92	0,58	0,51
	Tactical diameter	$D_т$	2,40	2,12	1,55	1,37
	Constant diameter	D_y	2,06	1,82	1,09	0,96
Angular speed of involuntary circulation $\pm\omega_0$=0,12						
Rear steering angle $\pm\delta_{po}$=3°						

2.A navigation device for calculating the abscissa of the center of gravity XG [6]. This device makes it possible to automatically determine the coordinates of the ship's center of gravity by the characteristics of the empty ship, which are given in electronic format, based on the volume and location of the cargo. This makes it possible to speed up the process of controlling the ship along the predefined path.

3.A navigation device for the high-precision planning of the pre-defined route of the ship by the trajectory points of the center of gravity, representing the path in the form of the sum of the matrices of the coordinates of rectilinear and curvilinear sections of the path [2]. This device calculates, based on the available coordinates of the waypoints and characteristics of the maneuverability of the vessel, set in the program in advance, the matrices of the sections of the path along which the ship would navigate. The principle of work is based on the calculation of coordinates using a method of segments [9].

4.A system of selecting the number of tugboats for safe maneuvering under extreme conditions [1]. The principle of the system operation is based on determining the number of necessary tugboats by the magnitude of the force of inertia at the allowable speed in the port, which is necessary to ensure the guaranteed safety of maneuvering and to choose a mode of movement. The use of the device to inform the ship's control process during maneuvering when entering a port for mooring could avoid an accident caused by motion control when there is a failure in the main engine operation.

5.A system for assessing the position of a turn pole and its visualization [6,8,9] makes it possible to calculate the TP abscissa based on the values of the vectors of the bow and stern tips of the vessel's waterline. These data come from the Doppler lag and show its position on the indicator. That notifies the shipmaster of the beginning of the turn and the expansion of the width of the maneuverable displacement lane.

6.A system for counting the coordinates of the satellite dish to the center of gravity of the vessel [9] makes it possible to significantly improve the accuracy of the ship's location. This is since the corrections to the position of the antenna are many times higher than the radial rms error in determining the ship's location by modern satellite systems when they operate under a differential mode. The position of the antenna is given in the ship's documents regarding the origin of the coordinates in the form of a distance to the antenna along the X–ɩax and Y–ɩayaxes, as shown in Fig.1.

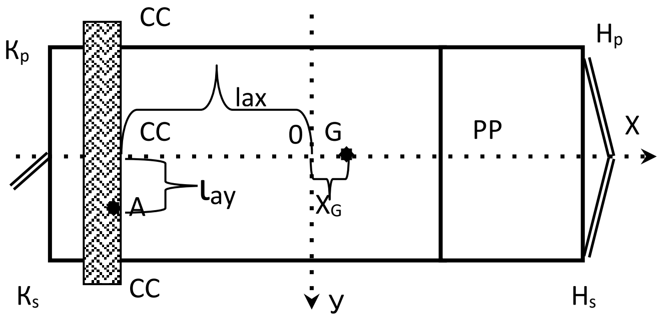

Fig.1. Location of characteristic points on the contour of the waterline:
A–the antenna of a satellite system; XG–the center of gravity abscissa

7.A system of high-precision control over the deviation of the center of gravity of the vessel, from the line of the predefined path, to prevent the ship's grounding, calculates the lateral displacement of the ship's CG relative to the nearest planned trajectory point. It allows for the timely identification of unacceptable sway to take adequate measures to compensate for it [4]. Continuous monitoring of lateral bias automatically makes it possible to assess in a timely manner an unacceptable shift relative to the planned trajectory determined by the high-precision TP matrix.

8.A device for assessing the risk of collision of ships on the course angle of the line of relative movement makes it possible to assess the risk of collision of ships based on a single information parameter – a change in the direction of RML. That makes it possible to increase the speed of decision-making by the shipmaster on the choice of maneuver for divergence.

9.A system for selecting the type of maneuver for divergence based on the nature of change in the line of relative movement during maneuvering [4] makes it possible to determine, based on a catalog, the nature of change in the relative movement based on the situation of convergence and to choose the type of maneuver. A given maneuver must comply with the rules of vessel divergence MPPSS-72/2016.

10.A navigation device for assessing excessive, dangerous, or emergency rapprochement makes it possible to automatically constantly monitor it and, according to the law of the last moment maneuver, to determine the nature of change in the situation. Also, this device selects the type of maneuver for timely collision prevention.

11.A device for estimating the width of the maneuverable displacement [7] makes it possible to constantly determine the width of the maneuverable displacement and requires the introduction of data on the current angular velocity ωf, the boundary value of the angular yaw rate ωpr when following a constant course, and the accuracy in determining the location of the radial root mean square error M0. It takes time to enter and calculate these data. For this reason, better and faster methods for determining maneuverable bias should be used, which make it possible to constantly show the true width of the maneuvering bias, without the need to enter the data required for calculations. In the curvilinear motion shown in Fig.2, the width of the maneuverable displacement of the vessel increases compared to the rectilinear section and is determined by the position of TPs. The limit for determining the nature of the movement is the magnitude of ωpr. To establish the dependences describing the width of the maneuverable displacement.

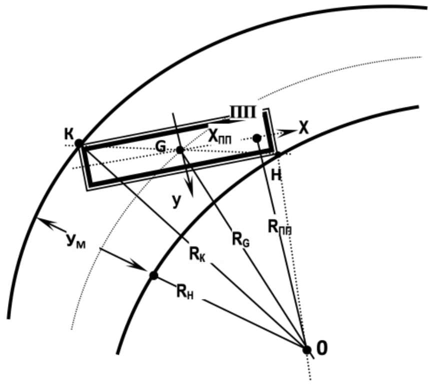

Fig.2.Curvilinear motion scheme at the turn of a ship

Algorithms and computational schemes determine the procedure for increasing the accuracy of planning the route of movement to anchorage area, taking into account the water area for maneuvering, characteristics of braking and turnability and the use of methods for planning the route of movement by trajectory points, including curved sections. To achieve this goal, we will perform the inverse route planning when anchored m / v "MSC Canaberra" on the roadstead of the Chernomorsk Port, as shown in Fig.3.

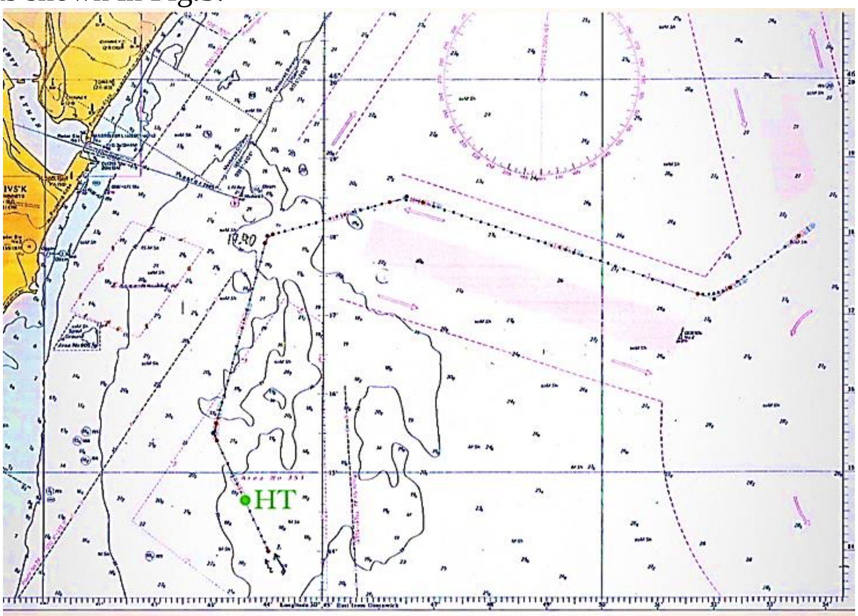

Fig. 3. Planning of the TP maneuvering route when the vessel is proceeding to anchored area No.351 on the roadstead of the port of Chernomorsk

The developed navigation information and analytical complex "Planning the path trajectory using the waypoint matrices" contains modernized methods and techniques for creating a given algorithm for the operation of the ship control system and control over the process of moving along the trajectories, including curved and straight sections of the track when anchored. It automates the anchorage route planning process and controls safe maneuvering, including the use of motion control techniques using dynamic positioning.

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THE ROLE OF SHIPBUILDING STEEL PRICE IN THE SHIPBUILDING MARKET DURING POST-LOCKDOWN PERIOD OF 2020 COVID-19 REALITY

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Abstract: During 2020, the world has witnessed an unprecedented situation where most of world productive plants were forced to be closed for months. This had its effect on markets during the entire 2020 and the echo of this effect is still visible now. The shipbuilding market, being a part of a very sensitive system, was no exception. Now we see an interesting development in the shipbuilding market. The main objective of the present article is to examine the link between steel production prices and shipbuilding market.

Keywords: *Shipbuilding, Steel Price, Shipbuilding Market, COVID-19*

I. INTRODUCTION

Ever since ships became the steel giants of the seas, the price of building a new vessel has been linked to the price of shipbuilding steel. This development helped both shipping and steel producing industry by implementing new technological methods of steel production. This also led to the surge of a highly complex steel producing industry, the influence of which is by no doubt connected to shipbuilding [1].

During 2020, many aspects of modern world were paused for almost the entire first half of the year. Even though major companies in the beginning of the lockdown seemed ready to face this challenge, its relatively long period combined with the post lockdown insecure reopening, made the period that followed even more challenging.

According to Offshore Energy, the number of ordered ships in the first half of 2020 were almost been halved when compared to the same period a year earlier. Namely, the valuations agency's record showed that in the first half of 2020 there were around 332 new ship orders across all sectors, a 47 % fall when compared to a total of 625 orders in H1 2019 across all sectors. This was further down from the corresponding 2018 figures that equaled to 881 orders. According to data from Vessels Value for the first half of 2020, at the same point in 2019 there were 873 live vessels delivered, while there were 758 for the same period in 2020. However, these numbers also show that the delivering was only postponed, and the ordered vessel number remained high compared to the previous year.

There is no doubt that such a development had its impact on steel demand, even though the biggest consumer of steel is the construction industry, making between 10 and 15% of the domestic demand of steel in China. The statistics show that very few countries did not have a decline in steel production during 2020[5]. This unusual situation kept prices of steel low during the entire 2020, reaching a 2-year low during the first half of the year.

Table.1 Top 10 steel-producing countries

Rank	Country	2020 (Mt)	2019 (Mt)	%2020/2019
1	China	1053.0	1001.3	5.2
2	India	99.6	111.4	-10.6

3	Japan	83.2	99.3	-16.2
4	Russia (e)	73.4	71.6	2.6
5	United States	72.7	87.8	-17.2
6	South Korea	67.1	71.4	-6.0
7	Turkey	35.8	33.7	6.0
8	Germany	35.7	39.6	-10.0
9	Brazil	31.0	32.6	-4.9
10	Iran (e)	29.0	25.6	13.4

II. THE EFFECTS OF COVID-19 IN 2021

During 2021, with the start of the mass vaccination in most countries, the economies started to reopen slowly and we see that the demand for steel is once again in the hands of the major heavy steel consuming industries. In the first half of 2021, we notice a sharp increase in steel prices, triggered mainly by China demand for construction steel. This led to the increase of the iron ore price, reaching a peak of $229,5 per ton. As a result, the price of steel also went high, reaching 5999CHY/t for steel rebars, also in May. This development, together with a relatively weak dollar in the summer, led to an increase in the shipbuilding prices. According to Cleaves Securities, newbuild prices rose by 12% year-to-date, the majority of the price increase down to higher steel prices. A VLCC newbuilding has increased by $12m in steel costs alone this year.

Never the less, in the end of summer, we notice a sharp decline in iron ore price. The reason was that Chinese demand for steel products, a domestic product for China, was expected to shrink sharply because the Beijing’s stimulus plan supporting the construction industry peaked in the first half. The analysts do not expect the demand impact seen during the early part of this year to return next year as construction projects have been completed and there is a lower number of new projects planned.

On the other hand, let us see how shipbuilding went through COVID-19 crisis. When we make a complex analysis, we notice three key points:

- First of all, the pandemic hit European shipbuilders, mostly engaged in the construction of cruise and Ro-Ro vessels, extremely hard, as yards faced construction delays from cruise liners and sought to secure financing for continuation of activity on existing ships. The German shipbuilder FSG filed for insolvency and soon after Kleven Verft filed for bankruptcy after a loan termination. Operations at STX Offshore & Shipbuilding Co. in Korea stopped after unions launched a general strike on June 1 demanding an end of unpaid furloughs, as reported by the Korea Herald. The shipbuilder didn’t succeed in securing any new orders at the beginning of 2020. This places additional pressure on yards, which had to take actions to keep their workforce available.
- Secondly, there was also the issue of vessel overcapacity in the industry at a time when demand is constrained, particularly in the container shipping sector. BIMCO’s data shows that in the last three years of the past decade (2017-2020), demand outgrew the fleet as the TEU capacity of the fleet grew by 75.6% whereas demand measured in volumes was up 46.1%.

Restricted demand growth prospects together with overcapacity across shipping markets make it clear that the industry must up its efforts when it comes to demolition and retiring old, inefficient fleet.

- The third impact factor is the growing pressure for the industry to cut its emissions and decarbonize. There is a growing need to build greener and more technologically-advanced ships. With the environmental problems becoming more and more influential as a development factor, the time has probably come to make that giant step into the future.

At the beginning of 2021, we saw a massive development in shipbuilding industry. The order book increased during the entire year. This was triggered by the demand for new and more energy efficient container vessels. Most of the major container lines took the opportunity to renew their fleet. Chinese shipbuilders secured most of shipbuilding contracts during the third quarter of 2021 with some 68% in terms of gross tonnage (GT), followed by South Korea and Japan[3]. With this surge in ordering activity, containerships now make up some 33% of the current orderbook (see Fig. 1). This is followed by the dry cargo (bulk carrier and general cargo) and tankers/gas carriers. Cruise vessels, even though making some 6% of the global orderbook, are still likely to be cancelled, as cruising industry still cannot fully recover from the COVID crisis.

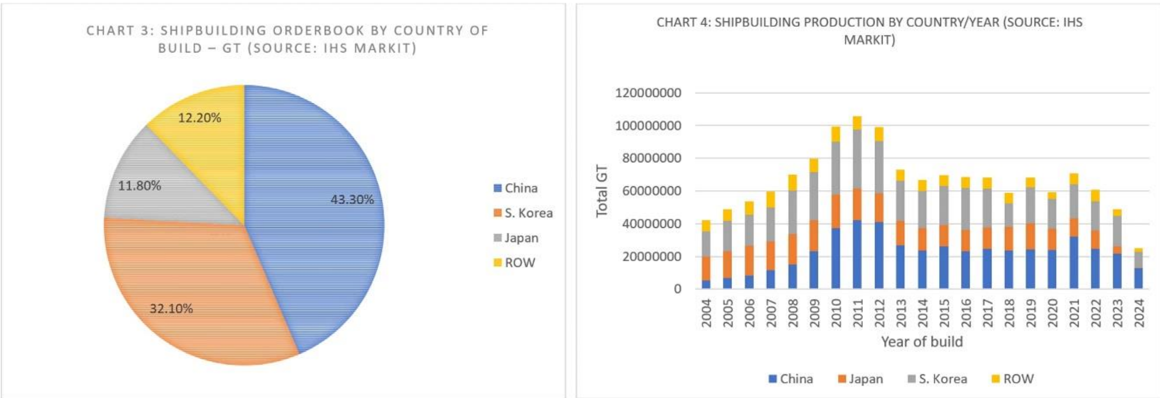

Fig.1 State and prognosis for the shipbuilding orderbook

Increasing demand for containerships allowed shipyards to increase their contract prices (see Fig. 2) and at least provide an improvement in margins which had been historically low since the fallout from the global financial crisis. Nevertheless, contract prices are still only slightly above those seen during the previous bull market of 2006-2008.

Allied Shipbroking noted in July that the record levels of freight earnings have pushed up owners' demand for further fleet expansion. Nevertheless, yards are being troubled by a disappearing margin pared by rising shipbuilding costs, in particular the steel prices. A senior yard executive said many of the contracts announced in the second quarter of this year were options of the firm orders signed in the first quarter or even earlier. Hence, these were loss-making deals with almost the same ship price yet much costlier ship plates, he added. The Clarkson's Newbuilding Price Index climbed from 126 points at the end of 2020 to 138 points as of mid-June 2021, its highest level since 2014. The guidance price for very large crude carriers and capesize dry bulkers and 15,500 TEU boxships were up by 14%, 26% and 24%, respectively, over the period[4]. Further upward pressure is expected as iron ore prices continue to surge amid strong demand for the commodity, despite China's attempts to curb the mark-ups[2]. As a result, ordering enthusiasm could be tempered in the second half of the year. Some brokers, however, argue that owners who have or are making a fortune out of the hot market will not stop ordering as they are less sensitive to the high newbuilding prices. Others pointed out that the uncertainties over new emission-cutting measures and the extra investment in energy-saving devices and fuel technologies on board may help owners keep a cool head.

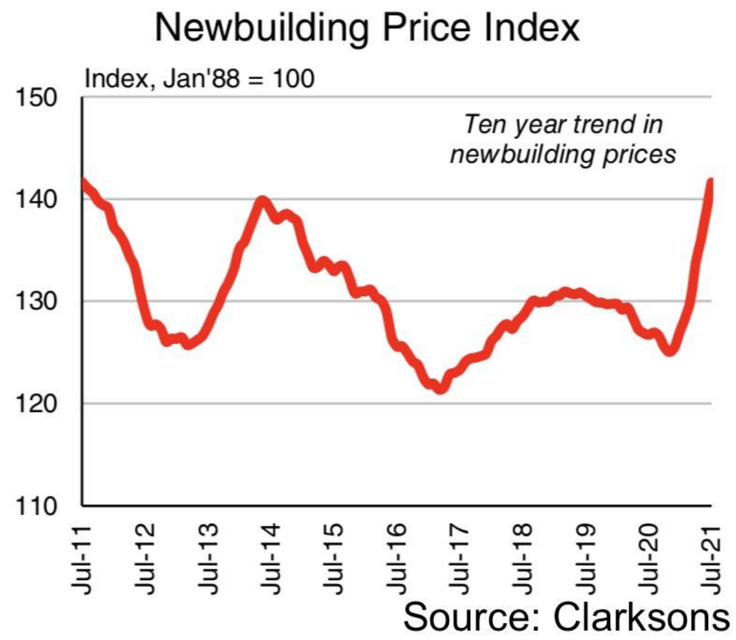

Fig.2 Development of the newbuilding price index

III. CONCLUSIONS

Based on the above research, we see that there is a real boom in shipbuilding, triggered by many factors. Even with such a sharp increase, there are still some alarming signs, showing the crisis is not completely gone. One of the factors, determining the shipbuilding price is indeed the price of its main raw material – steel. Unfortunately, it is impossible to predict what percentage of a vessel's building cost could be attributed to its building materials. In every case is based on the individual situation and the influencing factors, so there is a lot of variation. One of the most important conclusions, based on the above research, is that the demand from the shipbuilding is not the main factor, influencing its price. There are other, more powerful industries to cause its price to fluctuate.

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SITUATIONAL METHOD OF NAVIGATIONAL SAFETY ASSESSMENT

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In process of navigation navigational safety is a matter of upmost importance. Navigation is a process of realization of complicated goal driven organizational and technical system of shipping. This system functions in an environment consisting of various chaotic factors arising from navigational hydrographic and hydrometeorological conditions as well as vessel's own condition and maneuverability and navigator's skills to make a full appraisal of the situation in the prevailing circumstances and conditions. [1]

Actual control over a vessel consists of appraisal of situation, making decisions to maneuver and conducting the maneuver. Any element in this chain of actions may be the cause of some error which can respectively cause additional impact on a risk of navigational hazard.

Various aspects give reason to not consider navigational hazard as a probability which may occur when approaching another vessel at range less than preassigned but as an expected value of dangerous navigational situations. Knowing rate of transition from dangerous navigational situations to averages and collisions, it's possible to analytically predict casualties, ecological and economical losses caused by occurred hazards.

Mathematical model of organizational and technical system of navigation is made in respect to modern methods of algebraically formal systems which include methods of functional-structural human-machine systems, I-nets, semi-Markov chains, semantic chains, etc. [2]

Sequence of occurring events is similar for all these methods, it's represented by arcs of oriented graphs. Starting and ending events of a specific event are represented by peaks. The main unit of measurement in this system is probability for the event to occur.

It will be common sense to include situations which are most likely to happen in our logical data model of navigation: a single vessel going on a voyage in complex navigational environment, and situations when two vessels pass each other in complex navigational environment, when collision is possible, as well as encountering navigational hazards, which may lead to at least one of said vessels to run aground. Then, all events considered in mathematical model of navigation will have disjunctive connection with separated events.

Logical data model characterizing connections between main events in navigation is given in Fig 1.

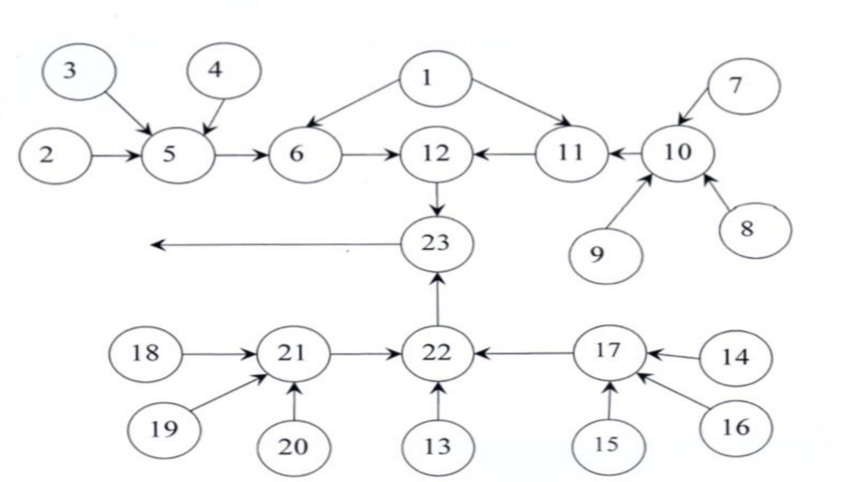

Fig. 1. Logical data model of dangerous navigation situation

In this model following dangerous navigational events to happen in constrained navigational environment included:

1. Event P_1 characterizing good navigational circumstances in sailing area.

2. Event P_2 characterizing correct appraisal of prevailing situating on single vessel.
3. Event P_3 of making correct decision to maneuver on single vessel.
4. Event P_4 characterizing correct performance of maneuver by single vessel.
5. Event P_6 characterizing navigational hazard appearance e.g. running aground.
6. Event P_7, P_8, P_9 similar to events P_2, P_3, P_4 but for other vessel; P_5, P_{10} – additional events.
7. Event P_{13} – event characterizing good above-water circumstances.
8. Events $P_{14}, P_{15}, P_{16}, P_{17}, P_{18}, P_{19}, P_{20}, P_{21}$ – events characterizing correct appraisal of above-water circumstances, decision making and maneuver performance on both vessels passing each other.
9. Event P_{22} – event characterizing vessels approaching at distances closer than assigned.
10. Event P_{23} – event characterizing appearance of dangerous navigational hazard caused by vessels' approaching each other at close distances or running aground during passing in complicated navigational circumstances.

Main events are linked with each other by disjunctive connections that highlight tasks of determining the highest probability of possible navigational hazards during navigation in complex circumstances.

To find probabilities for complex situation to happen disjunctive normal function [3] should be found. Logical operations of disjunction, conjunction and inversion should be exchanged with their probabilistic equivalents as follows:

$$\begin{aligned} a &= a_1 a_2 \rightarrow P_{a_1} P_{a_2} \\ b &= a_1 \cup a_2 \rightarrow P_{a_1} + P_{a_2} - P_{a_1} P_{a_2} \\ c &= f_1 \rightarrow P_z = 1 - P_{a_1} \end{aligned} \quad (1)$$

General expression of probability for dangerous navigational situations to occur when navigating in complex circumstances looks like:

$$P_{OHC} = (1 - P_1)P_6 + P_1(1 - P_4)P_5 P_6 + P_1(1 - P_3)P_4 P_5 P_6 + P_1(1 - P_2)P_3 P_4 P_5 P_6 \quad (2)$$

Where $P_1 - P_6$ – probabilities for respective events included in logical model of navigation in complex circumstances to occur.

This method of assessment gives us opportunity to assess risks to navigation as well as operator's skills. Results of our assessment show how even tiniest changes in probabilities lead to drastic increase in hazard occurrences, as well as the importance of proper lookout from navigator, probability of which should be not lower than 0.95. This model may be improved by further research and investigations which would help to input more accurate probabilities true to the actual environments and adjust position of events in our model.

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AN ANALYZIS OF THE PERSPECTIVES OF THE MODERN APPROACH TO THE VESSEL TRAFFIC SERVICES OPERATION AND ITS IMPLEMENTATION

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ABSTRACT

Nowadays, the growth of density of marine traffic is expected due to the development of the world-wide trade and the demand for the resources to be transported all over the world. With the rise of density of traffic, the workload of the VTS in regard to monitor the vessels’ behavior is expected to increase, which may result in the growth of the risk to safety of navigation. On the other hand, the availability of the modern algorithms may make it a perspective opportunity to develop an aid to the operation of those services [1].

The goal of this study is to explore the state-of-the-art algorithms’ core ideas and analyze their compatibility with the stated task, as well as to projects the implementation issues of them into the current system.

VTS overview

According to the description of Odesa VTS: “Safety control of all vessels in port waters is performed by Vessel Traffic Service (VTS). All maneuvers in controlled water areas and port waters must be done under the VTS control. For all operations including entering the controlled area, dropping and heaving up anchor, mooring and leaving berth, shifting, heaving the log and so on, vessels must request VTS permission.”

Marine traffic is controlled by Vessel Traffic Services (VTS). All VTS operations can be split into three categories, as defined by IALA - Information Service (INS), Traffic Organization Service (TOS) and Navigational Assistance Service (NAS). The main point of the interest is the operation of NAS [2].

According to the Dmitry Rostopshin, Director of the Ship Traffic Control and Management Solutions, Transas Marine International, the most discussed ways of increasing the quality of this part of VTS are enhanced route monitoring, automatic under keel clearance calculation tools and active decision-support system.

Modern algorithm overview

Due to the nature of maritime trade, it’s impossible to develop a strict set of rules in regard to the most navigation aspects. Even COLREG rules leave room to deviate from them, which makes the idea of developing any aid to the evaluation of maritime traffic an overwhelming task, but there are some ways of approaching this problem.

Artificial Neural Network (ANN) simulates the processes of the human brain. The ANN makes associations between varieties of information. The ANN realizes the intuitive reasoning rather than the logical reasoning normally executed by machine. The main advantage of ANN is the ability to incorporate uncertainty as well as data whose dynamic character has led to a number of studies that establish its applicability in prediction of marine traffic [2].

One of the ANN schemes is the back-propagation (BP) network. The back-propagation neural network architecture is designed by fully interconnected layers or rows of processing units. The inter connections are called weights, and provide the means for the ANN to save knowledge, the process of A learning B. Also, the errors are calculated during this process. These errors are used to back-propagate from the output neurons to all the hidden neurons, so all the weights are adjusted by the errors. This learning process continues till the error is reduced to specified minimum values. After that the weights are saved as the ANN knowledge. The weights are used to perform information processing operation by back-propagation algorithm. The ANN may have as large numbers of neurons as it needs. Likewise, the number of layers is exchangeable. The ANN behavior depends on the simple activation function which could be a linear or a non-linear [3].

The ANN knowledge is training by pre-mined data and the weights are saved. Moreover, the

ANN has the capability to learn with any complex structure of data. So, the ANN is capable to implement a learning algorithm and make decision support ability of marine traffic prediction.

Modern algorithm model

A three-layer neural network model can be developed to predict the turning regions of vessels in marine traffic. The ANN inputs were vessel's:

1. Latitude of turning regions;
2. Longitude of turning regions;
3. Speed;
4. Course;
5. MMSI number;
6. Dimension (length & width);
7. Type of vessel.

The ANN outputs were used to predict the next action of the vessels. The ANN output is a matrix which contains:

1. The angle of vector of further proceeding;
2. The magnitude of vector of further proceeding for each vessel.

The ANN was fully connected and every neuron is connected to second layer neuron. The output of each neuron was calculated by an activation function. All the inputs were summed by neurons with threshold. To develop the ANN, the pre-mined data was divided into two parts: 90% of turning points were used to train the ANN and the rest of observations were used for validation. All data was normalized to common interval of [-1, 1]. The algorithm was solved by python 3 with neuron package. The relationship between the output (yt) and the inputs ($yt-1,\ldots,-p$) has the following mathematical representation:

$$yt = w0 + \sum wjg\ (w0j + \sum wijyt-1\ p\ i=1\ ) + et\ Q\ j=1\ ,\ (4)\ \text{Where} wi,j(\ i = 0, 1, 2, \ldots , P,j = 1, 2, \ldots ,Q) \text{ and } wj(j = 0, 1, 2, \ldots ,Q) \qquad (1)$$

The activation function is often used as the hidden layer transfer function. That is, Sig(x) = 1 1+exp(−x)

Once a network structure (P, Q) is specified, the network is ready for training, a process of parameter estimation. The parameters are estimated so that the cost function of neural network is minimized. Cost functions - an overall accuracy criterion such as the following - mean squared error. This minimization is done with some efficient nonlinear optimization algorithms other than the basic propagation training algorithm. After the artificial neuron network receives the inputs, it will propagate them from the input layer through the hidden layers to the output layer, where the responses are obtained. This artificial neuron network learning process deals with speed of convergence and the local minima.

Conclusion

How to implement the described model into the real life? The program that we have described states the expected tendency of the development of the situation. And so, it is now clear how to predict the vesssel's behavior according to the program's data, which means that it may state its awareness about the unusual behavior to the VTS operator, who is responsible for the monitoring. The best part of that approach is that the program does not stop learning after being given the initial data. It continues to absorb the information about the "normalness" of the vessels' behavior and will adapt to the style of the operators of the VTS, which may make it a perfect aid for their work.

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THE EVOLUTION OF SHIP'S SAVING ENERGY POLICY IN THE WORLD

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Environmental problems and rising fuel prices lead to the need to search for alternatives. The main goal in this matter is to find all kinds of energy sources that will lead to a decrease in CO2 and sulfur emissions into the atmosphere and can be used more efficiently than the currently used types of fuel [1]

The International Maritime Organization has introduced the most severe measures in the Emission Control Areas - in such regions it is possible to use only such fuel that contains no more than 0.1% sulfur. These areas include: Baltic Sea, North Sea, Caribbean Sea, North America (including Canada), USA [2]. The coordinates of all such areas are defined in Chapter VI of the MARPOL convention [3].

Now let's consider what requirements apply to all other areas. For the first time, measures for areas other than ECA were introduced in 2005, when the IMO obliged all ships to use fuel with a sulfur content of not more than 4.5%. In 2012, this figure was reduced to 3.5%. On January 1, 2020, the IMO 2020 convention was adopted, which introduces much stricter restrictions on the fuel - the permissible amount of sulfur in the fuel should not exceed 0.5%. Or the second option is possible - installation of a scrubber. In this case, the vessel is allowed to transport fuel with a sulfur content of more than 0.5%, due to the principle of the scrubber operation, because of which the outgoing gases are 98% cleaned of oxide elements, which prevents damage to the atmosphere [4]. According to a report from the MPA (Maritime and Port Authority) Singapore, almost all ships calling in Singapore comply with the IMO 2020 requirement. The only exception were a couple of ships that were subsequently detained [5]. Another way to comply with IMO 2020 standards is to switch to other types of fuel, such as liquefied gas and others. Also, IMO has plans to reduce greenhouse gas emissions by 50% by 2050.

There are several types of scrubbers [6], but the principle of operation is the same for all of them. In the picture (fig. 1) a simplified diagram of the scrubber operation is shown, which in reality can have up to several dozen nozzles

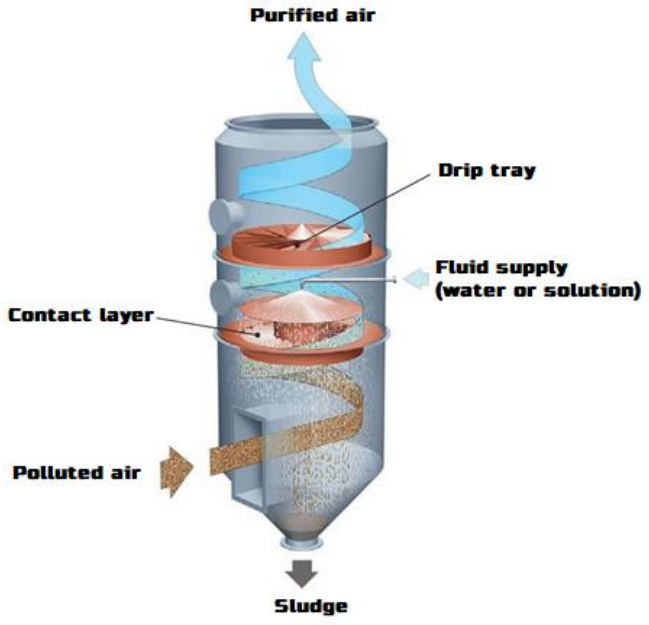

Fig. 1 - The principle of scrubber’s operation on ships

There are scrubbers with open and closed cycles. The first type takes water for purification from the kingston box and pumps it through a scrubber, purifying the air from sulfur, after which this water is discharged overboard.

In scrubbers with a closed cycle, about the same thing happens, only the water as a result does not drain overboard, but remains on the ship and is discharged in ports as sludge. There is also a hybrid system (fig. 2) that includes the ability to use both of these cycles.

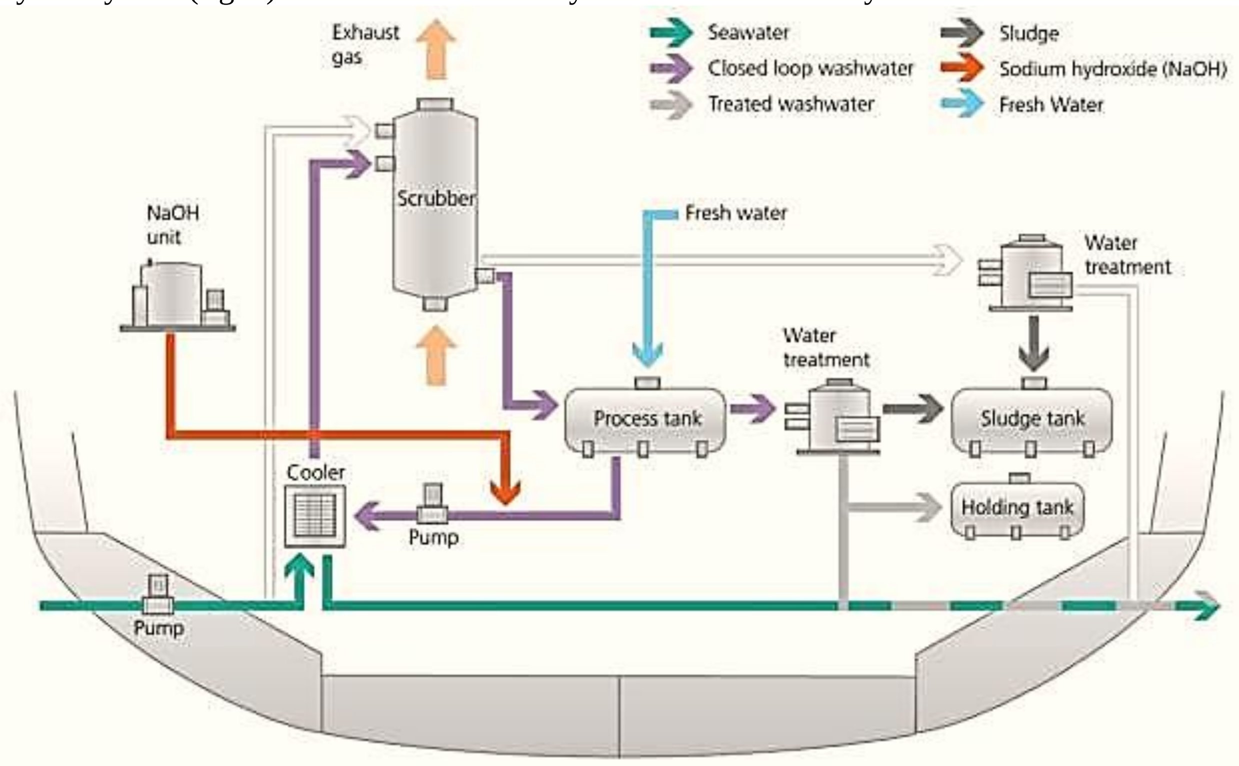

Fig. 2 - Schematic diagram of the operation of the hybrid cycle scrubber

According to DNV GL statistics, there are 4669 vessels equipped or being built with a scrubber. One fourth of these all ships are bulk carriers, half are container ships and tankers, and the rest are ships of all other types. Almost ¾ of the vessels were re-equipped with scrubbers, but did not have them initially.

The second option to meet IMO 2020 requirements is to buy and use VLSFO - very low sulfur fuel oil [7]. Firstly, it is worth noting that for a complete transition of the vessel from heavy fuel to low-sulfur fuel, it is necessary to completely clean the entire system of fuel tanks, pipes and equipment for fuel processing.

Another possible cons of this fuel is that the researchers found higher soot emissions in the low sulfur VLSFO fuel than its predecessor, high sulfur fuel oil (HSFO). This is stated in the report submitted by Finland and Germany to the International Maritime Organization (IMO). The presented research results, funded by the German Environment Agency and with technical support from the classification society DNL GL and engine manufacturer MAN Energy Solutions, show that new marine fuel mixtures with a sulfur content of 0.50% may contain a large percentage of aromatics, which have a direct impact on soot emissions (fig.3).

The submitted documents urge the inclusion of aromatics in the ISO 8217 marine fuel specification. A number of research and production associations have already called for a ban on low-sulfur, aromatic marine fuels for use on ships, especially those sailing through Arctic waters.

Fig. 3 - Heavy fuel prices in different countries of the world

Thus, the initial conclusion can be drawn that the advantages of using low sulfur fuel instead of installing a scrubber are not obvious. First, the complete conversion of a vessel from heavy fuel to low-sulfur fuel is quite expensive and not an easy process. Secondly, it is much more expensive in the long run. Thirdly, a number of studies show that even this fuel can be harmful to the environment. Therefore, it makes sense to consider what other types of fuel can be used in shipping (fig. 4).

Fig. 4 - Low sulfur fuel prices in different countries of the world

First of all, when considering alternative fuels, we need to understand that they should be evaluated according to three criteria; availability, environmental sustainability, security.

The list of the most promising alternative fuels includes: LNG (Liquified Natural Gas); LNG (liquefied natural gas); electricity; Methanol fuel (fig.5).

LNG was first used as a fuel in gas carriers in the 1960s. The cargo on board was used as a power source for the main engine, and thus almost zero fuel costs were ensured when loading ships [8]. This has made a significant contribution to the development of technology and the use of LNG as a fuel.

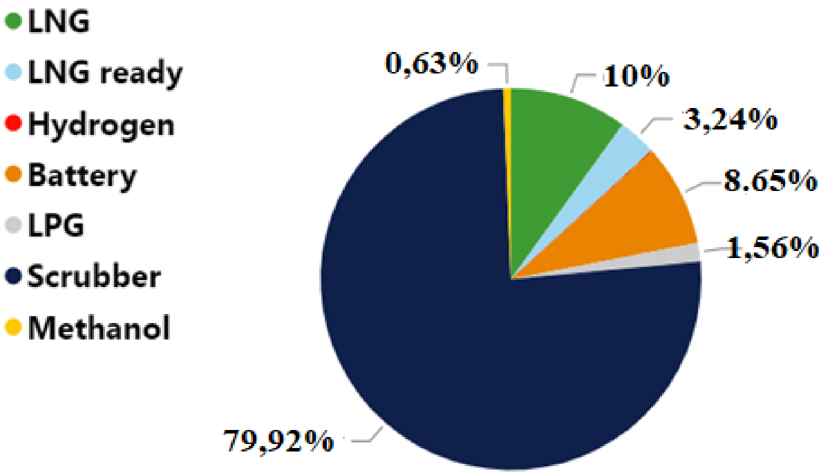

Fig. 5 - The total number of ships using different types of fuel

Comparing prices for low-sulfur fuel and gas is quite problematic (fig. 4), since this difference depends a lot on the tendencies of the world market, which tend to change very fast.

Now let's look at the impact of natural gas on the environment. First of all, it should be said that sulfur emissions when using gas are up to 90% less than when using heavy fuel. Natural gas is also popularized because its CO2 emissions are lower than coal or oil, but on the other hand, methane, the main component of natural gas, is 25 times more potent as a greenhouse gas than CO2. Consequently, methane leakage during the extraction, transportation and use of natural gas can, in principle, negate the benefits obtained from the switch to another type of fuel. The US Environmental Protection Agency estimates the leakage to be 1.3%, while other researchers suggest a leakage rate of up to 3%, particularly in shale gas production. Most natural gas engines currently operate using the Otto cycle, an engine combustion principle in which combustion air is premixed with natural gas before entering the engine[9]. It has been shown that this combustion medium often results in an increased concentration of methane in the exhaust, commonly referred to as methane slip. This leakage is approximately 3%.

According to DNV GL calculations, a total methane leak of 5.5% (including production / transportation and combustion) will bring greenhouse gas emissions from LNG to levels equivalent to those from diesel. Therefore, the problem must be solved by reducing leaks both during production and during combustion in engines. While there are no regulatory requirements to reduce methane slip in marine engines, various technologies can be used to address this issue. In Otto cycle engines, the amount of unburned methane can be reduced by means of an EGR system, which improves combustion stability, or by post-treatment of the exhaust gases. Diesel engines can use a high pressure dual-fuel injection concept, resulting in reduced NOX emissions. With this approach, natural gas does not mix with air before entering the engine. Instead, it is injected directly into the combustion chamber during the compression stroke following pilot diesel injection. Engine manufacturers say this technology limits methane slip to about 0.1% slip, which virtually eliminates the problem.

In conclusion, it can be said that the use of LNG can reduce greenhouse gas emissions by up to 25%, provided that methane leaks can be eliminated during the production and combustion stages. In practice, some leaks are to be expected and best practices and appropriate technologies should be used to minimize them. This can lead to real reductions in greenhouse gas emissions by 10-20% compared to conventional petroleum-based fuels.

Obviously, fossil LNG cannot be classified as an environmentally friendly fuel, but it has the advantage of reducing sulfur and nitrogen oxides emissions as well as reducing greenhouse gas emissions when used correctly.

In terms of safe use, LNG has a number of advantages over other fuels:

- methane vapors are lighter than air and dissipate quickly, unlike other fuels, which accumulate on the ground and pose a great fire hazard, as well as leave stains, sludge and other dirty residues. Thus, LNG is completely safe for the marine environment.

- methane is non-toxic.

- All LNG tanks are double-walled and very thick, which makes them much stronger and more reliable than tanks for other fuels and chemicals.

Batteries today are the most common storage facility where electricity can be stored and used in the future to power a ship. There are 337 battery powered vessels in operation worldwide today, with another 195 under construction. Such vessels are divided into two types: hybrid ships, completely electric.

Depending on the method of generating electricity on the grid, energy losses can be reduced. The potential for reducing emissions largely depends on the structure of electricity: in regions with a high level of use of renewable sources or nuclear energy, emissions of both greenhouse gases and other pollutants will be low (fig. 6).

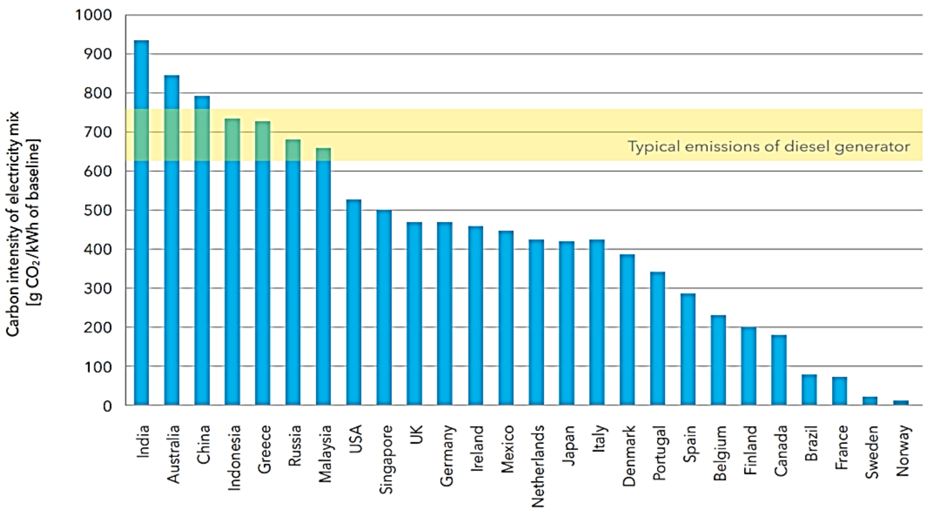

Figure 6 - Specific carbon emissions in electricity production in different countries

The figure shows the carbon intensity of electricity structure in different countries, expressed in grams of CO2 equivalent emitted per 1 kWh of electricity produced. Other emissions such as NOx, SOx and particulate matter will show similar trends. The differences between countries can be attributed to the extent to which carbon-free energy sources have penetrated into each country's electricity mix [10].

Using onshore electricity also provides significant reductions in local emissions, which is an advantage for ships operating near densely populated areas such as local ferries. Operating costs can be low, provided the electricity price is competitive with the prices of marine fuel.

Methanol is an alternative fuel, otherwise called methyl or wood alcohol. Interest in methanol as a marine fuel increased after Stena Line decided to convert one of its vessels to use methanol as a solution to the low sulfur fuel problem.

First of all, methanol has a big advantage over other alternative fuels - it is similar to current marine fuel in the sense that it is liquid. This means that the existing fuel storage and refueling infrastructure will require only minor changes for methanol processing, which will require relatively modest infrastructure investment costs compared to the large investments required to build liquefied natural gas (LNG) terminals or power supply systems [11]. What's more, the ship's engine can also run on low sulfur fuels, switching to them and back to methanol completely painlessly, with both systems completely isolated, with separate fuel and supply tanks and separate bunkering manifolds (fig.8).

The toxicity charge was used to counteract the development of methanol. In fact, methanol is one of the five major marine chemicals that have been safely handled for over 50 years. Methanol is no more toxic than heavy or low sulfur fuels. With proper handling of this fuel, personnel will not come into contact with it in any way.

Methanol has been shipped worldwide for decades. It is available worldwide through existing infrastructure in over 100 ports around the world and there is no difficulty in purchasing methanol for bunkering. Methanol is either available or in close proximity to many ports. Since methanol bunkering is similar to distillate fuel, very few modifications to the existing bunkering infrastructure are required. There are currently several global bunkering suppliers and trading platforms interested in supplying methanol fuel for ships.

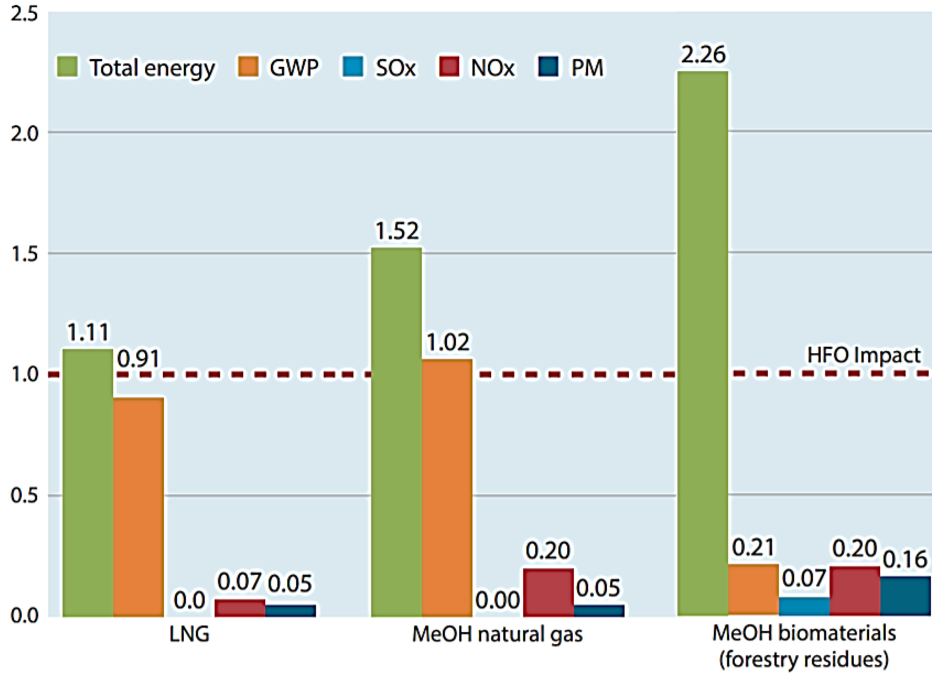

Fig. 8 - Comparison of emissions during LNG and methanol production

For a more visual conclusion, a general table is presented for assessing different parameters of all considered types of fuel:

The scrubber is the most profitable in the long term, since for several million the shipowner gets the opportunity to supply the vessel with the cheapest fuel, which pays off in just a couple of years. It is also easy to install on a ship and can be done in most docks in the world. However, the scrubber does not solve the problem of pollution at all and has no long-term prospects given that the IMO plans to further tighten the requirements for environmental pollution from ships [12]. In an accident, a heavy fuel oil spill is a terrible natural disaster that destroys all flora and fauna in the vicinity.

Low sulfur fuels are quite expensive, but still cheaper than LNG. For the complete transition of the vessel to this type of fuel, it is necessary to flush all tanks and systems, however, in comparison with the installation of systems for other alternative types of fuel, this is a much easier process. It is supplied to all parts of the world. Against the background of heavy fuel, low-sulfur fuel has a much milder effect on the environment, but in comparison with other alternatives, it still loses [13]. When spilled, the impact of this fuel is no better than a heavy one. In the next few decades, this fuel will definitely meet IMO standards, but in the distant future it may happen that it will not meet the standards.

Today Liquefied natural gas is the most expensive of all fuels compared in this work. Equipping a vessel with an LNG power system requires a complete redesign of the vessel's fuel system, and it should be borne in mind that LNG takes up a larger volume with the same energy efficiency as other fuels, which further reduces its profitability [46]. It is not possible to supply a vessel with gas in all ports of the world and it will take more time before LNG bunkering systems are available everywhere. With due observance of the standards during the production of LNG and its use, this fuel has almost no effect on the environment. During a spill, the gas evaporates quickly and does not harm the environment.

Electricity is a very controversial alternative and highly dependent on the place of its production. In some countries, like Norway, it is the best choice for local ships, as it is cheap there and generating electricity causes minimal damage to the environment. Electricity itself during use does not affect the environment in any way. To make a ship capable of sailing exclusively on electricity, you need to install a completely different power system than a fuel one, which is very costly and problematic. If the batteries are damaged, it can have catastrophic consequences for the vessel itself, its crew and cargo, and for the environment [14]. The prospects for electricity as an independent fuel are dubious. Most likely, electricity can become an auxiliary form of energy to reduce the cost of the main fuel. It is also possible that the system of supplying the ship with electricity in the port will become relevant, which will allow shipowners to save well.

Methanol is the most promising, but so far underestimated fuel. It is cheaper than LNG and takes up less space with the same energy efficiency, making it more competitive with low sulfur fuel than gas. Converting a vessel to methanol requires doing the same as converting to low sulfur fuel, which is not a difficult process. As long as methanol is available in few ports in the world and in order to begin its mass use, its production must acquire a large scale. Its impact on the environment is the most beneficial both in extraction and in use. Also, its significant advantage is that methanol is a renewable resource. In an accident, methanol quickly reacts with water and dissolves, making it harmless.

During the search and analysis of information for this report, such types of energy sources as hydrogen and ammonia were also considered. However, at the moment they absolutely cannot provide competition to the types of fuel described in this work, since their production and price are much more expensive, they take up even more space than LNG, during an accident they pose a great danger to the ship's crew and the environment. From the point of view of the impact on the environment, the use of these two types of fuel with proper technologies can be even more harmless than that of methanol, but the development of such technologies has not yet been completed.

Thus, according to the findings of this research, methanol is the most likely fuel for the near future.

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CALCULATION SCHEME AND ALGORITHMS FOR PLANNING THE PROCEEDING PLAN OF TRAJECTORY POINT DURING MANEUVERING FOR ANCHORING

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In confined waters, the water area for maneuvering is commensurate with the geometrical dimensions of the vessel and planning the trajectory of movement, and especially its curvilinear section, becomes of paramount importance.

Algorithms and computational schemes determine the procedure for increasing the accuracy of planning the route of movement to anchorage area, taking into account the water area for maneuvering, characteristics of braking and turnability and the use of methods for planning the route of movement by trajectory points, including curved sections.

To perform route planning, the following vessel data are required: permanent vessel data; two tables of characteristics of braking and turning ability [1-8]; a chart with an area for maneuvering and recommended paths of movement, determined by geodetic methods.

The further algorithm of the meaningful model will be as follows:

1. The coordinates of the anchoring point are plotted, which are agreed with the VTS.
2. The total vector of the wind and current direction is determined, and the approach line is drawn in its direction for releasing the anchor until it intersects the recommended path line on the chart or the water area of the beginning of maneuvering, free from hazards and suitable in depth, and determine the coordinates of the penultimate maneuvering point.

For this, the navigator must set the initial data in the computer, namely, the coordinates of the waypoints and the maneuvering characteristics of the vessel, which must be available on the vessel in electronic form in the form of tables. After that, the trajectory point's matrices will be automatically given to the skipper, along which the vessel will follow every 2 cables.

3. Make a table of waypoints and calculate the TC, the distance from the previous WP to the next one, the angle of rotation at each waypoint and the required rudder shift angle as follows.

When performing a turn automatically, the routine work of calculating the necessary data - the moment of the beginning of the turn, choosing an angle rudder shifting, determination of the coordinates of the current position, the onset of the moment of holding the vessel is performed by a computer. The navigator gives the necessary commands to the helmsman and controls on the computer screen the actual position of the vessel relative to the planned one and corrects its movement.

All the calculations performed are summarized in Table 1, and are necessary for planning the coordinates of the planned path by trajectory points (TP) and navigation control along it, including curved sections of the path, when anchored.

Table 1. Summary table of turnability parameters

WP	LAT	LON	Course	Distance, S, cables	θ	δ
0	46º18,0' N	30º53,5' E				
1	46º17,2' N	30º52,0' E	233	13,2	56	10
2	46º18,5' N	30º46,5' E	289	40,0	23,3	5
3	46º18,0' N	30º44,0' E	265,7	18,5	61,6	15
4	46º15,5' N	30º43,0' E	204,1	15,8	40,1	10
5	46º14,0' N	30º44,0' E	164	16,9		

With the automatic execution of the turn, the process of movement is planned and carried out by a computer without the participation of the navigator and the helmsman. The navigator exercises control over the normal operation of the control system and, if possible, visually evaluates the position of the vessel relative to the signs of the navigational situation.

The next task is to calculate the coordinates of the rotation matrices every 10 degrees by the method of segments. To do this, it is necessary, according to the method described above, to determine for each section the beginning, end of the turn and TP with a step of 10 degrees. These data for each turning angle when anchored in the port of Chornomorsk are given in Tables 2-13. It should be emphasized that the calculation takes place for small sections of the path. Therefore, in order to increase accuracy, it is necessary to leave 10 decimal places.

Table 2. Rotation elements of angle of rotation 1 as line segments

Angle	10º	20º	30º	40º	50º	56º
MC	1,081958282	1,408883289	1,746053028	2,099410462	2,476012182	2,71669
ME	0,328082488	0,661226178	1,004809472	1,364888378	1,748653718	1,99391

Table 3. Rotation elements of angle of rotation 2 as line segments

Angle	10º	23,3º
MC	1,121244311	1,835173414
ME	0,54855392	1,292749344

Table 4. Rotation elements of angle of rotation 3 as line segments

Angle	10º	20º	30º	40º	50º	61,6º
MC	0,031844958	0,267266499	0,51006536	0,764521121	1,035715294	1,37972
ME	0,230095185	0,463739959	0,704706376	0,957241716	1,226389141	1,56779

Table 5. Rotation elements of angle of rotation 4 as line segments

Angle	10º	20º	30º	40,1º
MC	1,081958282	1,408883289	1,746053028	2,103048453
ME	0,328082488	0,661226178	1,004809472	1,368595571

Having received the data of the lines for each parcel, you can determine the geographic points in which they will be located. These calculations are best done in tabular form. To do this, it is necessary to initially find the difference in latitude (DLat) and the difference in longitude (DLon) between each point, using formulas (1) and (2).

$$DLat = MC * cosTC \quad (1)$$

where TC is the heading before the turn.

$$DLon = DMP * tgTC \quad (2)$$

The difference between the meridional parts can be determined by the formula (4).

$$DMP = 3437{,}75 * \ln\left\{\frac{tg\left(45° + \frac{\varphi_E}{2}\right)}{tg\left(45° + \frac{\varphi_C}{2}\right)}\right\} \quad (3)$$

It must be remembered that for the calculation of the first section, it is the coordinate of the turning point. For each section of the turn, the data of the difference in latitude and longitude between each segment of the MC and ME were calculated. Having received the segments of the difference in latitude and the difference in longitude, using simple navigation formulas (4) and (5), we determine the coordinates of these points.

$$j_C = j_M + DLat, \quad (4)$$

where j_M is the latitude of the turning point.

$$l_C = l_M + DLon, \quad (5)$$

where l_M is the longitude of the turning point.

Thus, having determined its coordinates for each point of the turning section, it is possible to construct the rotation matrices, which are given in Tables 6-9.

Table 6. Matrix of trajectory point for turning angle 1

M_{t1}	ϕ_{c1}	46º17,29810' N	λ_{E1}	30º52,3879' E
	ϕ_{E11}	46º17,26745' N	λ_{E11}	30º52,3532' E
	ϕ_{E12}	46º17,23683' N	λ_{E12}	30º52,3528' E
	ϕ_{E13}	46º17,21277' N	λ_{E13}	30º52,2773' E
	ϕ_{E14}	46º17,20443' N	λ_{E14}	30º51,9039' E
	ϕ_{E15}	46º17,21461' N	λ_{E15}	30º51,8827' E
	ϕ_{E1}	46º17,23895' N	λ_{E1}	30º51,7195' E

Table 7. Matrix of trajectory point for turning angle 2

M_{t2}	ϕ_{C2}	46º18,46415' N	λ_{C2}	30º46,8146' E
	ϕ_{E21}	46º18,46738' N	λ_{E21}	30º46,5507' E
	ϕ_{E2}	46º18,44780' N	λ_{E2}	30º46,313' E

Table 8. Matrix of trajectory point for turning angle 3

M_{t3}	ϕ_{C3}	46º18,00621' N	λ_{C3}	30º44,0808' E
	ϕ_{E31}	46º17,98465' N	λ_{E31}	30º44,0734' E

Table 9. Matrix of trajectory point for turning angle 4

M_{t4}	ϕ_{C4}	46º15,61518' N	λ_{C4}	30º43,04254' E
	ϕ_{E41}	46º15,60160' N	λ_{E41}	30º43,02962' E
	ϕ_{E42}	46º15,58431' N	λ_{E42}	30º43,01078' E
	ϕ_{E43}	46º15,43542' N	λ_{E43}	30º43,01337' E
	ϕ_{E4}	46º15,42106' N	λ_{E4}	30º43,03575' E

The next task is to determine the matrices of straight sections. It should be noted that the matrix for the first segment will start from the zero point and end with the turn start point 1. The second straight segment matrix will start from the turn end point 1 calculated above. It will end as the starting point of the turn at WP 2. Subsequent matrices of straight sections, except for the final one, will have the same construction principle. For the last leg, the straight matrix will start at turn end point 4 and end with waypoint 5.

Having received the DLat and DLon points for each trajectory point with a step of 2 cables, it is not difficult to construct matrices of straight sections using the segment method, remembered that the course remains unchanged.

Having determined the matrix of the final straight-line section of the path, it is necessary to find the braking start point. Let us resort to the assumption that the entire segment of the way to the approach to anchor, the vessel was moving at an average forward speed (the HA (half ahead) speed for this vessel is 10.3 knots). According to the maneuvering characteristics of the vessel, the active braking distance for HA is 14.59 cables.

We start the calculation from the final fifth point. The distance from it to the turning point will be 14.59 cables. To do this, replace the MC segment with a number equal to the active braking segment and then calculate using the formulas as usual.

Table 10. Braking start point coordinates

M_{BS}	ϕ_{BS}	46º14,84149' N	λ_{BS}	30º43,42921' E

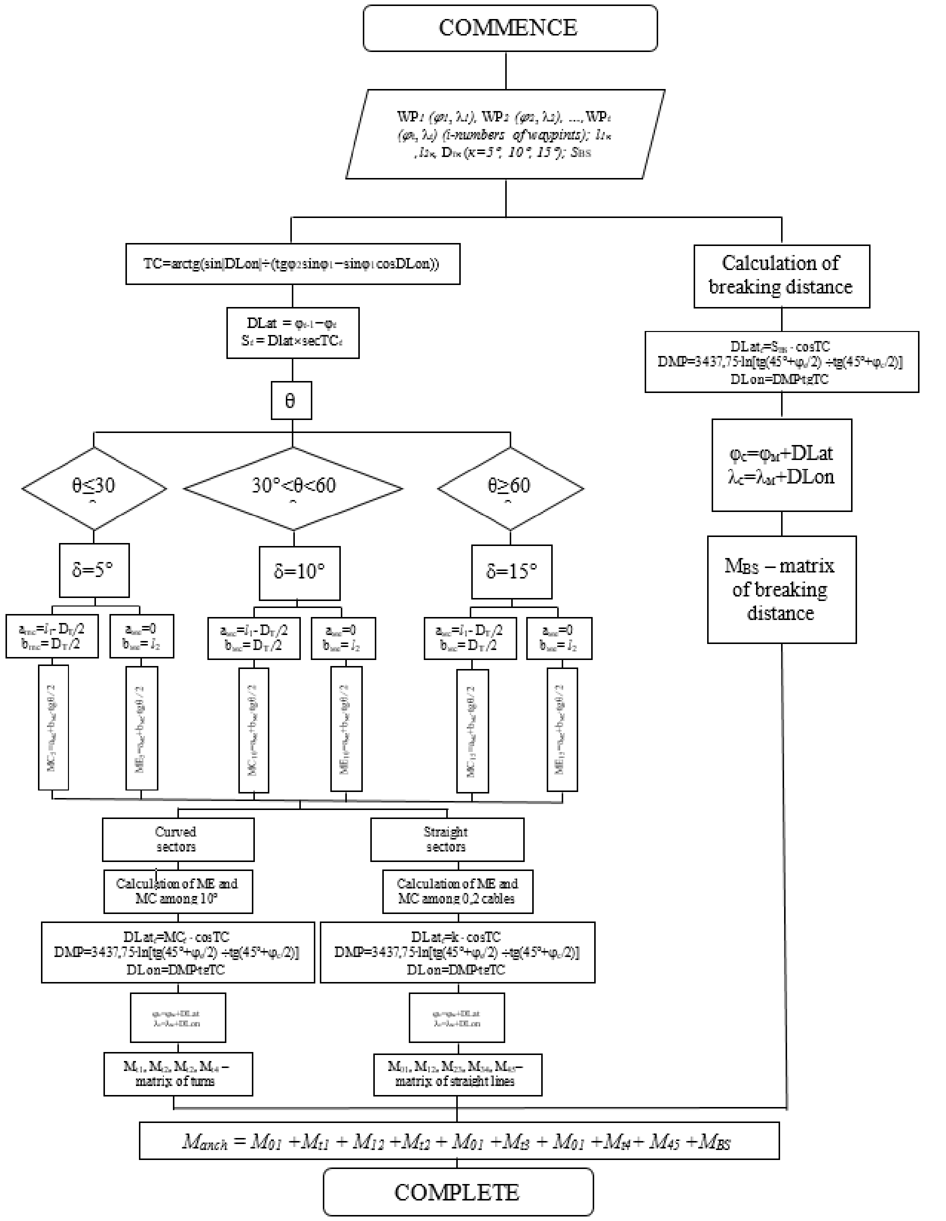

Fig. 1. Block diagram of the automation of calculations of a given algorithm for the operation of the control system in the form of an algorithm for calculating the coordinates of the trajectory points of anchoring, presented in the form of coordinate matrices of straight and curved track sections

Then the given algorithm for maneuvering control during anchoring Manch can be represented as a sum of matrices of straight and curved track sections.

$$M_{anch} = M_{01} + M_{t1} + M_{12} + M_{t2} + M_{23} + M_{t3} + M_{34} + M_{t4} + M_{45} + M_{BS}. \quad (6)$$

The results of this calculation algorithm can be summarized in one flowchart for automating the calculations of a given algorithm for the functioning of the control system in the form of an algorithm for calculating the coordinates of the trajectory points of anchoring, presented in the form of coordinate matrices of straight and curved track sections, which is shown in Figure 1.

The developed navigation information and analytical complex "Planning the path trajectory using the waypoint matrices" contains modernized methods and techniques for creating the given algorithm for the operation of the ship control system and control over the process of moving along the trajectories, including curved and straight sections of the track when anchored. It automates the anchorage route planning process and controls safe maneuvering, including the use of motion control techniques using dynamic positioning.

The results of the developed navigation information-analytical complex can be used on unmanned ships, as well as on commercial and passenger ships during practical work, in order to accurately control the place of the vessel, in maritime educational institutions in the preparation of senior cadets for work on ships and in refresher courses.

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HOW DOES MATH GUIDE OUR SHIPS AT SEA

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As you can imagine, 400 years ago, navigating the open ocean was difficult. The winds and currents pushed and pulled ships off course, and so sailors based their directions on the port they left, attempting to maintain an accurate record of the ship's direction and the distance sailed. This process was known as dead reckoning, because being just half a degree off could result in sailing right past the island that lay several miles just over the horizon. This was an easy mistake to make.

The purpose of this work is to determine with the help of what tools and thanks to what people dead reckoning became possible to use all around the globe.

For realization of this goal such systems have been considered:

1. The impact of John Bird innovation;
2. The importance of John Harrison in the history of dead reckoning;
3. How John Napier and Henry Briggs simplified calculations;
4. Connection between different sciences

Thankfully, three inventions made modern navigation possible: sextants, clocks and the mathematics necessary to perform the required calculations quickly and easily. All three are important. Without the right tools, many sailors would be reluctant to sail too far from the sight of land.

John Bird, an instrument maker from London, made the first device that could measure the angle between the sun and the horizon during the day, called a sextant. Knowing this angle was important, because it could be compared to the angle back in England at the exact same time. Comparing these two angles was necessary to determine the longitude of the ship [1].

Clocks came next. In 1761, John Harrison, an English clockmaker and carpenter, built a clock that could keep accurate time at sea. The timepiece that could maintain accurate time during ~~a~~ pitching, yawing deck in harsh conditions was necessary in order to know the time back in England. There was one catch though: since such a timepiece was handmade, it was very expensive. So, an alternative method using lunar measurements and intense calculations was often used to cut costs. The calculations to determine a ship's location for each measurement could take hours. But sextants and clocks weren't useful unless sailors could use these tools to determine their position [2].

Fortunately, in the 1600s, an amateur mathematician had invented the missing piece. John Napier toiled for more than 20 years in his castle in Scotland to develop logarithms, a calculation device. Napier's ideas on logarithms involved the form of one over E and the constant 10 to the seventh power. Algebra in the early 1600s was not fully developed, and Napier's logarithm of one did not equal zero. This made the calculations much less convenient than logarithms with a base of 10. Henry Briggs, a famous mathematician at Gresham College in London, read Napier's work in 1614, and the following year made the long journey to Edinburgh to meet Napier. Briggs showed up unannounced at Napier's castle door and suggested that John switch the base and form of his logarithms into something much simpler. They both agreed that a base of 10 with the log of one equal to zero would greatly simplify everyday calculations. Today we remember these as Briggs Common Logarithms [3].

Until the development of electric calculating machines in the 20th century, any calculations involving multiplication, division, powers, and extraction of roots with large and small numbers were done using logarithms. The history of logarithms isn't just a lesson in math. There were many players responsible for successful navigation. Instrument makers, astronomers, mathematicians, and of course sailors. Creativity isn't only about going deep into one's field of work, it's about cross-pollination between disciplines too [4].

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ICE CLASS IN ARCTIC WATERS

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It has long been thought that the Arctic is of interest to the states bordering or located near the Arctic. These countries have established the Arctic Council to take care of the ecosystem and monitor-Arctic climate change.

Global warming and the presence of significant deposits of minerals have been of increasing interest in recent years. The countries of the world, which have observer status in the Arctic Council, are showing interest in working in the Arctic.

The UK's plans include research, environmental protection, future trade routes and the development of energy infrastructure.

Germany's policies in the Arctic region are the development of raw materials and energy resources, as well as the search for optimal and rational ways of delivering goods.

Japan's interests lie in technology exports, Arctic shipping and scientific cooperation. Today, Japan invests in Greenland companies, providing expertise for fishing and mining companies.

South Korea's Arctic strategy is to develop Arctic shipping and related industries. Investments in the development of marine technologies and the development of land infrastructure.

Singapore is convinced that climate change in the Arctic is affecting the situation in other parts of the globe.

It is impossible not to pay attention to the significant growth of Beijing's interest in the Arctic. China believes that international maritime law guarantees it some access to the Arctic marine environment, including the right to conduct research, freedom of navigation, flight, use of natural resources, offshore hydrocarbons, international seabed areas and others special marine waters and areas, laying of submarine cables and pipelines, fishing in the international waters of the Arctic Ocean [12].

Fig. 1. The "XueLun" in Arctic waters

The fleet operates the icebreaker ship "XueLun" ("Snow Dragon") - icebreaker-transport diesel-electric ship, ice class B1 / 1 A Super, built by the Kherson Shipyard.

In September 2018, the Xue Lun-2 icebreaker, a joint development of Aker Arctic Technology (Helsinki) and the Marine Design and Research Institute in Shanghai, was launched. The ice class ship Polar Class 3, can break ice 1.5 meters thick at a speed of 2 to 3 knots and operate at temperatures down to minus 30º C.

Fig. 2. 2020, Chinese research icebreaker "Xue Lun-2" in the port of Shanghai

It should be noted that Ukraine is involved in the Arctic issue. However, for the last 20 years, Ukraine has not had its own icebreaker for Antarctic research, which has significantly limited its work. Ukraine's recent acquisition of the James Clark Ross icebreaker (renamed the Noosphere) will allow it to return to exploring the world's oceans, solve logistical problems at the Academic Vernadsky Antarctic Station, and expand seasonal expeditions.

Fig. 3. Ukrainian icebreaker

Ukraine and Malaysia signed a Memorandum on Scientific and Technical Cooperation in the Field of Antarctic Research.

South Africa is interested in exploring Antarctica with Ukraine, using the capabilities of the purchased vessel.

NASA scientists have released a video showing the melting of Arctic ice since 1984. Rapid climate and environmental changes (global warming) are facilitating navigation by the Northern Sea Route from Northeast Asia to Europe.

In total, three sea routes are considered. The two main routes, the Northwest Passage and the Northeast Passage, which connect the Atlantic to the Pacific Ocean, create the right conditions and give quick access for Northeast Asia to European and Norrth American markets. It is estimated that this route is 40% shorter than the traditional route through the Indian Ocean and the Suez Canal. The Third Arctic Passage, or Transpolar Sea Route, crosses the Arctic [12]. However, it can be accessed only with the help of icebreakers. But it should be noted that most Arctic routes have an underdeveloped infrastructure, limited opportunities for search and rescue operations.

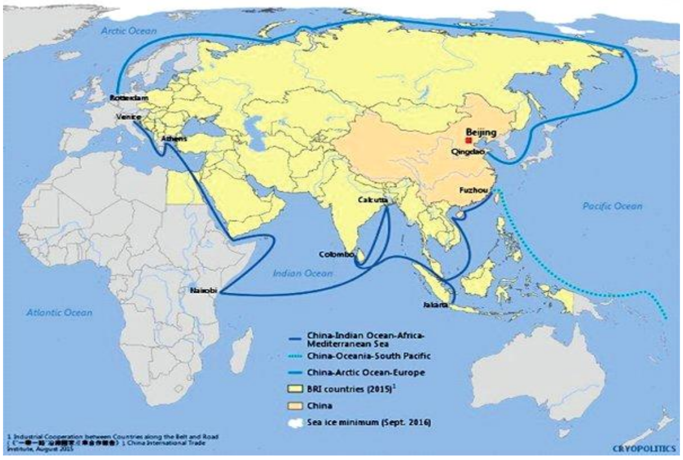

Fig. 4. Map of three sea routes

The conditions of the Arctic and Antarctic are so severe and specific compared to normal maritime conditions that the application of normal standards to the design and equipment of a vessel creates an unacceptable level of risk. On January 1, 2017, the International Code for Ships Operating in Polar Waters (Polar Code) entered into force [10].

1. Ice can affect the structure of the hull, the characteristics of stability, mechanical installations, navigation, working conditions in the open air, maintenance, lead to disruption of the normal operation of equipment and safety systems [3];

2. Icing of superstructures, cargo can reduce the stability and efficiency of equipment [3];

3. Low temperatures affect the working conditions and efficiency of people, the properties of materials and efficiency of equipment, survival time and performance of equipment and safety systems [3];

4. Prolonged periods of polar night and polar day can affect navigation and people's ability to work [3];

5. High latitudes affect navigation systems, communication systems and the quality of visual information about the ice situation [3];

6. Remoteness of the navigation area - possible lack of accurate and complete hydrographic data and information, limited number of navigation aids and signs, remote location of search facilities [3];

7. Potentially insufficient experience of crew actions in polar conditions - and this is the possibility of people committing wrong actions [3];

8. Lack of adequate equipment for emergency assistance [3];

9. Severe weather conditions, which can change rapidly can potentially lead to an increase and development of the scale of events [3];

10. The environment in terms of its sensitivity to harmful substances [3].

Mandatory part I-A sets out the requirements of the Polar Code for ship safety. In particular: to the equipment of the bridge, special equipment for ice removal, rescue equipment and equipment for firefighting in low temperatures.

According to Chapter 3 of the Code (Ship Structure), materials that can withstand particularly low temperatures, and in ice, must be used in the construction of ships approved for operation in subpolar waters. The requirements for water tightness of the vessel and its protection from other atmospheric phenomena, provisions on fire safety on the vessel, provisions of stability of the vessel, on increased requirements for the machine equipment of the vessel allowed for navigation in polar waters are of regulatory importance. The decision on the conformity of the vessel design to the established requirements shall be made by the state of registration of the vessel or an organization authorized to do so by such state. According to the Polar Code, a vessel must have a Polar Navigation Certificate and a ship's Polar Water Operation Manual."Polar vessel certificate" contains confirmation that the vessel meets the requirements of the Code regarding the construction of the vessel, the availability of life-saving equipment, means of communication, fire safety, etc [5].

Prior to the Polar Code, Arctic and Antarctic vessels were built under the supervision of various classification societies that develop and apply technical standards in the field of design, construction and supervision of marine facilities. There are more than 50 classification societies in the world. The International Association of Classification Societies (IACS) unites 10 major national classification societies, which classify about 94% of the world's commercial tonnage.

Table 1. MAKO classification societies

I. ABS - American Bureau of Shipping
2. BV – BureauVeritas
3. CCS - ChinaClassificationSociety
4. DNV – DetNorskeVeritas
5. GL – GermanischerLloyd
6. KRS - Korean Register of Shipping
7. LR- Lloyd Register of Shipping
8. NKK – NipponKaijiKyokai
9. RINA – RegistroItalianoNavale
10. RS - Russian Maritime Register of Shipping

In 2006-2008, the association developed and adopted a "Unified requirements for Polar Class ships". In developing this classification, the description of ice types adopted by the World Meteorological Organization was taken into account.

Table. 2. MAKO ice classes

Polar Class – PC	**GeneralDescription requirements for the vessel**
PC 1	Year-round swimming in any waters covered with ice
PC 2	Year-round swimming in conditions of perennial ice of medium thickness
PC 3	Year-round swimming in biennial ice, with areas of perennial ice occurring.
PC 4	Year-round swimming in conditions of one-year-old ice of large thickness, with areas of old ice that occur.
PC 5	Year-round swimming in conditions of annual ice of medium thickness, with areas of old ice occurring.
PC 6	Swimming in the summer-autumn period in the conditions of annual ice of average thickness, with the sites of the old ice meeting.
PC 7	Swimming in the summer-autumn period in the conditions of one-year thin ice, with the sites of the old ice meeting.

The requirements of the Polar Code apply to all new ice-floating vessels built after the entry into force of the Code. To be able to apply the requirements of the Polar Code to ships of Arctic and Antarctic navigation, built earlier, it is necessary to establish correspondence between the classes of classification societies, MACO, the Code. During the preparation of the Code, a table of such approximate compliance was drawn up.

Table 3. Sample correspondence between the polar classes of MACO and the ice classes of classification societies

Классификационное общество	Ледовый класс				
IMO Guidelines, 2002 (IACS Polar Ship Rules, 2006)	**PC2**	**PC3**	**PC4 / PC5**	**PC6**	**PC7**
Russian Maritime Register of Shipping (Rules 2007)	**Arc9/Arc8**	**Arc7**	**Arc6**	**Arc5**	**Arc4**
CASPPR, 1995	CAC2	CAC3	CAC4	A	B
American Bureau of Shipping	A4	A3	A2	A1	A0
Det Norske Veritas	POLAR-20	POLAR-15	POLAR-10 ICE-15	ICE-10 ICE-1A*	ICE-05 ICE-1A
Lloyd's Register	AC2	AC1.5	AC1	1AS	1A
Germanischer Lloyd	Arc3	Arc 2	Arc1	E4	E3
Finnish-Swedish Ice Rules	-	-	-	1A Super	1A
Bureau Veritas	-	-	-	1A Super	1A
Nippon Kaiji Kyokai	-	-	-	1A Super	1A
Korean Register of Shipping	-	-	-	ISS	IS1
China Classification Society	-	-	-	B1*	B1
Registro Italiano Navale	-	-	-	1AS	1A

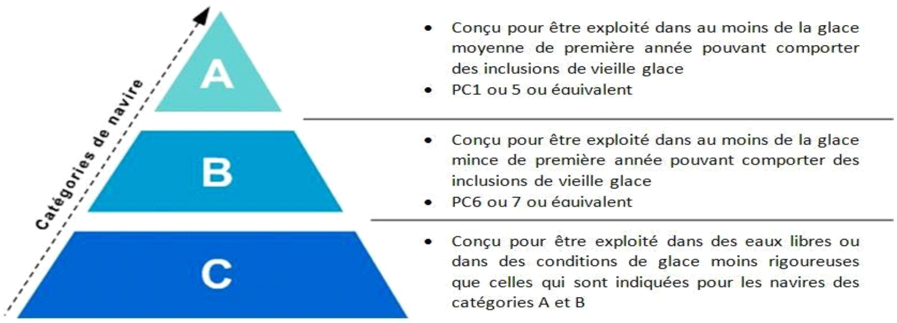

Fig. 5. Sample correspondence between IMO polar classes and MACO ice classes

Thus, due to the lack of consistency in the ice classes of different classification societies, additional risks and difficulties are created for ship-owners, flag administrations and classification societies, as they will have to decide this issue on their own, based on the recommendations contained in the Polar Code.

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ANALYSIS OF THE DNIPRO RIVER CARGO TURNOVER

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Introduction.

The Dnipro is the fourth-longest river in Europe. This river has the longest channel within the Ukrainian borders. The length of the Dnipro in its natural state was 2,285 km. The river was not very suitable for safe navigation, due to its shallow depths and dangerous currents. However, the favorable location of the river became the reason for the emergence of a large trade route - “From the Varangians to the Greeks”. From the Swedish port cities, it lies along the Baltic Sea, the Gulf of Finland, Lake Ladoga, the Volkhov River and Lake Ilmen, further following the Lovat River, then via the Dnipro tributaries to the Dnipro River, finally reaching the Black Sea, to the shores of Byzantium. [1]

The route experienced the highest load during the period between the 10th and 13th centuries. At that time traders had to cross the areas between river basins and riffles by land. Cargo turnover included the following:

- Import of weapons, whale skin and walrus bone from Scandinavia;
- Export of fur from Veliky Novgorod;
- Import of wines, silk and spices from Byzantium; - wine, silk and spices.

The Trade Route from the Varangians to the Greeks lost its significance in the 13th century, due to the change in the geopolitical situation.

During the next period, the Dnipro River was used for the transportation of wood, grain, sugar and salt to sea on rafts and small wooden ships - Chaikas. However, land routes continued to be used to ensure complete and permanent cargo transportation, due to unpredictable tides and rocky seabed. By the 19th century, when technology made it possible to build steam-powered ships, the Dnipro had become one of the shipping development centers. One of the first ships on the Dnipro was the wooden ship “Nadezhda” (1823), later used on the Odesa - Kherson passenger route. [3]

The year of the foundation of the first shipping company on the Dnipro is 1835. Having two steamships at its disposal, it was engaged in the transportation of stone for the castle construction in Kyiv. In 1858, the Dnipro Shipping Company was founded, which dealt with passenger transportation. The main routes were Kyiv - Kremenchug - Ekaterynoslav, Kyiv- Chernihiv, along the Sozh to Gomel and Pripyat to Pinsk. However, the shipping company was limited in routes, due to the fact that for relatively large ships it was not possible to cross the rapids, thus the river was divided into upper and lower parts. [3]

For many years, the natural rapids located in the lower part of the river have been limiting cargo transportation. The issue could be solved by the construction of dams. The first attempts were made in the middle of the 19th century. However, due to the technical complexity, it was only after the building of the Dnipro hydroelectric power station in 1932, that the possibility of managing natural barriers emerged. [5] Dnipro HES played a huge role in the connection of the upper and lower flows of the river, so that it became possible to deliver goods from Kyiv to the Black Sea ports by ships using the power plant gateway.

From 1900, the cargo turnover was relatively low, for example in 1912, around 2,260,000 tons of various cargoes were transported along the river per year (about 5% of the river traffic, and about 2% of Ukraine's cargo turnover). In addition, around 2,400,000 people were engaged on passenger cruises. The main types of cargo transported included wood (55%) and grain (27%). By 1940, the mentioned values decreased slightly to 32% and 14%, respectively. After the First World War and the Civil War, the cargo turnover decreased significantly to about 752,000 tons in 1928. The recovery took several years; pre-revolutionary values were reached in 1932 – about 2,960,000 tons of cargo. Further figures were 5,800,000 tons in 1935 and 10,000,000 tons in 1940 with about

4,800,000 passengers. In the middle of the previous century, the main port on the Dnipro was Kyiv - having 50% of the river cargo turnover, the second place was taken by port of Kherson, where oil had been transshipped for import and wood, grain and metals for export. [1]

By 1990, the Dnipro's cargo turnover reached 60 million tons per year and was the largest artery in Ukraine. Furthermore, the Dnipro River was useful for traveling between coastal cities, the development of infrastructure provided a passenger turnover of 20 million people a year. After the collapse of the USSR in 1991, cargo the turnover began to drop and reached 3 million tons by 2021, in 30 years it decreased by 20 times. With respect to the passenger turnover, the figure was limited to 500 thousand people, which is 40 times lower than 30 years ago. [4]

One of the reasons for the decrease in cargo turnover and passenger turnover on the Dnipro was that declared depths were not provided in the fairway (fig. 1). According to the documents, it was supposed to be 3.65 meters along the entire length of the Dnipro, while the actual depth was 3.0 meters. [4] Under these conditions, the cargo capacity for ships did not exceed 1.5 thousand tons, whereas with depth of 3.65 meters they could carry up to 5 thousand tons on board.

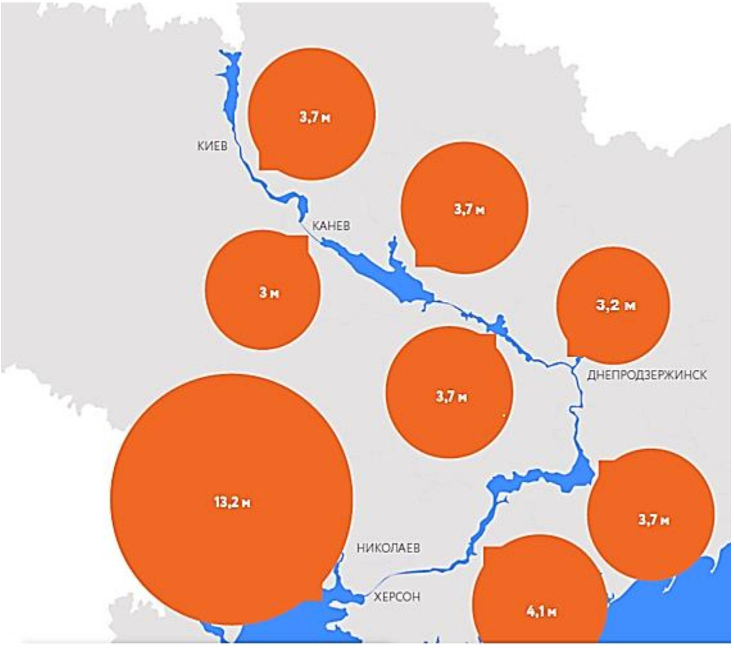

Fig. 1 – Declared depths the Dnipro River

To maintain the declared depths, a modern dredging fleet is required. In order to ensure 3.65 meters of depth along the entire river, it is necessary to extract about 1.5 million tons of sand and 20 thousand cubic meters of stones. [2] Moreover, the navigation and radio equipment has to be modernized, as most of the buoys were installed in the 1950s, and at the moment about 1,100 buoys must be professionally maintained and repaired and 125 must be replaced, which requires sufficient funding.

These days, the most popular cargo transported along the Dnipro is construction materials - 64% of the total cargo, the second is grain 25% and 11% presented by metal products. The comparison of the equivalent periods in 2020 and 2021 demonstrates that the volume of freight traffic increased by 61%. Meanwhile, railway transport alone carries 305 million tons of cargo per year with prevailing iron ore - 79.7 million tons, followed by construction materials - 60.4 million tons, coal - 48.6 million tons and grain - 35.2 million tons. [4] The container transportation market is monopolized by rail and road transport and amounts to about 700 thousand TEU per year.

Several types of cargo could be transported by vessels of river-sea or non-self-propelled type along the Dnipro river. Unfortunately, due to the low development of the river transport as well as lack of the government support, shippers prefer land means of transportation. At present, the agro company "Nibulon" provides cargo transportation support with a turnover of about 20% of the total number of transported goods. Regardless of the fleet belonging to "Nibulon", the average age of vessels, operating on the Dnipro, is approximately 35 years, which requires critical control of their technical condition. One of the possible solutions for this issue could be the establishment of favorable conditions for private carriers and good conditions for logistics companies operating on the Dnipro.

The transport network in its present state remains almost in the same condition as in the days of the USSR. In the past 30 years, no reformations have been carried out in order to develop river transportation. On a yearly basis, the government allocates the funds for the maintenance - UAH 72 billion. From them, UAH 36.5 billion is spent on the network development, UAH 13.5 billion is used to cover loan obligation. In addition, UAH 39 million is allocated every year to maintenance the gateway infrastructure, not including the cost of repair works. This is the standard amount allocated for the State Enterprise “Ukrvodshlyakh”. The deterioration of locks reaches significant values, which negatively affects the dynamics of river cargo transportation. The difference between the costs of road restoration and maintenance of the river's navigation varies significantly. However, the river's potential is not used at its full capacity, locks are idle most of the time, the official data on the use of the river's potential is 18.5%, the design number of locks per day is 36, in fact, 34 are carried out in a month’s time, which sets a barrier for traffic improvement. [6]

Grain transportation. Four barges and one pusher tug carrying 8,000 tons of grain along the river is the equivalent of a hundred railroad carriages or five hundred trucks. The total volume of transported grain cargoes in Ukraine in 2020 amounted to 82 million tons, river transport transported approximately 2.5 million tons, which is approximately 3%. In case 30% of cargo turnover traffic is transferred from land to river, the road network would be discharged by about 700 thousand trucks. For instance, on the route Dnipro – Odesa with a cargo weight 2000 tons, 3rd class grain. The price per ton for transportation by road will be about $ 45 / ton, with a duration of 1-2 days. Railway transportation - $ 16-17, up to 3 days, by the river - $ 14, approx. 4 - 7 days, depending on the type of vessel. Delivery by the last option can be effective for non-urgent delivery of goods.

Transportation of metal structures. Transportation by road is unprofitable due to the high specific weight of the cargo, so this option is not considered. Transportation by the river will cost $ 8 per ton, which is slightly less than by the railway.

The general idea of progressive marine infrastructure has to unload highways in Ukraine (Kyiv-Odesa, Kyiv-Mykolaiv, Kyiv-Dnipro). To achieve greater benefits, carriers often overload cars, which affects the condition of the road surface, and as a result, affects the budget. Shipping allows avoiding the mentioned negative effects. Furthermore, the development of the river and sea shipping industry could create a large number of jobs for graduates of Ukrainian maritime universities.

Additional cargo transportation problems of the Dnipro River.

Amur bridge in Dnipro city has a height limit of 14 m. This restriction does not allow many types of ships to pass safely under the bridge and implies delays in granting permission for passing. The navigable section of the bridge is open once a day for 1 hour. This allows the height to be increased up to 20 meters. For such a passage, the shipowners face expenses not only for the vessel’s delay but also for the bridge opening. One of the options to eliminate this problem could be the opening of the bridge by the prior order of the shipowner, the expansion of the opening schedule of the bridge, or the bridge reconstruction.

Technical condition of the locks:

1) When locking lifting buoys often fall, it complicates the locking process and exposes the ship, cargo and crew to danger. In case a sufficient number of buoys break down, sluicing off becomes impossible.

2) The hydraulic mechanism of the Zaporizhzhia lock is extremely worn out, which causes delays in the opening of the lock gates, affects the work schedule of the lock and the ship itself.

3) The water pumps are outdated causing a decrease in the rate of water intake into the lock chamber, so the process can take more than an hour.

4) Lack of lighting on the lower tier of the Kakhovsky lock, which affects the safety of

operations.

The above listed issues may be solved by overhauling the gateway network. The funding of approximately $ 4 million is required to restore each lock. To open a three-tiered non-working lock of Zaporozhe will cost around $ 6 million.

To implement the project, it is necessary to improve the existing infrastructure: to improve ports infrastructure in Kyiv, Kanev, Cherkasy, Kremenchuk, Svetlovodsk, Kamenskoe, Dnipro, Zaporizhzhia, Nikopol, Kherson, Novomoskovsk, etc. Furthermore, the development of automobile and container terminals could be a benefit for the following ports of: Kyiv, Cherkasy, Kremenchuk, Dnipro, Zaporizhzhia, Kherson. In the present time, containers and vehicles are delivered by roadway. Their transportation by marine transport would be a profitable alternative, in case of non-urgent delivery of the goods - the cost is lower, the risk of damage is lower, although it will take more time.

In addition, the option of buying a new fleet suitable for the transportation of various goods along the Dnipro is considered below. The crew completion is limited, with the maximum number of 6 persons on tug-barge. The fuel consumption is lower, the speed is higher and the majority of the automation class is A1, which allows reducing the cost of engineering. At modern freight rates, these vessels could be more profitable in operation in comparison with the vessels of the current fleet [4].

Table 1 - Fleet

Ship particulars	Containership	O-class hold barge of P110 project for transportation vehicles	Project 2731 M-SP3.5 oil barge	Project Europa-2	Tanker project RST27	Self-propelled dry-cargo vessel project RSD49	Tug SHOALBUSTER 3815 ultra-shallow drought (YN571738)
LOA	82m	99,7m	90,9m	76.02m	140,85m	139,95 м	38,35m
Breadth	11,8 m	17,3 m	16,24m	11.44m	16,7m	16,5 м	15,9m
Draft Loaded	2,58 m	2,1 m	3,81m	3.10m	3,6m	3,6 м	1,6m
Draft light	1,26m	0,81 m	0,73m	0.56m	2,7m	2,6m	1,2m
Speed	11,2 knots	non-self-propelled	non-self-propelled	non-self-propelled	10 kn	11,5 kn	8 knots
Deadweight	1000t	400 cars	4100 t	2033t	5378t	4518t	249t
Depth	9m	3,1 m	4,7m	3,90m	6m	6m	2,7m
Air Draft	11,2 m	7,3 m	5 m	6m	18m	18m	4m
Freeboard	4m	1m	1,1m	3.20m	2,4m	2,5m	2,2m
Dispalcement load/light	2004t/899t	2593t/1125t	5000t/862t	3000t/ 915t	7900t/2500t	7900t/2500t	750t/501t
Bow thruster	n/a	n/a	n/a	n/a	230 kWt, Shottel STT0170FP)	200 kWt	n/a
Holds, capacity	2	3 decks	5 tanks	1 hold	6 tanks	3, 10920 m3	n/a
Main engine	2 x 441 kWt, 8NVD 36/24 A-1	n/a	n/a	n/a	2 x 1200 kWt, 6L20 "Wartsila"	2 x 1200 kWt (WARTSILA 6L20)	4x Caterpillar C12-TA

Ballast tanks volume	600m^3	n/a	n/a	n/a	4123m^3	3959 м^3	---
Autonomity	12 days	n/a	n/a	n/a	12 days	20 days	5 days
Crew/ cabins	10/13	n/a	n/a	n/a	12/13	10 /12	7/11
Class	M (ice)	O	M-SP3.5	I3/3E side tank vessel loading and unloading in two runs /NP Nl2 ice	КМ ✪ Ice1 R2 AUT1-ICS OMBO VCS ECO-S Oil tanker (ESP)	КМ ✪ Ice2 R2 AUT1-C	Bureau Veritas I□HULL □ MACH Tug (Unrestricted navigation, with wind strength and wave height limitation)
Purpose	20-foot containers, general cargo, timber, bulk cargo	Vehicles transportation	Oil transportation	Bulk or general cargo transportation	Oil transportation	Bulk or General cargo	Pushing, towing of non-self-propelled ship

This paper considers the main problems and opportunities for the development of river transport in Ukraine. It can be concluded that the transfer of cargo flows from land to water could significantly reduce the load on land transport routes, saving funds allocated for road repairs, to be used more efficiently elsewhere. Thus, employment opportunities for graduates of maritime colleges and universities can be expanded in Ukraine. As for the disadvantages of the proposed project, the required investments and timelines can be noted. To summarize, it should be mentioned that for the successful development of cargo transportations along the Dnipro River it is necessary to create favourable conditions, which means governmental support and investors engagement.

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RISKS FOR TANKERS INDER REPAIR AT SHIPYARD

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Ship repairing is an inherently hazardous operation due to hot work in tanks with explosive or toxic fumes and other hazards. The most common and dangerous cause of accidents during dry dock, explosions / fire can lead to disastrous damage to both ships and seafarers.

Fires can spread quickly because of the flammable chemicals that are being used in the repair of the vessel, or because of the flammable materials contained at the dry dock (e.g., fuel, gas, paint, welding equipment, etc.). During dry docks, the engine room is filled with various electrical connections, and a short circuit can cause a fire. Over the years, hot work in docks, both on ships and onshore, has resulted in many serious fires and explosions that have caused death and serious injuries. On ships in docks, hot work may be carried out in connection with routine maintenance or voyage repairs. The situation is aggravated by the fact that during the repair period several ship's systems may be out of operation [1]. The ship and personnel aboard can thus be exposed to unexpected and unfamiliar risks and hazards. Masters of ships have the prime responsibility for the safety of their ship and everybody on board. No hot work should be carried out on board a ship in a dock without a written permission from the master or other officer in charge. If the master or other officer agrees to hot work being carried out by shore personnel, they should warn the personnel of any relevant hazard and take steps to ensure that all necessary precautions are taken. Care needs to be taken before any hot work is undertaken on board a tanker to ensure that all flammable materials and residues are removed from the area before the work begins and that the area remains gas free throughout the work. Guidance on such work can be found in the International Safety Guide for Oil Tankers and Terminals. In addition, OCIMF recommends that if a Company intends to assign a contract to carry out the work, whether construction or repair, it should be ensured that potential Shipyards have an HSE (Health, Safety and Environment) Policy and perform all work under a formal HSE Management System. This System should be adequately documented with an HSE Manual and be shown to be effective in implementing the aims and objectives of the Shipyard HSE Policy [1].

The standard of tank cleaning and gas freeing required when a vessel is proceeding to drydock, or a repair berth is dependent on the type of work to be carried out and the facilities available at the dockyard or berth. The Company will advise the vessel in good time of the standard required. The Company should arrange for the Ship to arrive with all cargo tanks, ballast tanks, void spaces, pipe tunnels, cofferdams, pump rooms and empty fuel tanks in a clean and gas free "safe for entry" condition and/or "safe for hot work" condition, if required, in accordance with local regulations. All cargo, vent, inert gas, and cow lines together with cargo heating coils and lines should have been flushed and/or ventilated. Fuel lines and associated equipment should be similarly cleaned so far this is practical "safe for entry" criteria are defined as: -Oxygen content of 21% by volume; -Hydrocarbon vapors not more than 1% of the Lower Flammable Limit (LFL) and Toxic gases below the relevant permissible exposure limit [2].

In tanks where significant work is to be carried out, the tank bottom and horizontal stringers and other major surfaces of tank structures should be cleaned of any significant oil residues. Further on, local cleaning may be required once access is obtained to the work site and cleaning can be further assessed. If there is work in an adjacent tank it may be necessary to remove residue from the other side of the bulkhead. In case removal of residues is allowed after the ship has entered the yard, hot work should be prohibited until the operation has been completed and all residues removed.

Prior to entry into the Yard an independent certified chemist should test all lines and tanks. On completion of the tests appropriate certificates should be issued to the Company representative and the Master. It is important that any tank which is not certified as being safe for entry or safe for hot work is clearly identified as such [2]. The continuing maintenance and verification of the status of any tank or space throughout the repair period is the responsibility of the Yard. During this initial and any subsequent gas free examination a deck officer must witness the gas measuring result and ensure that same is carried out in accordance with standard gas measuring procedure requirements.

In addition to above, the following must be adhered to:

• The Master and Chief Engineer must ensure that gas free certificates are renewed whenever so required.

• No work must be commenced before the gas free certificate has been issued.

• On tankers hatches and tank domes are not to be closed_on any account as gas may be present in the rust layer on bulkheads, superstructures and in pipes. It should be made the rule, however, to swing the hatch covers / tank domes over the openings to prevent rainwater from entering the tanks. On vessels where hatches are not suspended over the openings, they can be held open by means of double-angle cleats [3]:

• All tanks must be free of sediments or rust which may contain gas pockets. If sediment or rust is found, it must be removed in a safe manner.

• Once the ship is in the Yard, the main areas of concern with respect to safety are the following:

-Establishing and maintaining safe working conditions.

-Ensuring that all parties involved are aware of what work is being done, by whom, where and when.

-Securing the personal safety of the ship's personnel and others. Ship officers and Yard's Safety Staff should have the authority to stop any work, which is considered unsafe.

-Shipyard should ensure that the personnel and contractors comply with all relevant national statutory requirements and approved codes of practice.

-Protection of the environment.

The Master should be given copies of the Yard's safety and security arrangements and ensure compliance with these requirements:

-Fixed firefighting system, such as CO2, should have their normal operating means disabled so they cannot be inadvertently operated

-Charged fire hoses should be available at each location where hot work is being carried out.

-The Yard should have fire patrol organization on the ship.

-Fire watchers should be stationed in the vicinity of all hot work locations provided with appropriate extinguishing media.

-Combustible material should be removed from all work locations to eliminate the chance of fire.

Particular attention should be paid to ensure that environment pollution does not occur during shipyard repair period. Issues to be addressed should include [4]:

•All tank cleaning residues, including slops and tank sludge, must be disposed of properly in accordance with governmental regulations and MARPOL 73/78.

•Deck scuppers are plugged or led to facilities

•All transfers of liquids within the ship are planned so as to avoid accidental discharge of oil mixtures.

•Opening of any system should not release any fluids or ozone depleting substances, and ship's sewage should be disposed of in accordance with governmental regulations and MARPOL.

When the vessel is to stay in a shipyard or a dry-dock, the Master and his/her Officers should maintain the same safety and security standards as if in port. The Master and his/her Officers should request that the same level, if not increased, of safety precautions and safe working practices should be strictly applied by the dockyard workers to prevent not only personal injuries but also damage to the vessel itself, such as a fire or stability accidents. Close cooperation between the vessel's deck and engine officers and the shipyard engineers is required.

We are well aware of the accidents at sea, but dry dock accidents can be just as dangerous. There is always a potential risk of explosion in yards. Preventing dry dock accidents is a significant challenge, mainly because dry docks are especially dangerous workplaces. The most common and dangerous cause of accidents during dry dock - fire - can lead to disastrous damage to both ships seafarers (Fig. 1) [4].

Fig. 1. Fire on the m/t Jag Leela

The severe fire broke out on the Jag Leela, a 21-year-old Aframax tanker, which was under repair at Waruna Shipyard in Belawan, Medan (Fig. 1).

An explosion which wrecked the Norwegian Tanker “Man tilla”, from Tonsberg, Norway, resulted in at least nine fatalities and with many others badly injured. It occurred in the Bethlehem Shipbuilding Corporation, Sparrows Point, Md., The vessel was undergoing repairs in drydock.

An explosion and fire aboard an Aframax tanker at the Turkish Tuzla Shipyard took the lives of two workers, while 11 more were injured**.** The incident occurred aboard the Hong Kong-flagged crude oil tanker LR2 Poseidon during maintenance works at the repair yard.

Chemical type of explosion occurred inside the Residual Oil Tank onboard m/t “Sri Asih”, on November 3, 2020 at Sefine Shipyard, Turkey & consequent injuries of shipyard workers during hot work on main deck. In addition, the explosion heavily damaged the vessel’s steel structure and piping system (Fig. 2).

Fig. 2. Damage of bulkheads of residual tank m/t “Sri Asih”

Principal Causes of this accident:

• Lack of Supervision;

• Shipyard and Vessel Safety Standards Negligence;

• Work Permit Negligence;

• Error Chain due to improper compliance of Maintaining Ventilation of ROT tank, No Inspection of Tank, Buildup of Residues, Using Hot work without permission by Yard Workers, No Stop Work Carried out.

The accidents occurring during ship dry docking indicate both the failure of the technical solutions as well as the frequent occurrence of human error. The human factor is invariably a weak link in safety systems. It may be the first factor initiating undesirable events. In many cases, it is not a direct source of danger, but its incorrect actions intensify the dangerous development of events, which can have tragic and irreversible consequences [4].

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DYNAMIC POSITIONING METHODS UNDER LIMITED CONDITIONS

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The formulation of the problem of planning and controlling the movement of the vessel consists in choosing a method for forming the coordinates of a given safe path and control parameters in such a way that it moves without an emergency from the coordinates of the initial state to the final one. Usually, the movement of the vessel can be controlled at each moment of time t by the parameters u_1 (t),…, u_n(t), which make it possible to correct the movement vector when deviating from the given coordinates.

Written reckoning is of two types: simple; composite. In simple dead reckoning, the coordinates of the final point are calculated according to the known coordinates of the initial point of departure and course and navigation. Composite calculus is used when swimming is performed in several courses.

Thus, dead reckoning when determining coordinates is called a method of mathematical modeling. Its accuracy depends on the errors in calculating the value of the wind drift angle, the drift angle by the current and the presence of the drift angle during yaw during control. However, the methods of planning the coordinates of curvilinear sections of the path, considering the characteristics of the ship's turnability, have not been considered.

There are two main methods of dynamic positioning in compressed conditions: vector reckoning by the method of expert judgment and the method of mathematical modeling. To improve the accuracy of planning and performing dead reckoning in [1], the method of trajectory points (TP) was used for planning the route when maneuvering during port calls, developed in [2]. However, the method of mathematical modeling has the disadvantage that it requires calculating the parameters of the impact on the ship of external disturbances in advance [3,4], the accuracy of which is difficult to verify. In addition, the existing method of graphically calculating the drift angle during drift and current is not correct enough, since it is assumed that the direction of movement under the action of the wind does not change, but only returns in the direction of the wind by an angle α.

To improve the accuracy and efficiency of the control process, it is proposed to abandon the calculation of the parameters of external disturbances by means of drift angles. Instead, you need to represent the planned path in the form of trajectory point matrices, convenient for computer processing. In the future, the dead reckoning is carried out along a given path, as shown in Fig. 1.

TP is applied on the line of the true heading and reference points (0, 1, …i...n) are designated at the same time interval and distance, which are selected depending on the speed of movement and navigation conditions. At the moment of passing the 1st point, the expert determines the position of the vessel in a highly accurate way and promptly calculates the vector and the drift angle. The drift vector is directed to the 2nd control point and the observed point is connected to the beginning of the drift vector and the true heading to the second control point is determined, it is corrected by compass correction and compass control is performed. The sampling interval around the 2nd point is determined by the expert, and if the control and observed points coincide, this means that the displacement vector was determined correctly and external factors did not change. Therefore, the drift vector is directed to the 3rd reckoning point and the 2nd reference point is connected to the beginning of the drift vector in the third and the course is determined for further movement. If in the future the observed points coincide with the resisting ones, then we keep a certain course and speed. If there is a deviation from the line of the planned path, then the procedure should be repeated in the same way from the beginning.

The method of expert assessments differs from the method of mathematical modeling in that there is no need to calculate the parameters of external disturbances and to calculate the angles of drift from the wind, current and yaw during traffic control, which significantly increases the accuracy of movement and the efficiency of site control.

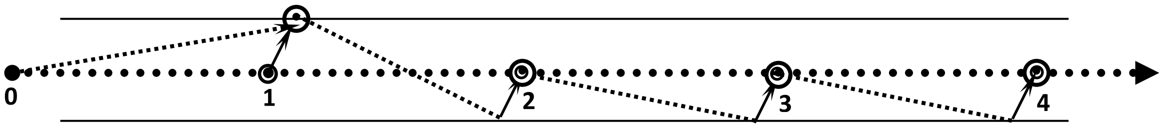

Fig.1. Graphic diagram of the choice of the vector of motion on reference points

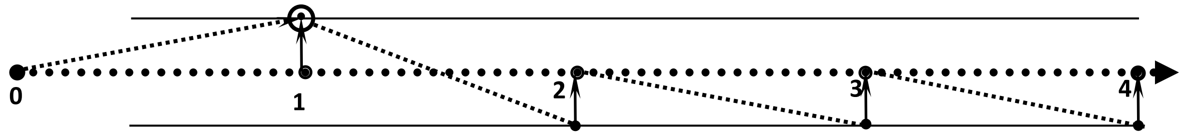

Fig.2. Graphic diagram of the choice of the vector of motion on the vector of lateral displacement

Fig. 2 determines the total vector of lateral displacement from all factors, calculates the motion vector by coordinates, which are determined by high-precision navigation tools and planned trajectory points by trajectory search and direct the vector of lateral displacement to the 2nd trajectory point. The motion vector from the observed point to the beginning of the lateral drift vector at the 2nd trajectory point is then calculated, and if the observation coordinates coincide with the control coordinates, it means that the external perturbations have not changed. Next, direct the vector of lateral demolition to the 3rd trajectory point and determine the vector of further movement. If 4 points are observed and the control point coincides, then continue the movement without changing the motion vector, and if the demolition vector appears, the procedure is repeated first.

Thus, the method of expert estimates has an advantage over the method of mathematical modeling in speed, considering all the factors acting on the vessel in full, which increases the accuracy of positioning in compressed waters. This method can be used in decision support navigation systems.

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NAVIGATION AND SEAMANSHIP IN ARCTIC AREAS

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The most perspective alternative is the Northern Sea Route. If the distance traveled by ships from the port of Rotterdam (Netherlands) to the port of Yokohama (Japan) through the Suez Canal is 12,840 nautical miles, the Northern Sea Route is only 5770 nautical miles. This allows to significantly optimize transportation costs.

However, in modern logistics, the most important factor is the predictability of transportation, which is not the case in the extreme northern conditions. The conditions of the Arctic and Antarctic are severe and peculiar compared to the usual conditions of navigation.

Navigation in such areas is a special activity, and knowledge and experience in this regard are available to a relatively small number of professionals. The application of traditional navigation standards in polar waters creates an unacceptable level of risk, as at the initial stage the decision will be made by the ones who do not have sufficient experience.

In order to increase the safety of navigation in the Arctic seas, the International Maritime Organization (IMO) has developed an «International Code for Ships Operating in Polar Waters» (Polar Code (IPC)), as amended to make it mandatory under International Convention for the Safety of Life at Sea (SOLAS).

The Code identifies 10 sources of hazards in polar waters that can increase the level of risk [13].

According to the IPC, for operation in polar waters, vessels are subject to a number of special requirements that will ensure the required level of reliability and survivability of the vessel when exposed to external factors.

In particular, the materials and dimensions of the structures must be sufficient to ensure the integrity of the hull during operation in ice. Vessels must be designed to minimize icing and be adequately equipped with ice removers.

Life-saving appliances must have thermal protection, taking into account the possibility of being in cold sea water (immersion suits with a heat-insulating layer at the rate of 110% of people on board). Additional special ship equipment must be installed: 2 additional 360-degree rotating searchlights, a red flashing light, anti-icing devices on antennas and portholes, a Global Navigation Satellite System (GNSS) satellite compass, and 2 additional echo sounders.

The main environment of navigation is not water, but ice, and navigation in ice is poses significant differences in the methods of ship management. Thus, the crew needs special training, understanding of the natural properties of ice and the dynamics of floating ice.

When solving tactical tasks, navigators must have methods of analysis of ice information to select the optimal path, methods of icebreaking and methods of forcing ice. The Code introduced a mandatory requirement for staff training.

Captains and chief officers must have advanced training, and officers of watch must complete basic polar water navigation training. Upon completion of the training, the competence must be demonstrated on a simulator or laboratory equipment and confirmed by the assessment of the results of preparation for the test in the form of an exam with the issuance of an appropriate certificate.

The master must obtain information on the state of the ice for the vessel going on a voyage in the area which ice encounters are possible and the weather in the area of the voyage both at the time of departure and the forecast for the time of the voyage.

He plans the passage basing on this information, i.e. chooses the path in the most favorable direction pays attention to such dangers as shoals, which can be squeezed by ice.

However, such information is rarely available to the captain.

Changes in weather/ice conditions/, temperatures in polar waters are unexpected, often unpredictable, and decisions must be made about voyages that can last weeks and months. Mostly, the captain will deal with many issues on the spot during the voyages.

It is necessary to remove the logs and all objects protruding overboard, which may catch on the ice during preparation for ice navigation; to prepare all drainage devices; to check up condition of watertight doors; check the patch, emergency equipment and damage control equipment in accessible places in case there is a need to repair the damage to the hull; to inform the shipping company about the start of the ice navigation; to inform the engineers about the forthcoming voyage in the ice and to reduce the speed of the vessel so as to approach the edge of the ice at a speed which would allow the vessel to be stopped at any moment.

The ice areas should be entered only after receiving the appropriate permission from the shipping company, according to the Guidelines for the navigation of the vessels in the autumn-winter period. It is not allowed to enter the ice areas without such a permission.

However, it should be noted that if the ice navigation had been arranged before the voyage started, there is no need to wait for a special permit to enter the ice [14].

Navigators must be aware of the signs of approaching the edge of the cohesive ice in order to detect the ice in proper time and prepare the vessel for sailing in the ice.

The first signs of the proximity of ice may be:

- icy sky - whitish reflection of the sky above the horizon or a brighter reflection of ice with low clouds in the part of the horizon there is the ice. The icy sky may appear at different distances from the ship, but the probability of its detection from great distances increases in cloudy weather with low dark clouds and a large area of cohesive ice[6];
- reduction or absence of swell away from the shores with fresh long winds, which is a sign of the proximity of the ice edge on the windward side [6];
- a significant decrease in water temperature when navigating in mid-latitudes [6];
- the appearance of individual ice floes on the leeside of the probable location of the ice mass [6];
- the phenomenon of refraction, which occurs most often on cloudless days due to wind from the ice. Significantly raising the image of distant objects, refraction makes it possible to see the image of ice on the background of the lower part of the sky at a distance exceeding the range of visibility by 2-3 times[6];
- the appearance in large numbers of sea animals (walruses, seals, seals) and some species of birds (cairns, scavengers, sea ducks). This is very typical of the edge of melting ice, where there is always plenty of plankton, which serves as food for animals and birds. This sign indicates that large ice clusters are located at a distance of not more than 10-15 miles [6];
- fog formed on the edge of cohesive ice [6].

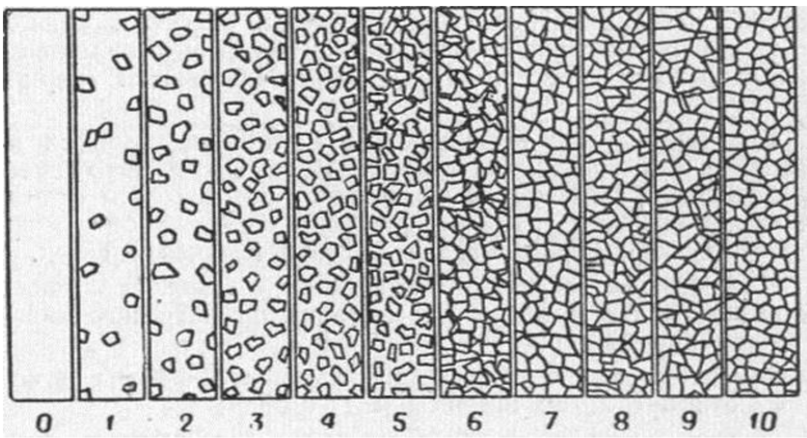

Fig. 1.Ice density on the surface

The leeward edge usually allows you to enter the iceareas always, because the strip of ice significantly calms the excitement that can be from the leeside edge. There is no danger of hitting the ice due to the relative movement of the ice and the vessel. The ice thickens gradually.

In many cases, the windward side edge is dangerous to pass through due to the fact that under the influence of waves, a certain strip of ice is in a dangerous motion for the ship [6].

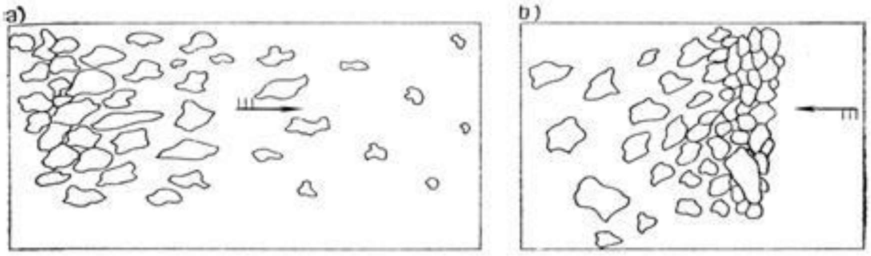

Fig.2. Schematicimageleeward (a) andwindward (b) ice edges

Therefore, in this case it is necessary to find a place that would safely allow the vessel to enter the ice. Such a place can be a strip of fine ice (Fig. 3), individual pieces of which are not dangerous to the vessel, or the protrusion of the ice field, under cover of which you can enter the ice [1].

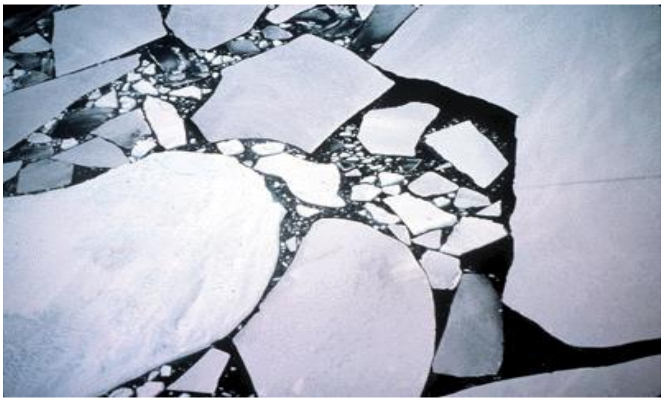

Fig.3. Ice cake - any relatively flat piece of ice less than 20 m in diameter

If the place that allows you to enter the ice can not be found, and the ice is heavy, it is better not to enter the ice, and wait for the calming of the swell or waves.

In all cases, it is not recommended to enter the ice in the fog or at night. It is better to wait for the visibility to improve and then enter the ice, because with poor visibility the right choice of path will be impossible.

Once in the ice, you can gradually increase the speed. As the speed increases, the propeller will increase the flow of water, which will clear the ice behind the stern, which will make safer the operation of the propeller and the steering gear.

Fig.4. Navigation in ice

The speed of the vessel depends on the location of the ice, greatly. The speed of the ship should be such that the navigator has time to study the nature of the ice from afar, to choose the best way in advance and to bypass large ice floes. The captain must take into account the maneuverability of his vessel, ie the ability to stop in time or alter course from the dangerous ice, when assigning the maximum possible speed of his vessel in the ice.

The maneuverability of the ship is significantly reduced, during ice navigation. This is due to the fact that when throwing the stern, it rests on the ice and prevents the ship from returning. In addition, the risk increases, because the ship encounters ice of different densities and tends to dodge towards the lowest resistance. Maneuverability is further aggravated by the fact that the inertial motion quickly fades due to greater resistance than when navigating in clear waters.

It is necessary to take into account the depth of the coastal strip and the nature of the ice, when sailing along the coast in the presence of ice from the sea,

If the coast is shallow with a gradually decreasing bottom, and the ice is heavy and hummorous, then along the coast there will be a strip of clear water, which should be used for navigating. Such a clean strip is a consequence of the fact that the hummock ice is aground at great depths and does not allow the mass of ice to throw the ship into around in the event of ice from the sea.

If the coast is deep, then heavy ice, pressing on the coast, can run ship aground. Such places the vessel must pass at the time of ice thinning. When you can not go more seaward and try to pass there, the coastal bridge created by ice, you should stop under the cover of ice floes stranded on the beach, and wait for the ice to improve.

When passing near the icebergs, remember that about 7/10 of their mass is under water and can stretchnear the surface of the water in the horizontal direction at a great distance from the surface part [1] (Fig. 4).

Fig.5. Iceberg

Icebergs should be given a wide berth at a considerable distance, as many of them float in an unstable equilibrium and can capsize with a slight disturbance of this equilibrium. In addition, they should be bypassed on the windward side, because if the ship goes around the ice berg on the leeward side, it will drift more slowly than the ice berg, due to less impact of the wind [7].

If you find anice berg at a close range in a poor visibility, give full astern is the best to avoid a collision with it.

If you try to turn your shipmoving ahead, you may come across an underwater ram of an iceberg and damage the bottom or underwater part of the ship's side, constantly approaching it.

Generally speaking, when navigating in ice, it is impossible to avoid collisions with ice completely. However, each ship is able to withstand some impacts on the ice.

To move the vessel in the ice field, it is necessary to chosethe way along the crack, while the vessel has the ability to break the ice into the crack and move forward, even very slowly. Having found the entrance to the ice crack, it is necessary to look for a way out, that is, planning beforehand. Attempting to pass straight through the ice field can lead to jamming and even jamming of the hull, because the inertia of the ship drops sharply after entering the ice field, and the field itself becomes stronger as it moves to its center. It should be borne in mind that even with a successful advance through a large field (if the engine power allows) the vessel can not make even the slightest turns in the field, it will lead to a sharp decrease in inertia or jamming of the vessel.

Crossing an ice jumperis a very risky operationwhen a vessel is sailing alone, because in addition to heavy loads on the hull and engine, the vessel has a probability of jamming.

Therefore, with the slightest doubt about the success of crossing such an attempt should not be made, so as not to get stuck in the ice for a long time, because the icebreaker will not be nearby and will not help anyone in the vacated vessels [5].

If the captain decides to cross the jumper, he must move with a little inertia, without accelerating the ship. If the movement is possible only by "blows", then the vessel should retreat along the canal until clear water appears in front of the nose in the canal to replace the broken ice (usually this distance is not more than the length of the hull). After that, the inertia of the vessel back should be smoothly extinguished, and, smoothly adding engine speed, start moving forward, with a small shift of the rudder to make a blow [8]. The small inertia of the vessel will not allow to damage the hull, and the relocation of the rudder - to avoid jamming of the hull of the vessel, as well as contribute to the expansion of the channel (Fig. 6). If the ice jumper cannot be broken immediately, the operation can be repeated several times until it is successful or it becomes clear that such attempts are futile.

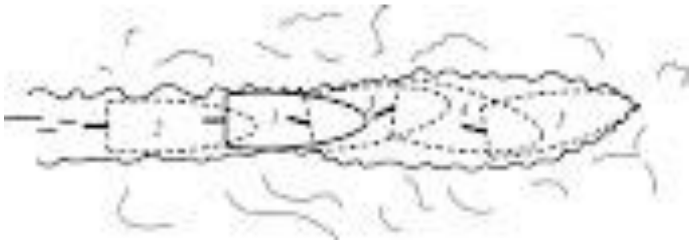

Fig. 6. Crossing ice

When crossing the ice, it is necessary to carefully observe the hull of the vessel and measure the water level in the hulls, as well as inspect the hull and hull set inside the vessel.

When moving astern, you should always put the steering wheel straight and send an experienced observer to the stern. When the vessel moves astern, the propeller must constantly rotate astern, due to a high risk of the damage to the stopped propeler. When movement astern stopped, it is necessary to give a dead slow ahead with the minimum possible r.p.m., that at first to dilute ice a little around screws.

If the ship finds itself in a situation where it becomes impossible to move forward and at the same time it is impossible to turn around to get out of the heavy ice in reverse, it is necessary to move astern. The rudder should be kept mid ship, and the navigator should be directed to the stern to observe the ice.

If the ship is surrounded by ice, it is necessary to form a space free of ice near the propeller and rudder before starting to move, (Fig. 7).

Fig.7. Exit from ice

To do this, start rotating the propeller at low r.p.m., so that the water thrust is formed, and wash away pieces of ice. In such cases, long bamboo poles with metal tips can be used, you can clear the area of the propeller from ice, which is still unaffected by the water thrust or stuck in the propeller's gaps.

Navigation in the dark, fog and poor visibility is inefficient, so it is better to drift in the ice and wait for improved visibility. The best place to drift in will be fine ice. You should not stop in large solid ice fields.

Leaving the ice region is a dangerous and important issue it should be done from the windward edge during big swells. It is better to follow the path against the waves or swell, then hitting chunks of ice is less likely. It may be wiser in some cases to wait in the ice until the situation improves.

As we can see, navigation in the Arctic areas has significant and specific additions to traditional standards of navigation in normal conditions and in accordance with the requirements of the International Code for Vessels Operating in polar waters the need of the additional training for crew becomes apparent [11].

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UDC 621.3.095.1

IMPROVING THE EFFICIENCY OF SHIP RADAR SYSTEMS FUNCTIONING

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Shipborne radar polarization complexes (SRPC) are remote means that, using electromagnetic waves, ensure the safety of navigation in difficult atmospheric conditions using the information contained in the parameters of the radar signal, while [1-3]:

- amplitude and phase parameters of electromagnetic fields form video signals about navigation objects of radar observation on the indicators of the SRPK;
- when the navigation object is in the zone of atmospheric formation, a total video signal is formed on the indicators of the SRPK, from which it is necessary to select the video signal of the navigation object [1-5];
- the main the operational task of the SRPK is the navigation support of ships along the trajectory of their movement.

When solving this problem, it is necessary to ensure not only the requirements for the potential and informational capabilities of the SRPK, but also for the synthesis of algorithms for detecting and distinguishing signals by their polarization with

When the navigation object is in the zone of hazardous atmospheric formation (heavy showers, hail, snowfall, fog), the SRPK operating at one of the wavelengths used, according to their technical characteristics, cannot carry out polarization selection of the echo signal of the navigation object from the total echo signal of the navigation object - atmospheric formation (complex object) [6].

To solve the posed problem of polarization selection, four polarizations of an electromagnetic wave for radiation were used and an all-polarized antenna of the ship's polarization radar complex received an echo signal of any polarization with measurement of its energy parameters represented by the actual Stokes parameters. The echo signal of a complex object S_{ref} will be partially polarized, and the Stokes parameters S_{1ref} , S_{2ref} , S_{3ref} , S_{4ref} , allow determining the degree of its polarization at the location of the SRPK antenna only from the measured intensities. The Stokes parameters of a partially polarized wave can be grouped using a vector represented in matrix form [7-8]:

$$\left[S_{ref}\right] = \begin{bmatrix} S_{1ref} \\ S_{2ref} \\ S_{3ref} \\ S_{4ref} \end{bmatrix}, \qquad (1)$$

where

$$\left.\begin{aligned} S_{1ref} &= \bar{E}^2_{xref} + \bar{E}^2_{yref}, \\ S_{2ref} &= \bar{E}^2_{xref} - \bar{E}^2_{yref}, \\ S_{3ref} &= \bar{E}^2_{x'ref} + \bar{E}^2_{y'ref}, \\ S_{4ref} &= \bar{E}^2_{Rref} + \bar{E}^2_{Lref}. \end{aligned}\right\}, \qquad (2)$$

The first Stokes parameter S_{1ref} represents the total intensity of the echo of a partially polarized wave of a complex object and consists of the intensity of the fully polarized part of the echo S_{1refP} and the intensity of the unpolarized part of the echo S_{1refNP}.

The second Stokes parameter S_{2ref} indicates *the predominance* in the echo signal of a complex object of an electromagnetic wave of linear horizontal polarization $S_{2refLLHP}$.

The third Stokes parameter S_{3ref} indicates *the predominance* of an electromagnetic wave of linear polarization in the echo signal of a complex object with an inclination of the electric vector of the wave at an angle of 45° i.e. $S_{3refLP45^o}$.

The fourth Stokes parameter S_{4ref} indicates *the predominance* in the echo of a complex object of an electromagnetic wave of circular polarization of the right direction of rotation of the electric vector $S_{4refCPR}$ or $S_{4refCPL}$.

Since the polarization parameters of an electromagnetic wave are determined only by the amplitude-phase relationships of its components and are stored at the output of the all-polarized antenna of the SRPK when receiving a partially polarized wave, taking into account its decomposition into two polarization-orthogonal components with subsequent amplification and transformation of each of these components in its channel, then Stokes parameters can be represented in terms of the amplitudes and phases of the orthogonal components of the electromagnetic wave in the following form:

$$\begin{aligned} S_{1ref} &= E^2{}_x + E^2{}_y, \\ S_{2ref} &= E^2{}_x - E^2{}_y, \\ S_{3ref} &= 2E_x E_y \cos\Phi_{xy}, \\ S_{4ref} &= 2E_x E_y \sin\Phi_{xy}, \end{aligned} \tag{3}$$

where $\Phi_{xy} = \varphi_x - \varphi_y$.

Relations (3) make it possible to determine the Stokes polarization parameters of the echo signal of a complex object in any polarization basis, taking into account the known projections of the electromagnetic wave on the axis of the Cartesian coordinate system of this basis. The SRPK all-polarization antenna receives an electromagnetic wave of any polarization completely without polarization losses by converting two components of the electromagnetic wave at the output of the polarization separator (selector) into an electrical signal at once, the parameters of its polarization in the radiation mode and in the receiving mode are the same.

The process of polarization selection of the echo signal of the navigation object located in the zone of atmospheric formation (precipitation of the liquid and solid phases) is based on the difference in the degree of polarization of the echo signal of the navigation object and the atmospheric formation and consists of two stages.

At the first stage, a complex object of radar observation by an all-polarization antenna with controlled polarization SRPK is successively irradiated with electromagnetic waves of four polarizations - three linear and one circular (Fig. 1).

At the second stage, the echo signals of a complex object of a partially polarized electromagnetic wave are received by the all-polarization antenna *9* and through the polarization separator *6*, the switch of the receiving channels *11*, the receiving devices *13*, *14* are fed to the device *15* for obtaining Stokes parameters. Stokes parameters S_1, S_2 , S_3 , S_4 in device *16* form the degree of polarization of the echo signal of the navigation object and the degree of polarization of the echo signal of atmospheric formation, according to the values of which, on the SRPC indicator or on the computer display, an echo signal of only the navigation object or echo is observed -signal of atmospheric formation only [10].

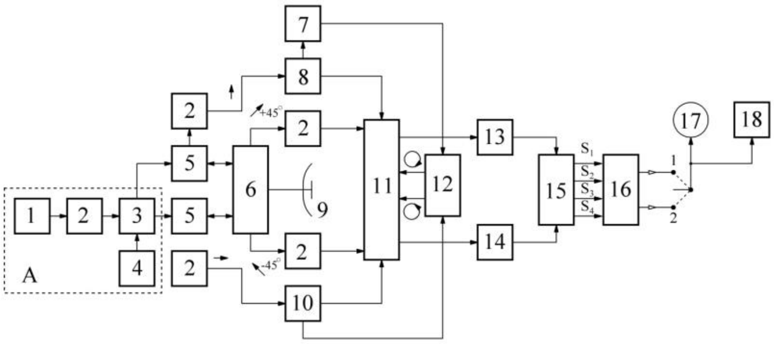

Fig. 1. Functional diagram of the polarization selection of the echo signal of the navigation object located in the zone of hazardous atmospheric formation according to the values of the degree of polarization of the electromagnetic wave

1 - microwave generator; 2 - circulators; 3,4 - device for generating an electromagnetic wave of a certain polarization for radiation, 5 - antenna switches, 6 - polarization separator; 7,8,10,12 - devices for receiving an electromagnetic wave of circular polarization in the receiving mode; 9 - all-polarized antenna; 11 - switch of receiving channels; 13, 14 - linear receiving channels, 15 - device for obtaining Stokes polarization parameters; 16 - device for obtaining the degree of polarization of the echo signal of the navigation object and atmospheric formation; 17.18 - indicator and display of the SRPK computer.

The presented results indicate the possibility of increasing the efficiency of the operation of ship radar systems using the difference in the degree of polarization of echo signals of objects when they are sequentially irradiated with electromagnetic waves of certain polarizations. According to the obtained algorithm, polarization selection is carried out on any of the four polarizations of the emitted wave or only on one of them, depending on the intensity of the process in the atmospheric formation.

The presented method of polarization selection of navigation objects located in the zone of atmospheric formations, using in as an informative radar parameter of the degree of polarization of an electromagnetic wave, it is implemented according to a special program of the ship's radar polarization complex on the presented functional diagram.

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PROBABILISTIC RISK ASSESSMENT IN DYNAMIC POSITIONING OPERATIONS

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The offshore oil and gas industry is associated primarily with high operational risks. Automated dynamic positioning of vessels involved in operations is one of the main methods of increasing navigational safety in this industry. Dynamic positioning operations contribute to high-risk tasks since incidents associated with the loss of a ship's position can lead to damage to the ship and platform, fire, significant environmental pollution or multiple casualties. For example, in 2005 the collision of a supply vessel with the Mumbai High North platform resulted in a fire and the death of 22 people. Fire losses were estimated at $200 million.

Dynamic positioning system – is a complex system designed to maintain required position and heading of the vessel or move the vessel on predefined track with slow speed. DP System contains seven components: thrusters, power generation and distribution, position reference systems (PRSs), sensors, controllers, human-machine interface (HMI) and DP Operator (DPO).

It is obvious that emergency situations inherent in dynamic positioning systems are primarily associated with the loss of position. Therefore, a DP Emergency is a system failure that results in an inability to maintain position or heading control (IMCA M103). The loss of position event can be a Drift Off or a Drive Off.

DP Drift Off is a loss of position caused by a partial or total loss of thrust leading the DP vessel/installation to drift. Drift off can be caused by a power system failure, thruster system failure, DP control system failure (DP control, reference systems or environmental sensors), fuel failure or DPO error.

DP Drive Off is a loss of position caused by an improper and undesired force applied to the DP system or a DP control system instability leading the DP vessel/installation to move on an undesirable direction (yaw, surge and/or sway). Drive off can be caused by a thruster failure (frozen pitch/RPM and/or azimuth), a reference system failure, a common failure on two or more reference systems, a DP control system failure, DPO error and sudden changes in weather/current.

Statistics made by the International Maritime Contractor Association (IMCA) on the basis of DP Station Keeping Reports shows that 'Thruster/propulsion' failure has the highest percentage (more than 30%) of main failure causes, which lead to DP incident, DP undesired event or DP observation, for last 5 years.

Some of the top secondary causes of failures are taken by "Human factors". For instance, all 30 causes reported in 2020 could be categorized as 'unintentional behaviour' for which there are four categories: 'sensory error'; 'memory error'; 'decision error'; and 'action error'. 'Decision' and 'action' errors led to proportionately more events and the loss of DP control than any others. 'Decision' errors are defined as errors where a clear decision was made to operate in a particular way and 'Action' errors − where a function or control was selected incorrectly.

In the context of ensuring the safety of operations, two types of risk assessment are possible: preliminary and operational. A preliminary risk assessment is made at the operation planning stage, considering the known conditions and factors. Operational risk assessment takes place in real time and takes into account changing conditions and emerging hazards.

The goal of this research is to create a decision support tool that will monitor the condition of the DP system, location of the vessel, and environmental conditions, and predict the most likely scenario based on previous states of the system.

Probabilistic risk assessment (PRA) is a structured method of quantitative risk assessment to navigate the design and operation of systems for achieving a certain safety or operational goal. Probabilistic Risk Assessment (PRA) has been utilized by NASA in a variety of space oriented projects.

Reliability of the system components, time interval available for reaction of Dynamic Positioning Operator (DPO), qualification and experience of DPOs, decision taking response time affect PRAs significantly.

Therefore, it is important to develop a method that can address time-dependent effects in PRAs and provide precise estimations. Dynamic PRA (DPRA) has been used to understand unintended time-dependent interactions between system components, including technical, environmental, and organizational factors, over time.

Different methods have been reviewed for considering these system interactions in risk assessment of which most are based on the dynamic/continuous event tree, dynamic fault tree, and dynamic Bayesian network methodologies.

In these methods, instead of a unique event sequence diagram (ESD) connected to specific fault trees (FTs) and BNs, multiple ESDs/FTs/BNs are developed for an incident scenario that can be updated over time according to the environmental and operational characteristics of the system.

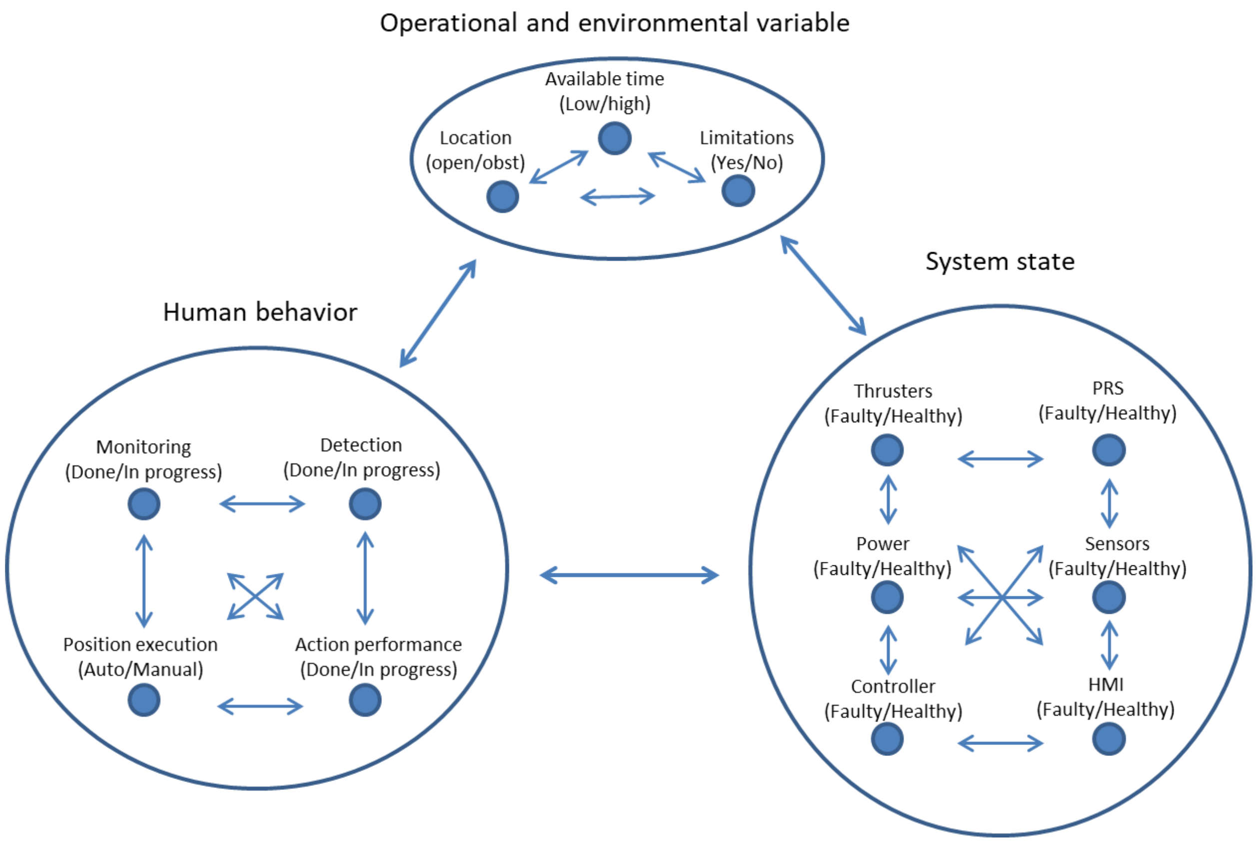

Fig. 1 – Agent based conceptual model of the DP system

Complex systems are mostly nonlinear and nondeterministic due to the heavily interdependencies among their elements. Considering nonlinearity and stochastic characteristics in risk modeling would enable a more accurate analysis and prediction of the complex system behavior. Such predictions can provide a valuable basis for decision support regarding the need for risk mitigation and accident prevention to operators. Generally, a complex system behavior is affected by human machine interactions, and operational and environmental conditions.

The agent-based conceptual model of the DP system is presented on fig. 1. The DP system has three main agents which are interconnected including “human behavior”, “system state”, and “operational and environmental variable”. The behavior of these agents and their interconnections with other agents is presented by edges that are governed by complex rules. The whole DP system is modeled by coupling the elements and edges governing principles and rules. DPO is excluded from agent “system state” to a “human behavior” as actions of DP operator require precise assessment and thorough consideration. For example, recognition of failure on early time intervals might save situation and avoid undesired consequences and in opposite, improper conclusions, and actions of the DPO may degrade entire DP System.

It is important to note that this is the most common model, which covers in general the great variety of DP operations. Level of complexity might be increased, and subagents might be added depending on the specific vessel and operation, which may increase the total number of alternative scenarios. Those scenarios are of different probabilities and the most probable needed to be considered first.

The objective of DPRA is to find scenarios with high risk level, e.g., scenarios with high probability and low consequences and scenarios with low probability and high consequences. In these cases, the objective function is equal to the risk level evaluation.

Conclusions and further research perspectives

In this study, three structured methods of quantitative risk assessment were analyzed: event sequence diagram, fault tree diagram and the Bayesian network.

In order to consider the effect of the Human error into the DP component, the Bayesian network for Human Risk Analysis was implemented into this study. As the Event Sequence Diagram includes both system failures and human errors, this method helps to combine Fault tree and Bayesian network together.

Proposed method of Dynamic Probability Risk Assessment allows predicting all failure scenarios based on agents and sub-agents model. By considering occurrence probability and consequences, it is possible to highlight most probable scenarios with high or low consequences. The probability is based on statistics of incidents and studies of human behaviors.

The method of real time scenarios assessment will be researched and proposed in further studies.

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ASSESSMENT OF THE FUNCTIONALITY OF USING VIRTUAL TECHNOLOGY BY MARITIME INSURANCE COMPANIES

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Marine insurance utilizes standard methods of insurance processes, which do not meet the challenges of modern Maritime Industry. The science is not intergrated well enough in the field of information technology to facilitate document management.

According to market participants, the existing system of marine cargo insurance is profoundly overloaded and inefficient, as it involves a large amount of paperwork that is exchanged between the shippers, insurance companies, ports, and so on. And the enterprises associated with cargo transportation take risks that could lead to exceedingly harmful consequences and immense losses.

The implementation of new technologies in maritime transport practice will significantly help the insurance industry to perform its functions at a highly competitive level.

Firstly, access to safe, decentralized transactions and accurate and timely notification of changes will improve aggregated risks and the ability to transfer large amounts of data based on more accessible and safe information about customer activity and the priorities of the third-party information services.

Secondly, the ability to integrate trustworthy third parties into the ecosystem will reduce the costs of their global platforms and implement more complex risk management of their products and services, including cyber insurance services.

As to innovative technologies development, business processes and activities, that are traditionally managed by insurance companies, they must be adapted to suit new digital models for insurance processes optimization.

Virtual automation is based on the principles of Blockchain technology - a distributed database that is shared among the nodes of a computer network in a way that makes it difficult or impossible to change, hack or override the system. This technology has many areas of application.

The main advantage of Blockchain in the marine realm is the capability of all parties to have a grasp of all financial facts and offers transparency based on their accounts. Members can track and record events and payments in any country associated with the insurance company [1].

A high level of transparency minimizes errors, attempted fraud and eliminates the necessity of additional essential data confirmation.

The application of virtual technology provides the insurance market with:

1) fraud detection and risk prevention;
2) digital claims management;
3) mobile, analytical system deployment;
4) the ability to monitor cyber liability.

To summarize, Blockchain technology reduces insurance processes risks, creates large decentralized databases with access to information for all participants in insurance transactions, acts as a guarantor of trust due to its properties.

The disadvantages of a decentralized database include the possibility of failure of the database or slowdown by reason of a significant increase in the number of executed transactions.

Analyzing the number of ships in the world fleet according to UNCTAD 2020, we can infer that this problem will not yet affect marine insurance companies and their customers, because now the number of world fleets is more than 50 thousand ships, that means that even if all vessels were insured simultaneously, the system would work in a proper and stable-way [2].

According to the research into feasibility assessment of using virtual technology by marine insurance companies, the approaches by insurance companies to optimize insurance processes are justified, which will enhance the work of marine insurance companies and bolster their capabilities.

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UDC 656.614

DEVELOPMENT OF THE CONCEPT OF INFORMATION SECURITY ON VESSELS AND IN SEA TRANSPORT COMPANIES

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It is known that a typical modern vessel uses a distributed network of connected and interacting electronic and computer devices that have access to the internet and provide settlement, navigation and repair operations, as well as data exchange with the external environment [1]. Examples of ship systems that are monitored and controlled through the use of information technology are: steering devices and propulsion, navigation aids, SPP service systems, ballast and fire protection systems. The processed results of measurement of parameters (rate, speed, temperature, pressure, consumption and quality of fuel and lubricants, etc.) are sent to storages and databases, and then transferred to shore services.

But at the same time, forms of unwanted, advertising and malicious software (SW) are being worked out and developed all over the world, which are integrated into the functioning of systems in order to intercept, steal and destroy valuable technical, economic and personal information. The most dangerous of these are the Trojan virus, publicity and disguise programs [2]. Examples include hacking attacks on Maersk systems in 2019, which resulted in a loss of about 300 million USA dollars. The company said that the NotPetya virus, which affected multinational companies, caused system interruptions that resulted in "significant business interruption" and prevented the processing of documentation for several days [3]. Also, there is a well-known incident with the hacking of data of the State Shipping Company of the Islamic Republic of Iran (IRISL) in 2011, in which the organization lost the available geolocation data for all 170 vessels, which also emphasizes the importance of the organization of information security (IS) [4].

Along with the development of harmful SW, new technologies are being created to organize the protection of confidential data. The most popular solutions in this area include data leakage prevention systems (DLP) and various methods of quantum cryptography. Work is underway in both the technical and legal segments, which is reflected in the improvement of domestic and foreign regulatory grounds. In particular, a number of legislative acts are being formed (Law of Ukraine of 05.10.2017 № 2163-VIII "On Basic Principles of Cyber Security of Ukraine", materials of the 40th session of the Committee FAL 39/WP.8, FAL 40/9, FAL 40/9/1, FAL 40/INF.5 and Resolution A.1098) on various aspects of the protection of sea transport networks from cyber threats. As an example of standardization of targeted and organizational measures to ensure IS, it should be noted the creation of BIMCO and ICS Union to combat cybercrime [5]. However, these solutions have a number of significant drawbacks. They are not universal and do not allow to take into account the specifics of various existing systems.

The analysis of the peculiarities of the data usage on vessels and in shore companies, as well as the existing precedents of hacking confirms the urgency of the problem of providing IS and developing new methods and models of secure access to these information resources.

It should be noted that the growing demands for IS form a stable trend, which consists of the systematic development of models for assessing the risks of hacking systems and requires those who make management decisions, develop and use the following actions to ensure information security:

- counteraction to threats of penetration into control units and modules of systems;
- organization of secure use of electronic information exchange subsystems;
- preventive assessment of the level of threats to the integrity, confidentiality and preservation of information used;
- encryption of transmitted data over open and closed communication channels.

The paper considers the analysis of IS threats to the service ergatic systems (SES), whose feasibility is eliminated with the help of a formalized discrete Harrison-Ruzzo-Ullmann (HRUA) model. It is justified due to its simplicity, clarity and flexibility. This model was adapted to the specific conditions of SES operation and a concept was developed, which includes separate stages, including: preventive identification and formalization of the most critical and vulnerable components of systems, assessment and analysis of system hazard risks, development of threat and attack models, integration of data protection, adaptation and improvement of existing intelligent methods of cybersecurity to the specifics of a particular SES, the formation of an integrated indicator of the level of IS SES.

To adapt the formalized discretionary model HRUA for SES, we introduce the following notation:

- W_{sb} – many entities (sea agents, technicians, guest users) that provide access to SES;
- O_{ob} – a set of all possible objects to which the user of SES gets access, and each object with W_{sb} is a part of O_{ob};
- $A = \{A_1,\dots, A_n\}$ – set of all possible access rights to SES (read – rd, write – wr, execution – ez, delete – del, save – sw, change – mod, create – cr, export – ex , search – sr);
- $S_{cn} = W_{sb} \times O_{ob} \times A$ – integral space of admissible states of SES;
- M_r – matrix of access rights, which allows you to display the ratio of current access rights of all eligible SES entities to its objects. The rows of the matrix correspond to the subjects, and the columns correspond to the objects;
- $M [w_{sb}, o_{ob}]$ – cell of the matrix of access rights to the SES, which contains a set of possible access rights of the selected subject of the SES to its object;
- $C = (W_{sb}, O_{ob}, M_r)$ – current state of the system.

The behavior of the system over time is expressed by transitions between all its possible states, which are carried out by adjusting the values of the matrix M_r by using commands of the conditional-production type:

The command ξ $(p_1,\dots, p_k)$ {If "A_1 is in the cell" $M [w_{sb1}, o_{ob1}]$) & (A_2 "is in the cell" $M [w_{sb2}, o_{ob2}]$) &… & An "is in the cell" $M [w_{sbn}, o_{obn}]$, then "execute" (elp_1, elp_2,… elp_n), "fix state" (T_{log}),
where ξ is the name of the command used from the allowable set of size m, defined by the semantics of the system $S = \{\xi_1 (x_1, ..., x_k), \xi_2 (x_1, ..., x_k),\dots, \xi_m (x_1, .. ., x_k)\}$.

p – input parameters of the command, which are unique identifiers of subjects and objects of SES.

elp – valid elementary operations:

- cns, <creation of a new subject W_{sb}>;
- cno, <create new object O_{ob}>;
- adso, <adding the subject W_{sb} rights in relation to the object O_{ob}>;
- chso, <change of the subject W_{sb} of the right in relation to the object O_{ob}>;
- dso, <removal of the right from the subject W_{sb} in relation to the object O_{ob}>;
- ds, <delete existing subject W_{sb}>;
- do, <delete existing subject O_{ob}>.

T_{log} – operation of creating an entry in the log pool of SES states in the format: "date-time-number-performed operations-current memory state-number of running processes". Braces are symbols of the beginning and end of the logical content of the command ξ.

Elementary operations elp_1 ... elp_n are implemented only if the entire list of conditions in the production unit <If ... Then>.

When describing the allowable elementary operations as a result of their implementation SES goes from state $C = (W_{sb}, O_{ob}, M_r)$ to state $C^/ = (W^/_{sb}, O^/_{ob}, M^/_r)$. In fact, the adapted model taking into account the specifics of SES is based on the aggregation of subsets of triplets of the form {"subject"-"operation"-"object"}.

The behavior of the system over time is considered as a sequence of sets of states {C}, each subsequent state is the result of applying some command to the previous one: $C_{n+1} = S_n (C_n)$.

As an example of constructing an access matrix according to the adapted discretionary model of HRUA, we give the following example. Suppose a typical SES has 4 different entities:

1. W_{sb1} – SES administrator, has full-featured access rights to all objects of the system;

2. W_{sb2} – sea agent, which has the right to create, read, write, delete and modify data in a number of functional forms;

3. W_{sb3} – a technical specialist who has the right to read, change and write data only to the forms of assessment of technical condition in the operation of sea vehicles;

4. W_{sb4} – shipowner who has the right to read, search and export data in all forms.

Let there be 6 different objects of the system:

1. O_{ob1} – graphical form of accounting for financial and production applications;

2. O_{ob2} – window of information retrieval and reference support of the stages of agency maintenance of the vessel;

3. O_{ob3} – window for the formation and management of document flow;

4. Oo_{b4} – graphical form of display of current and normative operational technical characteristics of vessel systems components;

5. O_{ob5} – a form of viewing logs of user interaction with the system in command form;

6. O_{ob6} – a graphical form of viewing, searching and exporting data according to selected criteria for a specified period of time.

The formed matrix of access to SES according to the HRUA model is given in table. 1.

Table 1. The formed matrix of access to SES according to the HRUA

	Objects						
Subjects		O_{ob1}	O_{ob2}	O_{ob3}	O_{ob4}	O_{ob5}	O_{ob6}
	W_{sb1}	rd, wr, ez, del, sw, mod, cr, ex, sr	rd, wr, ez, del, sw, mod, cr, ex, sr	rd, wr, ez, del, sw, mod, cr, ex, sr	rd, wr, ez, del, sw, mod, cr, ex, sr	rd, wr, ez, del, sw, mod, cr, ex, sr	rd, wr, ez, del, sw, mod, cr, ex, sr
	W_{sb2}	rd, wr, sw, del, mod, sr, cr	rd, sr, sw, del	rd, wr, sw, del, mod, sr, cr			rd, sr, cr
	W_{sb3}				rd, mod, wr,		
	W_{sb4}	rd, sr, ex	rd, sr, ex	rd, sr, ex	rd, sr, ex	rd, sr, ex	rd, sr, ex

For a given SES, the initial state $C_0 = \{W_{sb0}, O_{ob0}, M_{r0}\}$ is safe with respect to the right A, if there is no sequence of commands applicable to C_0, as a result of which the right A will be entered in the cell of the matrix M, in which it was not in state C_0.

If the right A is found in the cell of the matrix M_r, in which it was originally absent, this is a clear sign of the leakage of the right A. This is a criterion for assessing the safety of SES in this adapted model of HRUA.

Due to the fact that SES implements the concept of "man-technical system", where the role of man is given the main place, to ensure a comprehensive approach to the analysis of the level of information security of the system it is necessary to assess the human factor. One of the promising areas of development of the proposed method is the development of unified mathematical models of threats that allow to take into account sets of heterogeneous factors and perform numerical assessment of key characteristics of IS SES (analysis and assessment of information risks, information security, effectiveness of preventive measures and others) [6, 7].

The developed concept of IS SES can be used as a basis for various information systems to support the functional activities of specialists not only in maritime agency of ships, but also in any segment of service activities in maritime transport.

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CALCULATION OF THE EFFICIENCY OF AIS FOR CREATION AIS ATON NETWORK ON THE IWW OF UKRAINE

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ABSTRACT

Modernization of ports and fairways, as well as the latest advances in science in the development of new technologies and the growing demand for navigation services make it necessary to dynamically modernize navigation systems. It should be noted that the navigators during navigating in IWW, as a rule, prefer the pilotage as a method of navigation, which does not fully ensure the level of safety of navigation. The most constructive solution of the above mentioned problem is the conversion from the pilotage to the instrumental method of navigation, based on the using of E-navigation, as well as implementation of modern info-communication systems, such as virtual AIS AtoN, which allow to constructively link the structural elements of the transport process with a single architecture. In order to develop the AIS AtoN network, firstly, it is necessary to calculate the effectiveness of AIS, taking into account external circumstances that could meddle with the accuracy of the signal transmission. **Keywords:** effectiveness of AIS, AIS AtoN, IWW.

Defining the general matter

Waterway Administrations in European countries reguire remote monitoring and management of AtoN system to increase accessibility, force response times in dangerous situations, and improve maintenance planning. One of the most effective solutions is to use AIS technology, due to the fact that its equipment is standardized, and the AIS receiver must be established on all ships of the appropriate size. The aim of the research is to improve the safety of navigation by calculating the efficiency of AIS base stations for creation a reliable AIS AtoN network.

Previous researches analysis

A number of works which discuss the subject of increasing safety navigational level on the IWW were considered for the article.

The work [1] considers the prospects for the development of the Ukrainian section of the E-40 shipping route. The findings of the research foreground the necessity to create a common information space which will allow to solve a number of important tasks in the field of navigation in the IWW.

The source [2] describes the creation of the Aton network on critical sections of the Dnieper River, which allows remote monitoring of AIS AtoNs.

The work [3] describes the digital RIS index on the inland waterways of Ukraine in the process of introducing the information portal of the European Union.

The work [4] describes one of the methods of optimization the marine signalling system in the Venetian lagoon. The analysis aims at maximizing the safety level of maritime traffic in dangerous circumstances by development of electronic navigation.

The article [5] formulated the concept of creating a system of guaranteed safety for the control of maritime objects. The main idea is the automation of ship control and information processing.

Using electronic charts in integrated navigation systems in IWW is described in this article [6]. The results show increasing safety navigational level based the European system, where the ENC is, in its turn, based on the Inland ECDIS standard, serves as the source of basic navigation information.

For the development of shipping in IWW of Ukraine and for the high-quality implementation of the above mentioned goal, it is necessary to develop safety using modern technologies; first of all, we need to calculate the efficiency of AIS, which was not done in the above works.

Principal Research Data

AIS shore equipment is designed for monitoring; setting in the area of responsibility the necessary modes of operation of AIS class A, B and navigation equipment (AtoN). AIS of all modifications has access to VDM via FATDMA (Fixed Time Division Multiple Access) and RATDMA (Random Access Time Division Multiple Access) according to the recommendations of ITU-R M.1371-1 [7], IALA A-124 [8] and can work in a dependent (used in the coastal area under the control of the base station) and independent mode (used both on the high seas and in coastal areas), in self-supporting and in a duplicate configuration.

The line of coastal stations is designed in such a way as to ensure maximum coverage of coastal waters, port waters and approaches in working areas. In a particular case, the chain of coastal stations may consist of a single base station, which is installed in a small port located on an undeveloped coast with low intensity of navigation. In most cases, the chain of coastal stations consists of several base stations and repeaters, which cover the working areas of the coast for 60 - 300 miles or more. Let's consider the situation on the Dnieper River.

The table 1 provides information of the location of AIS base stations and their main characteristics on the Dnieper River.

The range of AIS stations can be calculated by the formula (1):

$$R = k \times (\sqrt{h_1} + \sqrt{h_2}) \tag{1}$$

Where R – the maximum range of radio waves in kilometers (excluding refraction); h_1, h_2 – height above the ground of the receiving and transmitting antenna in meters; k – the coefficient that takes into account the refraction, is taken in the range of 3.6 – 4.2 (when calculating the range of direct visibility, without taking into account the refraction, it is taken equal to 3.57).

The calculation of the efficiency of AIS base stations showed that the obtained data comply with requirements. However, it should be kept in mind that the range of shore stations at the height of the antennas from 100 to 250 meters is 55 – 80 kilometers, which is significantly exceeds the range of ship stations and AIS AtoN transponders. Therefore, vessels and buoys that do not have "radio contact" with each other can fetch the same slots for transmitting their messages within range of the one shore station. Moreover, in areas of intensive shipping when the AIS communication channel is overloaded, the vessel stations transmit part of their messages, where the most remote ship stations also transmit their messages in the slots. In this case, the shore station will receive superimposed messages and some information from the vessels will be lost. The longer the range of the base station and the higher the intensity of navigation, the more probability this situation will occur.

Table 1 – Location of AIS base stations and their main characteristics on the Dnieper River.

Name	**Locality**	**Km**	**Latitude**	**Longitude**	**Antenna height**	**Location height**	**River height**
1	2	3	4	5	6	7	8
BS1	Vyshhorod	871	50°35'22.20"N	030°30'19.80"E	25	100	98/90
BS2	Kaniv	724	49°45'45.00"N	031°27'48.00"E	25	88	87/80
BS3	Svitlovodsk	556	49°40'24.00"N 49°40'23.06"N	033°15'01.02"E 033°15'01.77"E	25	78	77/67
BS4	Kamyanske	434	48°32'49.80"N	034°32'25.20"E	25	67	62/51
BS5	Zaporizhzhia	305	47°51'46.80"N	035°05'24.00"E	25	44	47/13
BS6	Nova Kakhovka	93	46°46'30.00"N	033°22'30.00"E	25	14	13/0
BS01	Kyiv	851	50°23'52.20"N	030°34'24.00"E	34	97	90
BS02	Gnidyn	845	50°19'31.90"N	030°38'46.87"E	30	89	87
BS03	Stables	795	50°05'13.80"N	030°53'19.80"E	55	168	87
BS04	Rzhyshchiv	790	49°57'58.80"N	031°01'32.40"E	63	145	87
BS05	Cibli	710	49°59'16.80"N	031°34'31.20"E	58	113	87
BS06	Bubnivska Slobidka	704	49°43'06.00"N	031°42'06.00"E	50	86	79

Continue of Table 1

1	2	3	4	5	6	7	8
BS07	Svidivok	660	49°31'03.60"N	031°55'28.20"E	46	81	77
BS08	Moskalenki	655	49°26'59.31"N	032°29'42.06"E	42	119	77
BS09	Ratseve	592	49°07'42.60"N	032°44'00.00"E	34	97	77
BS10	Kelebreda	520	48°57'46.80"N	033°42'20.40"E	42	73	62
BS11	Kutsevolivka	505	48°52'09.00"N	033°49'34.80"E	51	77	62
BS12	Prydnipryanske	470	48°46'39.60"N	034°17'43.80"E	42	65	62
BS13	Taromske	410	48°26'46.20"N	034°46'23.40"E	30	161	51
BS14	Dnipro	380	48°26'00.60"N	035°07'31.80"E	56	68	49
BS15	Viyskove	354	48°09'16.20"N	035°10'00.60"E	46	109	47
BS16	Bilenke	270	47°37'25.80"N	035°03'04.80"E	38	28	13
BS17	Energodar	240	47°29'57.00"N	034°39'18.00"E	46	29	13
BS18	Oleksiyivka	209	47°35'30.60"N	034°14'12.60"E	32	27	13
BS19	Zolota Balka	178	47°22'29.40"N	033°57'24.60"E	40	89	13
BS20	Kachkarivka	152	47°05'48.00"N	033°45'03.60"E	35	66	13
BS21	Kairi	118	46°56'40.20"N	033°42'21.00"E	27	65	13
BS22	Poniatinka	65	46°44'58.80"N	032°54'40.20"E	27	39	0
BS23	Kherson	28	46°38'53.40"N	032°37'59.40"E	46	51	0
BS24	Kizomis	0	46°33'40.80"N	032°20'46.20"E	35	11	0

Conclusions and further research prospects

Consequently, it was concluded that in order to develop and implement the AIS Aton network in the Ukrainian IWW, it is necessary to solve the outlined problem. To prevent the loss of information by shore services in congested waters, it is necessary to use the following values or their combinations:

- Limit the range of shore stations by installing antennas at a relatively low altitude;
- Locate coastal stations with a significant (up to 50%) overlap of coverage areas with a corresponding increase in the number of stations;
- Areas of the water area with the most intensive shipping should be overlapped by working areas of 2 – 3 coastal stations at the same time;
- Apply the directed antennas that provide work of stations in the set sector on the section of shore stations;
- Install two base stations operating in adjacent sectors at one facility;
- Use a combination of an increased number of reception-only stations (with a small range or in a given sector) and a smaller number of stations with an extended transmission range.

For a more detailed study in subsequent researches, it is also necessary to calculate the potential efficiency of AIS under conditions of fluctuation noise exposure, as well as under the influence of an obstacle relief.

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PROSPECTS OF CONTAINER TRANSPORTATION DEVELOPMENT BETWEEN PORTS OF CHINA AND THE USA

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At present, about 90% of general cargo is transported by sea in containers, of which about 30% of such cargo comes from China. Considering these figures, we cannot but notice that the container fleet and the volume of traffic in standardized packaging has changed the world in the last century, and the world economy depends on the smooth operation of container vessels on the lines. Only one of the biggest players, namely A.P. Moller-Maersk, in 2020 alone transported 25.2 million TEU [1].

These figures prove, the slightest delay in the processing of containers in ports will lead to a crisis of traffic, and this happened during the crisis caused by Covid-19.

The situation leaves much to be desired. We are not going to focus on closing borders and reducing demand for certain groups of goods, although they have hit hard on the freight industry. But one of the main factors that caused the crisis in logistics was the shortage of containers. And in 2020, the situation with packaging for the transportation of goods became catastrophic.

This happens due to the outbreak of the Covid-19 pandemic and the closure of ports, stricter requirements for vessel control to enter the port, as well as even greater inequality in imports / exports between China and the United States.

Although China returned to full trade in May 2020 and began to increase imports of goods at a gigantic pace, the United States has become one of the most important markets for Chinese production. Ships loaded with containers from China filled the ports of the west coast of the United States, while trade between China and the United States was unbalanced. The fact is that the main US import market is not China. The biggest share of freight from the United States goes to the ports of Canada and Mexico – US nearest neighbors. At the same time, America has also established trade relations with China, but does not supply its goods.

Also, the difficulty the trade between the United States and China faces lies in the limit of the number of ships that can arrive from China to US ports and back. As it has been mentioned above, the ports of the west coast of the United States are overcrowded due to the influx of container ships, and the ports of the Caribbean and East Coast are limited, on the one hand, by the Panama Canal and, on the other, by the fact that they are too far from China by the Suez Canal-China route. For example, the capacity of the Panama Canal is 18.8 thousand vessels per year, which is the passage of a little more than 51 vessels per day, and this, of course, leads to the increased waiting time and long queues on both sides of the canal.

The passage of the container ship “NORTHERN JAGUAR” through the Agua Clara gateways is presented in Fig. 1.

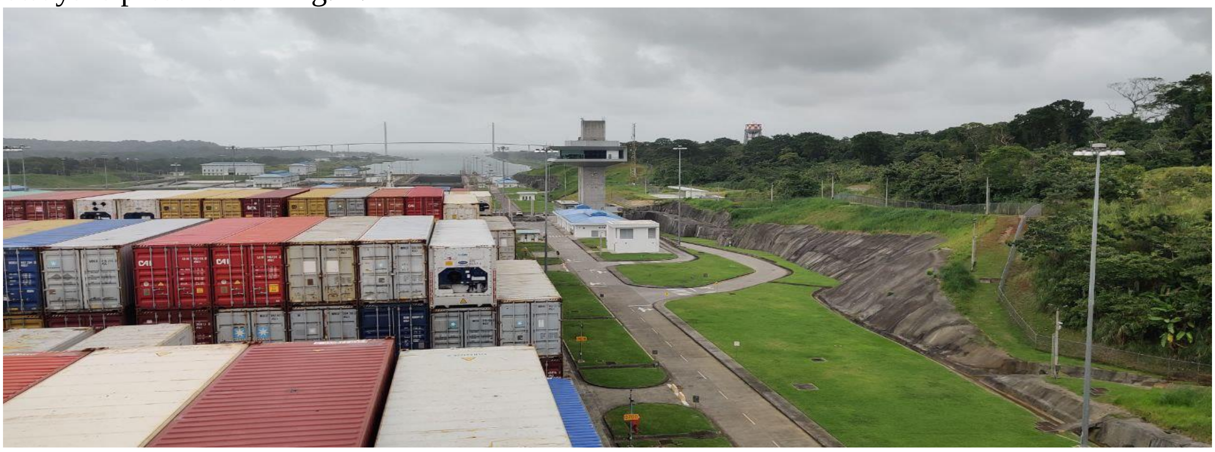

Fig. 1. Passage of the container ship “NORTHERN JAGUAR” through the Agua Clara gateways

After China's lift of the lockdown it increased imports of goods into the United States and the number of empty containers in ports, the United States simply do not have at least roughly comparable exports to China or the Far East. Also, the container operators themselves could not effectively, and in the right quantity, return the required volumes of empty containers to China, which led to a sharp and extreme increase in freight rates for the transportation of one 40-foot container from China to the United States. Based on various sources of freight of one container reached 10 thousand dollars in the spring-summer of 2021 [2, 3].

Assessing the loading of US ports, it should be noted that after the return of supplies from Asian ports to the US, imports into the US in the first eight months of 2021 jumped by 23% and amounted to 1.85 trillion dollars. USA Shipments from China rose 21% amid tariffs imposed by the administration of former US President Donald Trump on Chinese goods. And the biggest blow fell on the ports of Los Angeles and Long Beach (Fig. 2). These ports daily expect mooring of more than 40 container ships, while before the pandemic period there rarely formed a queue of one or two container ships.

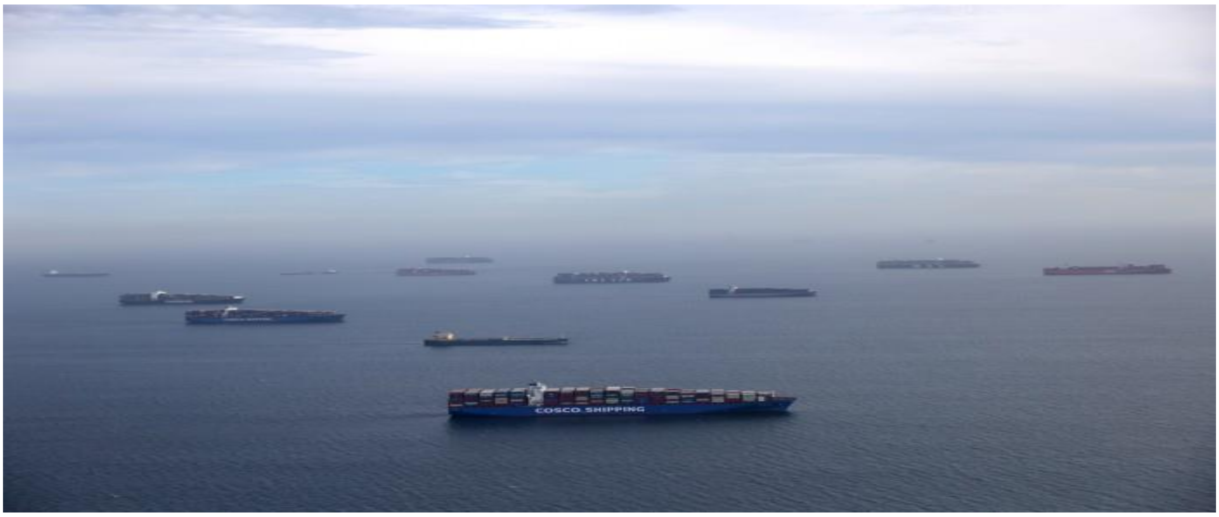

Fig. 2. Queue in the port of Long Beach, Southern California.

Due to long delays in the supply of goods, the US government is concerned about the situation and has already taken measures to increase the scale of processing, which leads to a positive dynamics of the situation.

Namely, companies will work to reduce the time during which cargo stays in these ports. FedEx aims to double the nightly handling of containers by optimizing the use of railways. Walmart plans to increase night operations to increase throughput by as much as 50% [4].

The port of Los Angeles will continue to operate at full capacity even at night and on weekends, while the port of Long Beach only introduces round-the-clock cargo operations. These two California facilities together account for about 40% of the containers delivered by container vessels to the United States. The International Union of Coastal and Warehouse Workers has stated that its members are ready to create additional changes.

This is already bearing fruit, as the port of Los Angeles became the first port in the Western Hemisphere to reach 10 million TEUs in one year. This result was achieved in the 2020/2021 financial year and was recorded on June 10, 2021. In the port of Los Angeles, the ship "Amerigo Vespucci" was loaded with a 10 million container owned by CMA CGM. The port noted that the rise in consumer demand caused by the pandemic began in the summer of 2020. At the same time, retailers' stocks began to be actively replenished and e-commerce revived, which contributed to the rapid growth of imported freight traffic. At the seaport itself, the emphasis was on digitizing supply chains, investing in infrastructure, and building relationships with business partners. By the end of 2020, 9.2 million TEUs were processed, which was the fourth result in the history of the port. The previous record of annual processing in the port was achieved in 2018 and amounted to 9.5 million TEU.

Analyzing data on Chinese ports, we also see positive statistics in the post-war period.

According to the China Ports & Harbor Association, between March 2 and 8, 2021 alone, the capacity of China's eight major container ports increased by 9.1%. In the ports of Dalian, Tianjin, Qingdao and Guangzhou, the growth rate increased by 10%. It is noted that the overall growth rate of container processing in the port of Bohai-Rome is higher than in other coastal ports. In January 2021, the world's largest container port, Shanghai, handled more than 4 million TEUs of containers, according to data published by the port operator SIPG [5]. The port's turnover in January exceeded last year's figure by 12%, according to TASS. Since October 2020, traffic through the port has increased by more than 10% in four months. Despite a nearly 7 percent drop in turnover in the first half of the year, the Port of Shanghai managed to break the 2019 record for the year as a whole.

In May 2021, the second largest container port in China and the third largest in the world, Ningbo-Zhoushan, exceeded about 2.85 million TEU, which is 14.5% more than a year earlier. Traffic through the deep-sea terminals of Qui-Qing Port in Hong Kong in December and January 2020 increased by: + 10.2% and + 11.1%, respectively.

But due to repeated outbreaks of coronavirus infection in Chinese ports, the problem with the cancellation of measures by ships remains acute. Although Chinese governments and container operators are trying to mitigate the crisis by using alternative ports. From May 23 to June 26, 2021, 135 measures at container services in the ports of South China were canceled. Most calls - 128 - were canceled in the port of Yantian, which limited the volume of operations due to the outbreak of coronavirus and still has not coped with congestion. In the port of Nansha, which is a reserve for the port of Yantian, canceled only 2 berths on the service Asia - Middle East and an additional 32 events. The port of Sheko was also an alternative to the port of Yantian during the crisis. During this period, 4 shipping calls to the port of Sheko were canceled [6].

Observing this situation, any professional in the maritime field or freight forwarder understands that the aggravation of this situation could lead to a greater crisis of container traffic. After all, with the increase in the price of freight containers, the price of the consumer goods themselves will not be able to remain unchanged for long. That is, all this can lead to the same sharp increase in the price of all consumer goods or to the fact that shippers and freight forwarders will boycott, because based on the latest news from operators such as Maersk, MSC, COSCO, EVERGREEN, CMACGM, they buy a record number of new containers to cover the created deficit. But even increasing the volume of available containers that will be available to container operators does not remove the problem of canceling ships in ports, due to outbreaks of coronavirus infection.

However, even here there are ways out of this situation, namely: the development of processing and approval of the cargo plan, approval of the successful implementation of the fastening and connection of refrigerated containers exclusively electronically. Minimizing the contacts of ship crews with port workers and even the complete exclusion of such a possibility, control of cargo operations only from the ship's bridge and the prohibition of the crew outside the superstructure can stop the crisis of container traffic and, soon, normalize and establish uninterrupted operation of container ships between levels [6, 7].

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METHODS OF TEACHING MARITIME ENGLISH

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The traditional teaching approach is always lecturer-centered with students or learners in a passive position. This will lead to low study interests of trainees and inactive atmosphere in a classroom and makes teaching inflexible and boring, which will naturally result in bad teaching effects. We do everything to heighten the English level of students, to improve the education system and teaching method.

For effective language teaching and learning, it is necessary to take the best methodology in order to be able to create tasks appropriate to their students' learning needs, to develop training courses, communicative competence and to implement a syllabus that meets the requirements defined by the STCW 1995 Code.

Teaching marine English covers many spheres - geographic navigation, celestial navigation, navigational equipment, meteorology, cargo stowage, marine law and regulation, ship handling, marine communication and so on. There are so many vocabulary units and terms in each course, their theory and principle are different. Its vocabulary and writing forms are different from general English standards. It requires a long time to have a good command of them. When explaining professional content, it is hard to arouse the interest of students and ~~gave~~ give them a heavy impression without professional knowledge, without cases, without incident, and all of them require a long-time study and sea experiences. Learners need to be competent in each of these skill areas in order to combine and utilize language systems effectively.

Successful knowledge requires more than the ability to integrate language systems and skills, however. They need to know the conventions for using the language in specific situations (e. g. using the telephone; writing telex) and, as it is so important, they should know some strategies for coping with misunderstandings in the event of communication failure. Teaching needs to reflect genuine use of the language so that the student is equipped for communicating in "the real world". [3]

When the new material is explained, students may not understand everything, every word, they can be helped through the use of pictures, diagrams and gestures. What forms a very important part of developing the skills, is their abitity the language in real-life situations. The advantage of the active teaching method has been recognized in the world pedagogics for many ten years. One of the best method of teaching is learning by doing the main teaching strategy mean includes students' activity, when they learn in the process of working. Such learning may be provided under the trainer's instructions (e.g. traditional relations of master and apprentice or assistance of scientific adviser), on relative's or elder friend's advice or in conditions of self-education. Generally, learning process in any fields is as follows: active knowledge may be gained only through learning by doing, although "doing" shall be understood not in the literal, but wide, generalized sense. For example, in natural mastering of native or foreign languages (when students learn through speaking, i.e. "texts making"); the same is in learning of reading and writing (only through "doing"); the same is in psychology and mathematics, as students do not really learn the things which they listen to, but do them by themselves [4].

To be able to develop lexical and grammar skills e. g: accidents and incidents on board the ship, ship handling, drills and etc. it's also very important to understand how one should behave in an emergency. To develop practical skills, the one of the best methods of teaching is learning by doing, which includes students' activity, when they learn in the process of working. To develop the practical skills of immediate response and reaction in any professional situation, it's recommended to take actions in drills. Drill is a creation of a real situation, where the experience of the English teachers and technical instuctors should be integrated. It is necessary to get cadets familiarized with sufficient information and instructions, in order to teach them to communicate with other people on board on elementary safety matters and understand safety information symbols, signs, alarm signals and etc.

The "integrated learning" and "learning by doing" methods will help to develop competencies which enhance individual and organizational performance and meet the requirements defined by the STCW 1995 code.

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CONTENT-BASED BLENDED LEARNING APPROACH FOR MARITIME ENGLISH

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In maritime business, in general, English has become the most dominant and leading means of communication, crucial device for survival in dangerous situations, a vital and sufficient tool for successful teamwork, for gaining and maintaining situational awareness of every seafarer and on-board safety culture by the shipping company, for solving problems and taking decisions.

Blended learning is an integration of a Computer-based Training (CBT) and other teaching Curriculum) media, such as teacher-led class, group study and practical training. Since each teaching approach has both advantages and disadvantages, they can compensate with each other by blending different teaching approaches within a single curriculum. Some aspect of Maritime English skill requirements, such as vocabulary acquisition, listening practice, and grammar study, will lend themselves to learning by CBT. On the other hand, speaking skill acquisition requires the interaction of learners in the classroom setting. [1]

Maritime English program at NU OMA follows a content-based blended approach where the practical "onboard training through professional English" is integrated with face-to-face classroom sessions and e-learning.

CLIL (Content and Language Integrated Learning) is an educational approach in which various language-supportive methodologies are used which lead to a dual-focused form of instruction where attention is given both to the language **and** the content. "Achieving this twofold aim calls for the development of a special approach to teaching in that the non-language subject is not taught IN a foreign language but WITH and THROUGH a foreign language" [2].

This abstract offers a conceptual framework based on 4 Cs: **C**ontent, **C**ommunication, **C**ognition, and **C**ulture.

Content in CLIL setting should be thematic, cross-curricular and have a focus on ways of preventing accidents at sea through expert analysis and investigation of every case.

These 4 major components will help senior nautical students to develop their professional skills through understanding, analyzing, evaluating authentic real-life case histories from official resources such as the Marine Accident and Investigation Branch (MAIB), Videotel, authentic audio and videoprogrammes and the Mariners' Alerting and Reporting Scheme (MARS).

The objective of a specific-domain vocational CLIL is to develop English competence so that they are able to carry out specific task-based functions which might range from giving orders to subordinates/ following orders from their suprvisors of different nationalities to monitoring, accessing and processing information, analyzing near misses, incidents and accidents causes orally (with agents, stevedores, surveyors etc.) and in writing (in accident/incident reports, sea protests, routine correspondence, etc).

Where applicable, this is carried out by content and language teachers working in tandem. It marks a shift away from existing practice such as teaching language for specific purposes (ESP) towards practice which seeks to achieve the same objectives through a closer link to content teaching and learning. In many marine institutions English language teachers are the only source for the students to acquire both content and language skills. So, it is common that senior cadets learn through the CLIL language and the first language, so that they can carry out specific tasks in diverse contexts.

The 4Cs do not exist as separate elements connecting the 4Cs into an integrated whole. It is fundamental to planning a curriculum.

This table illustrates the competences which can be acquired by a seafarer as a result of amalgamation of 4 Cs in one system. [3]

Language skills	Task descriptions and focus
Reading	1. Reading for gist 2. Reading for details or global understanding
Listening	1. Understanding for gist 2. Speech recording 3. Note-taking
Speaking	1. Social interaction 2. Discussion 3. Solving professional tasks 4. Role-play
Writing	1. Filling in a chart 2. Making up reports 3. Business correspondence

To sum up, exploring how cognitive elements interconnect with content will determine the type of tasks which will be planned. Relating cognition to communication will demand careful consideration of classroom activities to ensure that students not only have access to the content language but are able to carry out the tasks and solve the professional problems on operational and management levels.

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IMPORTANCE OF MIXING PROFESSIONAL AND GENERAL ENGLISH AT THE LESSONS OF ENGLISH

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In today's world, multilingualism is becoming more and more important. In addition to opening up employment opportunities, being able to speak a foreign language helps to make a real connection with people and to know more about diverse cultures, places and lifestyles. The more proficient you are, the better you can express yourself. [1]

English is the most internationally popular language, which makes it the most dominant language in the business world. Even if you have a good level of basic English, learning business English will give you the chance to demonstrate a wider professional vocabulary which can result in new opportunities in your career.

Studying business English allows you to develop English language skills that are useful in an office or other business environments. By understanding the communication skills needed in the workplace, you can gain the confidence to build strong relationships with your colleagues and clients. [2]

You will have an easier time getting promotions. Even if you start at the bottom of a company where knowing English is not that important, you will have an easier time getting promoted if you know English. Many managers, executives and other important company members must know English.

You will be able to communicate better. You will have the chance to work abroad. If you've been hoping to move someplace that speaks English, getting a job there will be important. Knowing English will give you an important advantage when you are applying. [3]

However, it is not just enough to learn professional English words and terms in order to succeed in business. Professional English is focused on communicating clearly in a business setting, with co-workers, customers, your boss or anyone else related to work. You need to acquire English reading, writing and speaking skills independent of your professional sphere. The basics of English are the same whether you are talking about the great movie you saw yesterday or the important meeting you have coming up.

That is why it is important to teach students professional English. Many large businesses now require that you speak English, especially if they deal with any international customers or partners. Knowing English will open doors for you to better careers and make you stand out as an applicant. Learning professional English is a great way to master English for advanced learners.

It is good practice to make English lessons more diverse. While paying all their attention to the professional patterns, students may relatively quickly forget some basic techniques.

Thus, grammar and casual vocabulary skills are vitally important to update and keep at a decent level during the studies.

Moreover, as our experience has proven, it can be difficult for students to stay focused only on professional topics. They become bored and tired of so much new information in a foreign language. Some casual themes for conversation, audio and video tasks or grammar review could be a good balancing and relaxing means of language studying.

Besides, students may be given some freedom in choosing the tasks for their more effective work. They even find their own video materials or listening activities, share them with their class and discuss. In such a way it would be easier for them later to take part in professional negotiations and socialization.

Students tend to study better if they are interested in the subject. So, teachers must do their best to help students to get involved in the studying process. It is vital to establish the right balance between the things they should learn during their academic year and activities which will favor their engagement.

Even the studying process of professional topics and terms is possible to turn from a boring activity into entertaining productive work. Students may practice their new vocabulary by trying to explain the meaning of the words, while their class-mates will try to guess the term. Another option is to make sentences with these words that were offered.

Thus, the general practices and exercises which are usually applied for basic English studies can also be used for professional purposes.

Students should not just learn some professional topics by heart, but also understand the scope of their application. They should learn how to express their professional thoughts and ideas using basic communication skills. Without constant practice and language review it will be quite difficult for students to make up their mind. Even if students know the specifics of their specialization well enough, they may be unable to formulate it in a decent way.

To sum it up, teachers should try to find the best way of promoting students' knowledge in professional sphere without losing their basic language skills.

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LEGAL ASPECTS OF SUPPORTING SEAMANTS IN UKRAINE

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One of the most influential and necessary levers of state influence on the country's economy is taxes, thanks to which budget funds are accumulated at the local and state levels to carry out the functions and tasks assigned to it [1].

For the state, seafarers are one of the most important and largest sources of foreign currency, which enters the domestic market, which in turn contributes to the maintenance and growth of the economy. There are about 200,000 Ukrainian sailors in the world, who bring to the country about a quarter of the total currency of "workers" (about $ 3 billion a year). But should sailors pay taxes and to what extent if they are not protected by the state and cannot wait to retire after completing their careers at sea? This question is very controversial among all seafarers, but any legal question has an answer and it is no exception [2].

The relevance of the topic lies in its prevalence as a seemingly open debate among seafarers for many years and hence the need for clear answers to a common understanding of this important topic and to promote interest in it as a subject that requires observation in the legal field and needs modern changes and improvements.

According to the current legislation, namely Art. 13 of the Tax Code of Ukraine, income received by a resident individual from sources of origin outside Ukraine, is included in the total annual taxable income, except for income not taxable in Ukraine in accordance with the provisions of this Code or international agreement, the consent of which is binding provided by the Verkhovna Rada of Ukraine. Amounts of taxes and fees paid outside Ukraine are credited when calculating taxes and fees in Ukraine according to the rules established by the PC [3].

Any income received is subject to taxation, whether it is a salary, income from the sale of property or even, for example, borrowed money and not returned on time. Thus, every citizen of Ukraine, having received income, must pay personal income tax (PIT) at the rate of 18% and military duty (for the period of the anti-terrorist operation) at the rate of 1.5%. Income received from sources of origin outside Ukraine, from the point of view of the legislator, is also subject to taxation. The Tax Code of Ukraine stipulates the obligation to submit an annual declaration of property and income (tax return). The tax return is filed by May 1 of the year following the reporting year.

The tax return can be filled in and submitted both personally by the seafarer and his representative - the person to whom the notarial power of attorney is issued. In addition, the tax return can be sent to the tax authority by mail with a notice of service and a description of the attachment. There are also many online services available today. In particular, the electronic office of the taxpayer, which allows you to file a tax return online.

International agreements (conventions) on avoidance of double taxation have been concluded between Ukraine and a number of states. The conventions are applied in order to avoid double taxation when collecting income taxes. As of January 1, 2020, there are more than 70 countries with which Ukraine has signed such conventions, including such large ship-owning states as Greece, Germany, Singapore, China, Korea and others. If the employer has paid taxes for a seafarer outside Ukraine, the amounts of such taxes may be included in the calculation of taxes payable by the seafarer in Ukraine. The specific procedure to be followed for the application of the right to avoid double taxation is set out in the convention with each individual country. As a rule, it is necessary to obtain a certificate from the relevant foreign body on the amount of tax paid abroad, as well as on the base / object of taxation. This certificate is subject to legalization in the country of payment of taxes and after its submission to the tax authorities in Ukraine, the amount of tax paid in another country can be credited in Ukraine. If the rate at which taxes were paid abroad is less than in Ukraine, the difference is payable in Ukraine.

On April 28, 2020, a new version of the Law of Ukraine № 361 - IX "On Prevention and Counteraction to Legalization (Laundering) of Proceeds from Crime, Financing of Terrorism and Financing of the Proliferation of Weapons of Mass Destruction" entered into force in Ukraine. The new rules stipulate that from now on not only banks but also insurance companies, auditors, realtors, lawyers, notaries, accountants, consulting firms and other entities (which are not financial institutions but provide separate financial services) are obliged to verify the legality of funds origin of their clients and prevent illegal financial transactions. Thus, when a seafarer puts money in his account, the bank must verify the legality of the origin of these funds - that they are not the result of illegal activities. At the same time, it is necessary to remember that the above-mentioned Law is aimed at preventing illegal financial transactions and should not create additional inconveniences for law-abiding citizens.

Payment of personal income tax does not entitle to a pension. Personal income tax and military duty are not those fees and charges that entitle you to a pension. Pension reform in Ukraine now provides for insurance instead of length of service. A person who is paid a single social contribution (SSC) in the amount of 22% of the amount of income is entitled to a pension. If a person works in Ukraine, the obligation to pay SDRs for him rests with the employer. If a person is not employed in Ukraine (as in the case of seafarers working under a foreign flag), there is an opportunity to pay for themselves SSC, for which it is necessary to enter into an agreement (by applying to the tax authority at the place of residence). You can calculate the amount of the monthly contribution from the actual salary received or from the minimum (set by the state). In the latter case, the amount of tax as of the current date will be UAH 1,100 per month [4].

So, summing up, we can say that the system of taxation of seafarers in Ukraine is not properly developed and instead of motivating seafarers to pay taxes, it, on the contrary, promotes and motivates them to look for ways of evading them.

It would be optimal, given the world experience and the experience of Ukraine itself (until 2004), to exempt from taxation the income of residents who work on board the vessels outside Ukraine for at least 183 days a year. However, taken into consideration difficult budget situation, such a solution (full exemption from taxation) may not seem fair to voters.

Therefore, it may be time to apply those positive changes that have been developed in the field of a single tax for entrepreneurs, to seafarers. It may be worth exempting them from income tax, giving them the right to pay a minimum single tax at the rates set by local councils for entrepreneurs who provide household services: from 1 to 10% of the minimum wage. There may be many solutions, but for them to take effect, the young and progressive generation of seafarers needs to be involved in these processes, as well as the good work of honest and qualified legal professionals [5].

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ACHIEVEMENT OF PROFESSIONAL COMPETENCE VIA EDUCATIONAL APPROACH "EDUCATION, TECHNOLOGIES AND SELF-DEVELOPMENT"

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At the present stage of development of the maritime transport industry, there is an active dynamic of technological progress aimed at improving safety, efficiency and economic benefits by reducing human resources. In such conditions, the level of requirements for the competence of seafarers increases, which is reflected in the selection of Crewing companies specialize in the selection of seafarers for their further employment. Every year the set of necessary minimum criteria changes and becomes more demanding. The following is a list of standard requirements:

- Availability of higher education in the relevant specialty;
- Availability of working documents, confirmations and certificates, US visas, with a margin of validity of at least one and a half years from the date of submission of documents;
- Experience in this position and on the appropriate type of vessel;
- References from previous jobs;
- Sufficient knowledge of English; the minimum required level depends on the position and is verified by tests and interview;
- Positive results during the interview with the captain as well as passing tests that confirm the level of knowledge (competence);
- No health problems;
- No criminal record, etc.

Work at sea is a constant confirmation of qualification at different stages of the professional path of each seafarer: obtaining higher education, working documents and certificates, passing the recruitment procedures, acquiring skills during the real voyage, regular inspections at sea (port, class, audits, etc.), as well as updating of documents and refresher course exams.

Thus, based on the known facts about the maritime profession, international conventions and resolutions, shipowners' requirements for crew training, tests and examinations related to certification, as well as taking into account the continuous development of the international maritime fleet, there is a desparate need for appropriate optimization of the educational process.

Despite the variety of courses and the amount of information presented in higher education institutions, to understand the importance of the educational process, the first-year students need to encompass this information.

Firstly, the modern educational process should be formed in accordance with the required level of qualification by such methods and approaches that would allow higher education students to acquire not only necessary theoretical knowledge, but also practical skills. For example, mastering the material in the "Navigation and Pilotage", "Ship Management", "MPZZS", "GMZLB" courses would be more informative and applicable if they were conducted immediately in the "shift" mode on the ship's bridge simulator. In this way, higher education students will gain deep understanding of exactly where and how this knowledge is applied in their future profession. [1]

Secondly, the scale of development of marine technologies today requires future professionals to be trained to work directly with any equipment and under any conditions. To replace the ship's crew in the port takes several hours, while the ship does not stop working and cannot postpone already planned operations (cargo, ballast, fuel ones, etc.). In other words, a new crew member starts working immediately, without time for adaptation and training, that is why "onboard training" should be implemented at the very beginning of training. In addition, it is desirable to introduce graduates to the equipment of various manufacturers used on ships of the international fleet.[2]

Thirdly, future professionals need to work out a habit of independent searching for necessary existing and new information. Because the seafaring profession is diverse, it is creative. Self-development is a necessary component of continuous professional development.

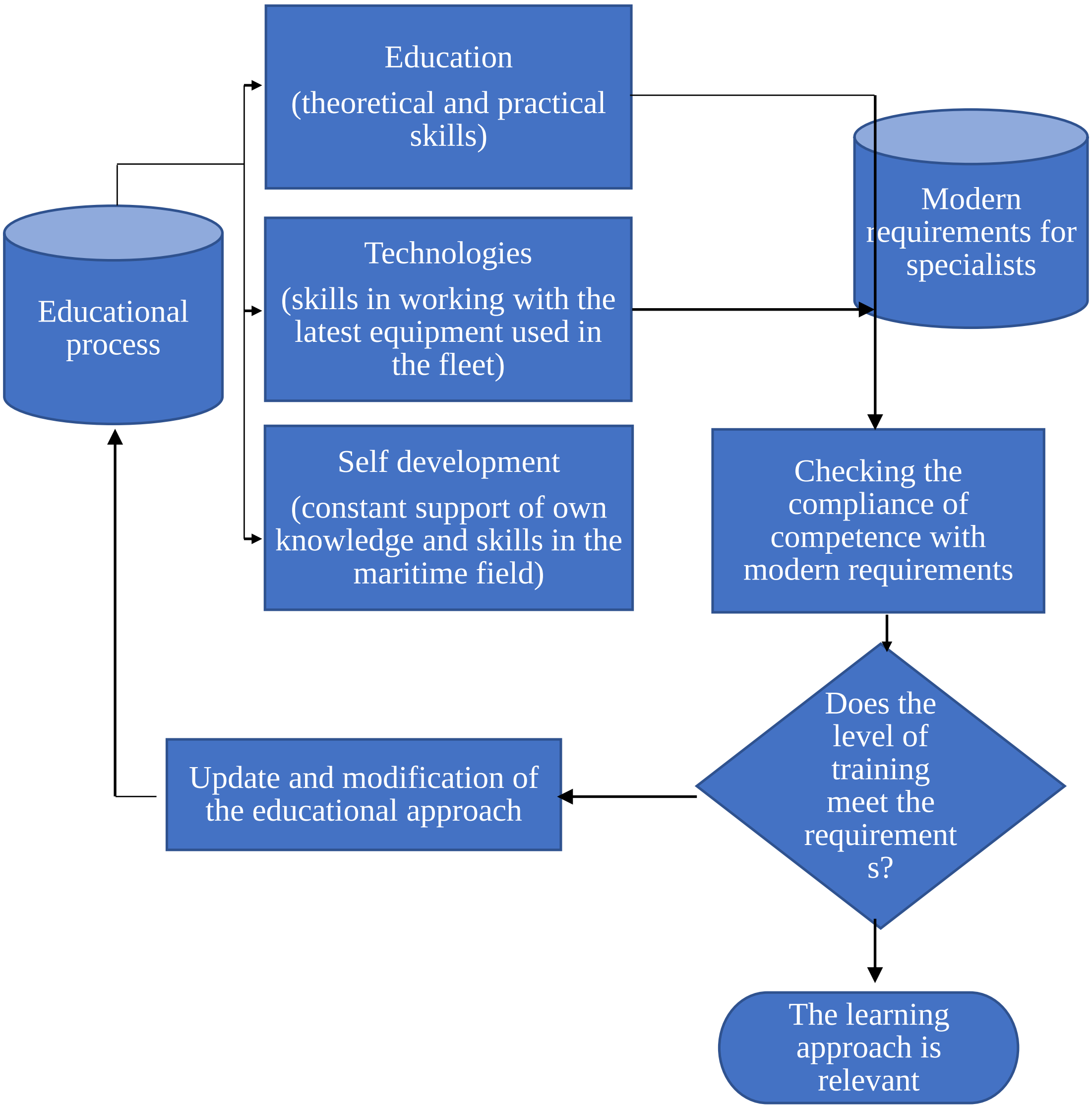

Fig 1. Block diagram of a simplified algorithm for constant educational approach

Nowadays, it is possible to get news in the marine industry virtually in any part of the world, so the desire to expand knowledge is always appropriate. [3]

The above mentioned three points can be combined in the educational approach "Education, Technology and Self-Development", which is based primarily on the requirements of the specialist in real time. The methodology for training qualified specialists in the maritime industry must be constantly updated. The simplified algorithm is shown in the diagram in Figure 1. Under these conditions, the future specialist will not only be more qualified, but will be protected from stress, which is provoked by the following factors:

1. Lack of knowledge, practical and theoretical.
2. Lack of sound assessment and understanding of the future profession, namely responsibilities and work style;
3. Inability to multi-task;
4. Lack of experience in performing tasks in a team;
5. Inability to adhere to subordination, etc.

Summarizing the given information, the lack of qualification training is a key destructive factor in shaping the professional path of seafarers. Thus, with innovative approaches in the educational process and the corresponding high requirements for future professionals, it is possible to achieve professional competence at a decent level, increasing the demand for Ukrainian professionals in the maritime labor market.

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ANALYSIS OF NAVIGATION DATA BY ARTIFICIAL NEURAL NETWORKS FOR DEVELOPMENT OF DECISION-MAKING SUPPORT SYSTEMS

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In difficult navigation conditions, there arise situations associated with multifactoriality [1,2]. The navigator experiences difficulties in such situations, especially if he does not have sufficient experience [3]. This happens when the situation that has arisen is close in its context to those ones that were encountered earlier, but in reality, differs in its parameters [4].

In such situations, the navigator has a high probability of error. Considering the limitations of the size of the locations and the ship's inertia, a tactical error while performing a maneuver can have negative consequences [5]. In order to prevent such incidents while sailing, it is necessary to create decision support systems. You also need to take into account the large amount of navigation data that arrive at the captain's bridge at the same time [6,7]. Such data are difficult to process in real time using standard statistical methods. To process them, it is necessary to use more complex systems that are based on the use of artificial neural networks.

Let us consider the implementation of this task in the form of a classification of the phases of a previously identified navigation situation in the port of Dover. The problem of comparing incoming navigation data with previously formalized hazardous situations associated with discrepancies with several ships is considered.

A method is proposed for using automated neural networks for processing a multifactor array of navigation data when performing complex maneuvers:

1. Give the priority of the operation of decision-making moments in taking into account ships - targets in the immediate radius, it is proposed to form the situation in the perspective of phases of events.

2. There are four phases of the situation and codes for training (Train) and control (Select) samples;

3. Consider the feature space for navigation data. To do this, build a graph of categories - scattering diagrams with overlap.

4. Then, select the variables for the primary classification of the situation (Fig. 1).

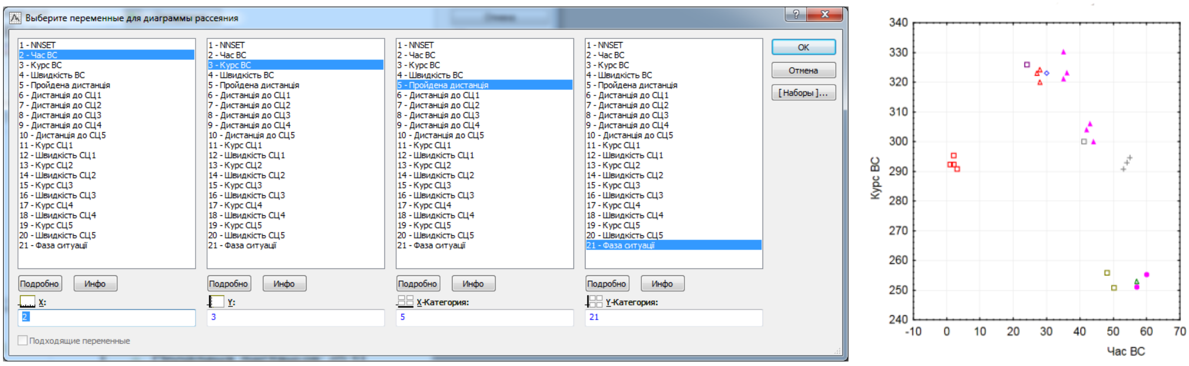

Fig. 1. Graph data for primary classification

As it can be seen from the graph, the navigation situations are visually well separated in relation to the "Phases of the situation". Thus, a preliminary analysis of the data showed that the task can be classified as areas of display of classification features that are logically related.

5. For a deeper analysis of the data, with their number of variables, it was decided to build neural network classification models (Fig. 2).

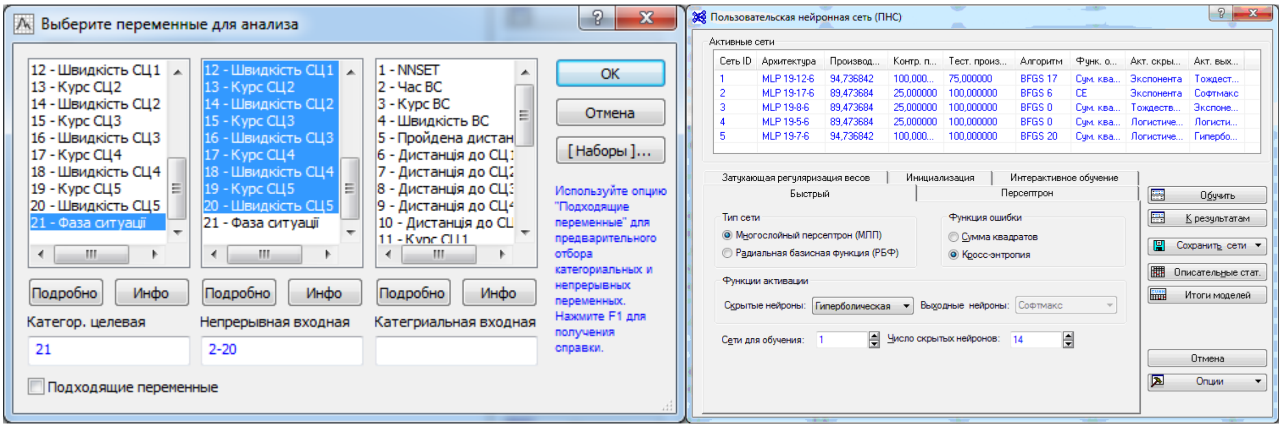

Fig. 2. Adjust the feature space for classification

The obtained data indicate high accuracy of modeling.

6. We will conduct an interactive study of the neural network based on 1000 epochs of modeling. As you can see, network performance ranges from 84 to 100%, which is quite high in a large array of navigation data.

7. Next, build multiple subsamples. Let's increase the data of the neural network: up to 2000 epochs and the number of hidden neurons - 20. This will clarify the elements of network modeling based on a multilayer perceptron.

The obtained data indicate a deeper processing of the neural network MLP 19-25-6 with performance indicators of 94.7%. Thus, this network can be taken as a basis for identifying the phases of the navigation situation in the port area of Dover.

8. Thus, we choose the most effective neural network model №7 and perform its detailed analysis (Fig. 3).

Описательные статистики
Нейросеть: 7.MLP 19-25-6

Выборки	Час ВС Вход	Курс ВС Вход	Швидкість ВС Вход	Пройдена дистанція Вход	Дистанція до СЦ1 Вход	Дистанція до СЦ2 Вход	Дистанція до СЦ3 Вход	Дистанція до СЦ4 Вход	Дистанція до СЦ5 Вход
Минимум (Обучающая)	1,00000	251,0000	0,00000	0,000000	0,00000	0,000000	0,00000	0,000000	0,000000
Максимум (Обучающая)	60,00000	330,2000	10,00000	8,800000	12,00000	9,000000	11,00000	7,000000	1,300000
Среднее (Обучающая)	30,78947	298,5000	7,35263	4,201053	3,75789	2,703158	2,33158	1,254737	0,210526
Стандартное отклонение (Обучающая)	20,51714	24,4482	2,36064	3,182371	3,81070	2,897066	3,15578	2,068610	0,472458
Минимум (Контрольная)	28,00000	251,1000	4,00000	4,310000	0,00000	0,000000	0,00000	0,000000	0,000000
Максимум (Контрольная)	60,00000	324,2000	8,00000	7,830000	6,00000	9,000000	3,00000	3,000000	0,160000
Среднее (Контрольная)	46,75000	283,6500	6,17500	6,162500	2,00000	2,550000	0,75000	0,750000	0,065000
Стандартное отклонение (Контрольная)	14,77329	36,1555	1,98053	1,816726	2,82843	4,337050	1,50000	1,500000	0,078951
Минимум (Тестовая)	43,00000	253,0000	5,00000	4,900000	0,00000	0,000000	0,00000	0,000000	0,000000
Максимум (Тестовая)	57,00000	306,0000	8,00000	7,300000	6,00000	9,000000	5,00000	0,700000	1,300000
Среднее (Тестовая)	49,50000	288,0000	6,55000	6,050000	3,00000	4,500000	2,00000	0,175000	0,400000
Стандартное отклонение (Тестовая)	31,38471	28,5397	2,58392	3,806810	2,99110	4,228475	2,88444	1,665083	0,591608
Минимум (Пропущенные)									
Максимум (Пропущенные)									
Среднее (Пропущенные)									
Стд (Пропущенные)									
Минимум (Общий)	1,00000	251,0000	0,00000	0,000000	0,00000	0,000000	0,00000	0,000000	0,000000
Максимум (Общий)	60,00000	330,2000	10,00000	8,800000	12,00000	9,000000	11,00000	7,000000	1,300000
Среднее (Общее)	35,92593	294,7444	7,05926	4,765556	3,38519	2,946667	2,04815	1,020000	0,217037
Стандартное отклонение (Общее)	19,69757	25,8255	2,17242	2,892602	3,57499	3,396328	2,85743	1,843250	0,455891

Выборки	Курс СЦ1 Вход	Швидкість СЦ1 Вход	Курс СЦ2 Вход	Швидкість СЦ2 Вход	Курс СЦ3 Вход	Швидкість СЦ3 Вход	Курс СЦ4 Вход	Швидкість СЦ4 Вход	Курс СЦ5 Вход	Швидкість СЦ5 Вход
Минимум (Обучающая)	0,0000	0,000000	0,00000	0,000000	0,0000	0,00000	0,0000	0,000000	0,0000	0,000000
Максимум (Обучающая)	114,0000	8,000000	90,00000	8,000000	227,0000	14,20000	300,0000	8,300000	132,0000	6,000000
Среднее (Обучающая)	58,7895	4,021053	26,26842	4,568421	73,1053	4,07368	58,5632	2,389474	20,3684	1,147368
Стандартное отклонение (Обучающая)	51,6281	3,403361	27,98529	3,290399	98,9618	5,58260	111,4246	3,153639	41,6443	2,289194
Минимум (Контрольная)	0,0000	0,000000	0,00000	0,000000	0,0000	0,00000	0,0000	0,000000	0,0000	0,000000
Максимум (Контрольная)	112,5000	7,000000	90,00000	7,000000	110,0000	5,00000	0,5000	8,000000	135,0000	6,500000
Среднее (Контрольная)	46,1250	3,000000	28,12500	3,500000	27,5000	1,25000	0,1250	2,000000	67,0000	3,125000
Стандартное отклонение (Контрольная)	55,7679	3,559026	42,59181	4,041452	55,0000	2,50000	0,2500	4,000000	77,3692	3,614208
Минимум (Тестовая)	0,0000	0,000000	0,00000	0,000000	0,0000	0,00000	0,0000	0,000000	0,0000	0,000000
Максимум (Тестовая)	74,0000	5,000000	94,00000	7,000000	115,0000	5,00000	294,0000	4,000000	137,0000	6,000000
Среднее (Тестовая)	36,2500	2,500000	46,50000	3,500000	56,7500	2,50000	73,5000	1,000000	55,5000	2,875000
Стандартное отклонение (Тестовая)	68,9354	4,203173	42,72587	4,041452	112,5015	7,09460	149,9286	4,472136	66,7108	3,204814
Минимум (Пропущенные)										
Максимум (Пропущенные)										
Среднее (Пропущенные)										
Стд (Пропущенные)										
Минимум (Общий)	0,0000	0,000000	0,00000	0,000000	0,0000	0,00000	0,0000	0,000000	0,0000	0,000000
Максимум (Общий)	114,0000	8,000000	94,00000	8,000000	227,0000	14,20000	300,0000	8,300000	137,0000	6,500000
Среднее (Общее)	53,5741	3,644444	29,54074	4,251852	63,9259	3,42222	52,1185	2,125926	32,4815	1,696296
Стандартное отклонение (Общее)	49,8106	3,288012	33,71390	3,392908	88,8728	4,94223	107,7276	3,072658	52,8134	2,675743

Fig. 3. Analysis of the effectiveness of the network 7 MLP 19-25-6

Analyzing the distribution of "Unidentified" situations, we can see that the distribution is quite significant, in turn, the distribution of distances to the courts of objectives 1.2 shows that the situations have their localized centers, characteristic of the phases of maneuvers. Thus, to identify situations, it will be sufficient to form models according to the parameters of distances to the nearest target vessels in the field of radar display or ECDIS. In turn, an indirect sign, with a normal distribution, for identification can be the course of your own ship, the distance and the course of the nearest ship - the target. This feature coincides with the rules of the MPPSS on the observation and execution of maneuvers while controlling the movement of the vessel (Fig. 4).

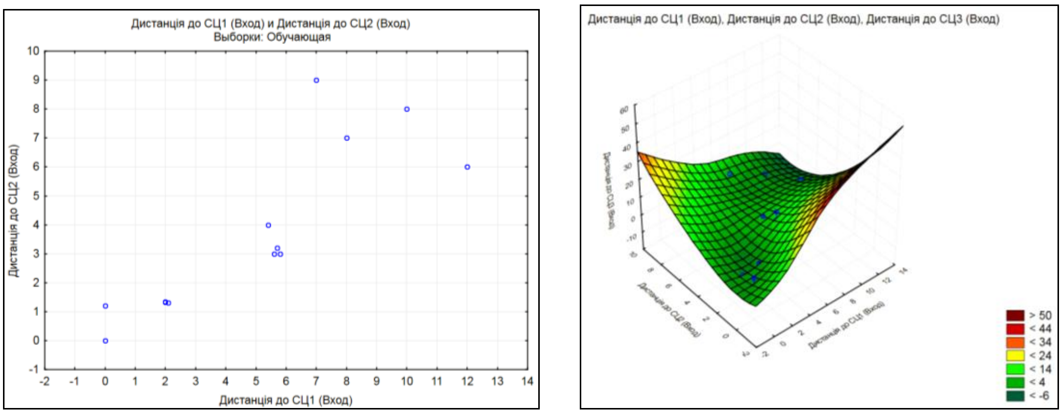

Fig. 4. Graph of identification of phases of navigation situation in difficult navigation conditions

Thus, the process of modeling and classification of the phase of the navigation situation was carried out at a sufficiently high level, as evidenced by the obtained data of automated neural networks. The obtained models make it possible to predict the occurrence of dangerous situations and their phases in the conditions of on-line observations of data of navigation information networks.

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UDC 656.61

NAVIGATION FROM THE FUTURE POINT OF VIEW OF GLOBAL CLIMATE PROTECTION

Hordiiuk Serhii, cadet group 1103, head Kateryna Shumilova, assistant of department of theory and structure of a ship (NU «OMA»)

Shipping is a branch of transport, the end products of which are various wastes and emissions of a number of substances into the atmosphere. The impact of shipping on the environment includes air pollution, water pollution, acoustic and oil pollution [1]. Modern shipping is responsible for more than a tenth of CO2 emissions (carbon dioxide, carbon dioxide, carbon monoxide) from maritime transport and is a major source of air pollution.

Shipping also contributes to climate change due to emissions of black carbon, tiny black particles formed during the combustion of marine fuel. Most of the particles of black carbon are produced by vessels burning fuel oil. Black carbon accounts for 21% of CO2 emissions from ships, making it the second most important factor in the climate's impact on shipping after carbon dioxide. Currently, there are no rules governing the emission of black carbon from shipping [2].

An alternative to decarbonization (reduction of CO2 emissions) may be the use of clean fuel in global shipping. Consider the possibility of using such fuels on ships.

1. Liquefied natural gas (LNG) is an environmentally friendly source of energy that emits less carbon dioxide than coal or oil. When using LNG, the least greenhouse gases are emitted, such as water vapor, carbon dioxide, methane and ozone (Fig. 1). The disadvantages of this fuel include the fact that unburned methane, which is the main component of LNG, generates emissions 20 times more powerful greenhouse effect than carbon dioxide CO2 [3].

Fig. 1. Left: "Ishin" – tugboat operating on LNG; right: LNG tank on board the vessel.

2. Liquefied hydrocarbon gas is a possible alternative to LNG. Liquefied petroleum gas is widely available and easy to handle and store, which leads to lower capital costs compared to liquefied natural gas. However, liquefied petroleum gas is a familiar problem: although it limits carbon emissions, it does not eliminate CO 2 emissions.

3. Methanol and ethanol. As an alternative fuel, they are easier to use than LNG and have a well-developed global network of terminals. At the same time, bunkering opportunities are limited, and vessels running on methanol and ethanol must be designed and operated with special care, taking into account the toxic and flammable nature of the gases.

4. Nuclear energy. Using nuclear energy and in the absence of accidents, ships will not emit any emissions as there are no SOx, NOx, CO2 or particulate matter.

5. Scrubbers. To clean the exhaust gases on ships use special devices – scrubbers.

Scrubber – device used to clean solid or gaseous media from impurities (see Fig. 2). When installing scrubbers, first of all you need to take into account fuel consumption – it is more profitable to install a scrubber or it is better to use LS fuel with a low sulfur content < 1.0%). Due to the increased demand for LS fuel, its price will increase. In this regard, financially, will win ships with scrubbers.

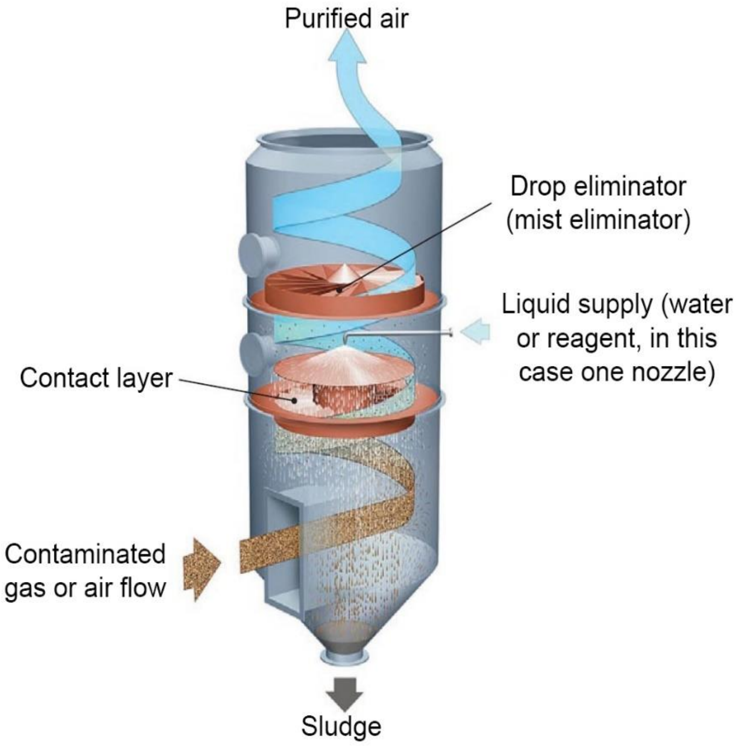

Fig. 2. Marine ship scrubber.

The age of the vessel is also an important factor. Does it make sense to install an expensive scrubber if the ship soon goes to scrap metal?

6. Electric motors. Battery-powered operation has environmental and operational benefits. Battery-powered provides more comfortable conditions for the crew (the ship does not make noise), as well as the absence of CO2 emissions and the unpleasant smell of spent fuel into the environment compared to ships running on fossil fuels. The cost of batteries still remains high, while their capacity is too low [2].

Conclusions

In the coming years, liquefied natural gas is likely to become one of the most popular fuels. The development of technologies for the use of nuclear fuel, hydrogen and ammonia is also expected. At the same time, the ships of the future are likely to use electric propulsion everywhere, including the use of "large batteries" (more than 4300 kW/h) as a source of energy, which as scientific and technological progress becomes more compact and efficient.

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UDC 656.61

EFFICIENCY OF INVERSE BOW TECHNOLOGY OF MODERN VESSELS

Vyacheslav Tatyanchenko, cadet of group 1103, scientific adviser Kateryna Shumilova, assistant of the "Ship Theory and Structure" department (NU «OMA»)

Inverted bow (inverted, reverse bow) is a variant of the front part of the vessel (bow), whose front point is not in the upper part, but in the lower one. This type of bow is inherent in many types of ships: yachts, cargo and military [1].

It is obvious that the inverted bow was not invented, in the 21st century. We can mention, for example, warships with similar bows centuries ago. Russian battleships of the Borodino class were equipped with the inverted bow, which, in their turn, was based on a French prototype and collapsed sides (Fig. 3). Vessels of similar design were built in other countries, in particular, in the United States, but later the inverted bow was almost forgotten [5]. Distant descendants of medieval Scandinavian warriors from the Norwegian company Ulstein claim that they returned to the well-forgotten old not even armored monsters of the beginning of the century, namely the Hokstad find and a number of other drakkars and knorrs (warships and cargo ships) of our time. The contours of the rounded bows of ancient ships inspired the authors of ships to design new vessels using X-Bow technology (Fig. 1-2).

In modern shipbuilding, the technology of the inverted bow is called X-Bow, and this name is used not just for the sake of originality. In the name X-Bow, the letter "X" sounds similar to the word "Axe" – indeed, the bow of the ship cuts through the waves like an axe.

Instead of simply rising on the waves and then falling with tremendous force, the X-BOW can distribute force evenly over its surface, allowing the ship to remain more stable in bad weather, increasing comfort for both passengers and crew. And because it uses less fuel to overcome waves, it also helps save energy. In stormy waters, shocks to the hull are reduced, which leads to reduced vibration. This is the peculiarity of the X-BOW design [2].

Fig. 1. Ship "Bourbon Orca" with technology X-BOW, 2006

Fig. 2. A new generation ship "Viking Poseidon", 2007

The Bourbon Orca, the first ship with X-Bow technology, was launched in 2006 (Fig. 1). The new X-BOW generation vessels have the best performance in bad weather. They are able to cross the stormy sea at high speed. There are two reasons for this, firstly, the main mass of the bow of a sea vessel is lower than usual, so such a vessel resists the oncoming wave better (Fig. 2), and secondly, in new vessels with a pointed bow the exit from the waves is gradual and smooth, rather than fast and intermittent, as in typical vessels [3].

The Norwegian company Ulstein Group was the first to use inverted bow technology in the construction of its ships. X-BOW (and later X-STERN) is one of ULSTEIN's major contributions to maritime history. X-BOW ships are built at the shipyards of many continents. Currently, more than 100 vessels with this concept of the bow are being built or ply in the world [3, 4] (Fig. 4).

In 2016, the world's largest new-generation stealth destroyer appeared in the US Navy (Fig. 3). The destroyer is 183 m long and 24.6 m wide. It has a crew of 148 people. The speed of the ship "Zamvolt" can reach 30 knots (55.56km/h).

Fig. 3. American destroyer type "Zamvolt", made by stealth technology with a nose X-BOW, 2016

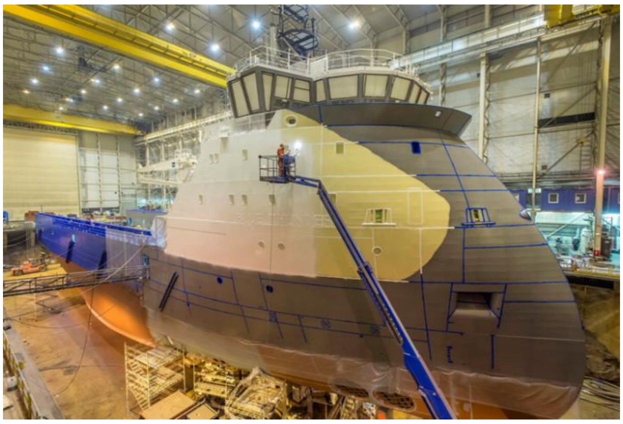

Fig. 4. Construction of the X-BOW building (Norwegian company Ulstein).

The destroyers are made with the wide involvement of "stealth" technology, integrated electronic weapons, as well as vertical launchers. The cost of a military "monster" is about $ 3 billion [5] (Fig. 4).

X-BOW enclosures are actually easier to build because the traditional enclosure has a bulb built into the X-BOW enclosure. This means that you do not have to use many plates with double curvature. It is much faster to build such a hull, and therefore, save of many working hours in the shipbuilding process are obvious [6].

Conclusions

Inverted bow technology is gaining popularity and is rapidly evolving in modern shipbuilding. This technology has a number of advantages over traditional raked bows, such as: increased energy efficiency; very low noise and vibration; reduction of blows to the bow and reduction of vibrations caused by waves; improved crew rest time; lower levels of acceleration; lower response in height due to volume; more comfortable conditions on board; reduction of speed loss; reduction of splashes on the deck.

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A BRIEF OUTLOOK ON SHIPS of TECHNICAL FLEET

Olinchuk V., PhD, Tikhonina S., PhD, Potapchuk I. senior lecturer

Introduction.

The present paper is dedicated to a very interesting subject – the description of Technical Ships. This topic might be very useful for the cadets of Maritime Academy and Maritime college of Technical Fleet.

The great majority of ships that are neither military vessels nor yachts can be divided into several broad categories: cargo carriers, passenger carriers, industrial ships, service vessels, and noncommercial miscellaneous. Each category can be subdivided, with the first category containing by far the greatest number of subdivisions. A ship is a large watercraft that travels the world's oceans and other sufficiently deep waterways, carrying passengers or goods, or in support of specialized missions, such as defense, research and fishing.

Historically, a "ship" was a sailing vessel with at least three square-rigged masts and a full bowsprit. Ships are generally distinguished from boats, based on size, shape, load capacity, and tradition. Ships have been important contributors to human migration and commerce. They have supported the spread of colonization and the slave trade, but have also served scientific, cultural, and humanitarian needs. After the 15th century, new crops that had come from and to the Americas via the European seafarers significantly contributed to the world population growth. Sea transport is responsible for the largest portion of world commerce. Because ships are constructed using the principles of naval architecture that require same structural components, their classification is based on their function such as that suggested by Paulet and Presles, which requires modification of the components. The categories accepted in general by naval architects are the following:

Technical fleet vessels are involved into technical service, maintenance, assistance, salvage, supply of various marine vessels, port facilities and waterways. They can be devided into two large groups according to the functions they carry out. The first group is represented by ships used for industrial facilities off-shore and on-shore works. The second group includes ships designed to carry out lifting and mounting construction works including repair off-shore and in ports. Here is the description of the above-mentioned types.

1.Industrial facilities ships. Dredging Vessels

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sediments located in the bottom to dispose them off at another place is called dredging sediments might be gathered for purposes like: making the navigation or fishing easier in shallow waters; for replenishing the sand on public beaches, which might have undergone severe coastal erosion. Also, gold and coal mining, removal of contaminants from the sea bed and reclamation of areas damaged by oil spills or natural calamities. And finally, creation of new harbors.

Although dredging can have very harmful effects on the marine and aquatic environment, in some situations it may be the only option available. The device used for excavation and scraping of the sea bed is called the Dredge and the ship or vessel a dredge is fitted to is known as a *Dredger***,** although these terms nowadays are used interchangeably.

Broadly the types of dredgers are classified into three categories; *Mechanical dredgers* which are suited for working in confined areas and are useful for removing the hand-packed material or debris, *Hydraulic dredgers* which work on the principle of adding large amounts of process water to change the original structure of the sediments, and other dredgers which do not fit in the above two categories.

Suction Trailer Hopper Dredgers

Suitable mostly for harbor maintenance and pipe trenching, a hopper dredger is a self-propelling vessel that holds its load in a large onboard hold is known as the hopper. They can carry the load over large distances and can empty it by opening the bottom doors or by pumping the load offshore. Hopper dredges mostly dredge the soft non-rock soils and because of their high production rates can carry out land reclamation projects easily.

Cutter Suction Dredger

CSD, as they are normally called, have a cutter head at the suction inlet which helps to loosen the earth and take it to the suction mouth. Used for hard surfaces like rock, CSDs suck up the dredged soil with the help of wear-resistant pump and then discharge it through a pipeline or a barge.

Bucket Ladder Dredgers

The bucket ladder dredgers use a series of buckets that are mounted to a wheel, which then using mechanical means pick up the sediments. They can be used for wide variety of materials including soft rock material and are powerful enough to rip out the corals as well. But because of their low production, high level of noise and the need for anchor lines, their use has hugely diminished in the recent times.

Backhoes

Like some onshore excavators, Backhoe dredgers have a digging bucket attached to it which digs through a wide range of materials and when it is excavated it’s brought out and placed on the onboard barges. Although they have few limitations where deep dredging is concerned but with some recent modern dredgers, deeper excavation is made quite easy.

Grab Dredgers

A revolving crane, fitted with a grab, placed on a hopper vessel or pontoon is known as a grab dredger. As the name suggests, it picks up the sediments at the seabed with a clam grabbing motion and discharges the contents. Often used for excavating bay mud it also is useful to pick up clays and loose sand.

Dumb Lighters or Mud Lighters and *Barges* are involved into dredging process. They download and carry the pulp and sediments. Barges may be *towed, hopper or self-propelled.*

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Oil platform

An oil platform, offshore platform, or (colloquially) oil rig is a large structure with facilities to drill wells (optionally), to extract and process oil and natural gas, or to temporarily store product until it can be brought to shore for refining and marketing. In many cases, the platform contains facilities to house the workforce as well. Depending on the circumstances, the platform may be fixed to the ocean floor, may consist of an artificial island, or may float. Remote subsea wells may also be connected to a platform by flow lines and by umbilical connections. These sub-sea solutions may consist of one or more subsea wells, or of one or more manifold centres for multiple wells. Types: Fixed platforms, Semi-submersible platform, Jack-up drilling rigs, Drillships, Tension-leg platform.

PSV is a ship specially designed to supply offshore oil and gas platforms. These ships range from 50 to 100 meters in length and accomplish a variety of tasks. The primary function for most of these vessels is logistic support and transportation of goods, tools, equipment and personnel to and from offshore oil platforms and other offshore structures.

2. Lifting and mounting construction ships. Crane vessel

A *crane vessel, crane ship* or *floating crane* is a ship with a crane specialized in lifting heavy loads. The largest crane vessels are used for offshore construction. Conventional monohulls are used, but the largest crane vessels are often catamaran or semi-submersible types as they have increased stability. On a sheerleg crane, the crane is fixed and cannot rotate, and the vessel therefore is manoeuvered to place loads. As the name suggests, a crane ship is that kind of sea going vessel which has a crane attached to it. A crane vessel is of great significance when it comes to the aspect of constructing structures in the high seas. It is only because of such vessels that many important constructions are carried out in trickier parts of the seas and oceans.

The first crane ship was created in the 14th century and since then the technology has helped generations and generations of people. In today's times, along with the basic ship that carries a single crane attached to it, there are also concepts like 'semi-submersible vessels' and the 'sheerlegs.'

Common Crane Vessels: These types of naval cranes are more commonly known around. They were the ones that were first introduced in the 14th century, as mentioned above. These cranes can be used to haul and lift around 2,500 tons. Additionally, another major feature is that it is movable, which means, the crane can be moved to the place where the item to be lifted is located, thus offering lots of flexibility.

Semi-Submersible: These types of cranes offer a lot of stability to the equipment that is being carried. As the name goes, semi-submersible cranes submerge partially into the water to give the weight placed on top of them the balance required. This balance provided ensures that the item carried does not topple into the water and thereby cause serious problems not just to the business concerned but also to the marine ecosystem. The weight carrying capacity of such semi-submersible cranes varies from one naval vessel to another. However, the heaviest limit that such semi-submersibles can carry extends to around 14,000 tonnes.

Sheerlegs: These types of cranes are immovable. In other words, the weight that has to be loaded on them has to be brought to them so that they can be hauled. The weight carrying capacity of such cranes varies from around 50 tonnes to around 4000 tonnes.

A crane vessel has enabled to solve the trickiest aspect of construction. Crossing the ocean and helping widespread places to come even closer has become so much easier. Also, in today's times, with the help of a crane ship important oil rigs are constructed so as to enable the world to get precious oil from oceanic sources.

Dock (maritime) and Floating Workshops

A *dock* (from Dutch *dok*) is the area of water between or next to one or a group of human-made structures that are involved in the handling of boats or ships (usually on or near a shore) or such structures themselves. "Dock" may also refer to a dockyard (also known as a shipyard) where the loading, unloading, building, or repairing of ships occurs.

3. Vessels collaborating with technical ships. Auxiliary and service vessels.

A *Cable Laying Ship* is created specifically to cater to the purpose of laying cable lines underwater. But at the same time since cable laying work does not take place round-the-clock and throughout the year, a Cable Laying Ship is also additionally used as *research* ships to monitor various happenings in the oceanic and sea waters. A Cable Laying Ship is built with every modern gadget required to make the process of laying the intricate lines of cable on the oceanic floor simpler. It is enabled with Dynamic Positioning and Dynamic Tracking systems which pinpoint the exact location of the ship in the mid-ocean and lay the underwater cable lines appropriately. The torso of a Cable Laying Ship is huge because of the nature of the work it undertakes. Most of the cable laying ships have a tonnage of over 11000 tons and are capable of laying not just one line of underwater communicative cable lines but two-three lines in addition. And because it is so bulky in its torso, a cable laying ship cannot be used for operations in shoals or shallow waters where there is a chance of land merging with the waters because the shallowness of the water tends to curtail and hamper the movement of the cable laying ship.

Another specific feature that is unique to a Cable Laying Ship is that it is built with every damage control tool and equipment that might be necessary in case there is any damage done to the underwater cable lines and contains both pneumatic – operated by air and hydraulic – operated by liquid (oil or water) operating systems for the process of laying underwater cable lines. The size specification of a Cable Laying Ship depends on the depth of the ocean floor where it is required to be positioning the cable lines. If the depth of the ocean bed or floor is more, then the size of the ship is bigger, whereas if the depth of the ocean bed or floor is not much, then the Cable Laying Ship's size tends to be smaller.

The *service* ships are mostly *tugs* or towing vessels whose principal function is to provide propulsive power to other vessels. Most of them serve in harbours and inland waters, and, because the only significant weight they need carry is a propulsion plant and a limited amount of fuel, they are small in size. The towing of massive drilling rigs for the petroleum industry and an occasional ocean salvage operation (e.g., towing a disabled ship) demand craft larger and more seaworthy than the more common inshore service vessels, but oceangoing tugs and towboats are small in number and in size compared with the overwhelmingly more numerous cargo ships. The *tugboat* has a number of *functions* ranging from towing vessels into berths, to *firefighting, salvage and anchor handling/positioning*. Tugs range in size (and power) depending on the tasks that they required to perform. A small harbour tug may only have 3 - 400 BHP (Brake Horse Power), whereas a large ocean- going salvage tug may have up to 10,000 BHP engines, capable of towing large cargo vessels off sandbanks and rocks.

Within technical fleet classifications one has to mention *icebreakers* and *research* vessels. Neither type needs to be of large size, since no cargo is to be carried. However, icebreakers are usually wide in order to make a wide swath through ice, and they have high propulsive power in order to overcome the resistance of the ice layer. Icebreakers also are characterized by strongly sloping bow profiles, especially near the waterline, so that they can wedge their way up onto thick ice and crack it from the static weight placed upon it. To protect the hull against damage, the waterline of the ship must be reinforced by layers of plating and supported by heavy stiffeners.

Damage to propellers is also an icebreaking hazard. Propellers are usually given protection by a hull geometry that tends to divert ice from them, and they are often built with individually replaceable blades to minimize the cost of repairing damage. *Electric transmission* of power between engines and propellers is also common practice, since it allows precise control and an easy diversion of power to another propeller from one that may be jammed by chunks of broken ice.

Research vessels are often distinguished externally by cranes and winches for handling nets and small underwater vehicles. Often, they are fitted with bow and stern side thrusters in order to enable them to remain in a fixed position relative to the Earth in spite of unfavourable winds and currents. Internally, research vessels are usually characterized by laboratory and living spaces for the research personnel.

To sum up, we have come to *the conclusion* that technical ships are the ships that provide technical service and create the necessary conditions for ship navigation. Among the biggest group are dredgers, the floating vessels used to make sea or river-floors deeper. This is done when ports and canals are built or maintained. Dredgers take out sand from the bottom and dump it on barges which bring it away. Dredgers can be either bucket dredgers, which have a series of buckets which go down to the sea bed and scoop up the sand and mud; they can be suction dredgers, which suck up sand and mud like a very large vacuum cleaner; or they can be grab dredgers, which can operate like cranes. The largest representatives of technical ships are floating docks, vessels which cannot move on their own and serve as places for construction and repair of ships. Other technical ships are floating cranes, power stations and workshops, cable laying ships, oil collector ships that surround the oil spills and clear them; and drill ships, offshore drilling rig supply vessels. One has to mention that technical ships work in close cooperation with other service and supply vessels designed as auxiliary and utility vessels.

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