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A Theoretical Analysis of Contemporary Vessel Navigational Systems: Assessing the Future Role of the Human Element for Unmanned Vessels

D. Polemis[1], E.F. Darousos[2] & M. Boviatsis[1]
[1] *University of Piraeus, Piraeus, Greece*
[2] *World Maritime University, Malmoe, Sweden*

ABSTRACT: This article aims to investigate the contemporary challenges of electronic navigation and assess the appropriate amendments should autonomous vessel technology becomes widespread in the near future. Vessel control systems and maritime communication are essential and sending and receiving alarm signals is critical to contemporary ship navigation. Numerous location and shipping information systems, such as GPS, Loran-C, and Decca, have arisen in recent decades to improve navigational safety. Other systems, including VHF and Inmarsat, have been developed to enhance the efficiency of maritime communication on board and to transmit risk and safety-related data. Additionally, safe navigation requires systems like Navtex, EGS, DSC, Epirb, and others [1].

1 INTRODUCTION

The International Maritime Organization (IMO) aims to ameliorate human element management in the shipping industry. The empirical evidence and accident data point towards the impact of human error in maritime accidents and most shipping failures, including collisions, allisions and groundings. An analysis of accident data from Australia, Canada, Norway, and the UK revealed that despite the overall reduction of maritime accidents, human error remained the main reason behind them in up to 80-85% of all cases, or even 96% [2, 3]. Likewise, the Japan P&I Club considers human error as the primary factor in 84% of 1,390 cases of maritime accidents [4], regardless of advances in marine technology contributing to reducing the frequency and severity of marine accidents [5].

This paper aims to assess the current and future technology used for navigational purposes, the advantages and disadvantages of autonomous vessels, and the importance of the human element in future navigational technology and reach conclusions regarding our proximity to the era of industry-wide autonomous navigation.

2 NAVIGATIONAL TECHNOLOGIES: BRIDGE INSTRUMENTS

2.1 *The Radar*

The name "Radio Detection & Ranging" (RADAR) comes from the initials of the English phrase RADAR. This means "detection and range of electromagnetic waves". As the name suggests, the operation of radar is based on electromagnetic waves, and according to Gao et al. (2022), in particular, the distance determination is based on a time measurement from the point when the electromagnetic wave pulse is emitted to the returning echo, the waves ultimately representing the detectable object) [6]. Also, the Radar uses a rotating antenna to determine the direction it emits and emits pulses of electromagnetic waves in the form of a beam of light. It also receives an echo back to it [7].

Today, depending on their use, the main types of radars relevant to the shipping industry are as follows [8]:

- Surface detection radar or navigation
- Air detection radar
- Meteorological radars
- Fire control radar
- Radar speed measurement

2.1.1 *Surface detection radar or navigation*

Surface detection radars or navigation radars are installed on the coast or on vessels to detect the surface of the sea. However, they can also detect airspace, but at minimal heights. Instead, they detect solid objects from relatively conductive material at sea level or low altitudes and provide accurate information about the distance and view of the target they locate. Precise detection is possible regardless of the visibility conditions and at distances more significant than the visible horizon [9].

2.1.2 *Air detection radar*

Placed on the ground (near mountain peaks or airfields) and boats, they explore long-distance and high-altitude airspace. The air detection radar ensures air traffic control to ensure the direction of the aircraft and the detection of enemy aircraft from long distances.

2.1.3 *Meteorological radars*

These weather radars ensure the timely detection and monitoring of upcoming storms and cyclones.

2.1.4 *Fire control radar*

Part of various weapon systems, they provide the necessary launch elements and even corrective elements for the direction of certain types of remote-controlled projectiles.

2.1.5 *Radar speed measurement*

Used to accurately measure the speed of ships in sea areas where speed limits apply [10].

3 THE AUTOMATIC RADAR PLOTTING AID (ARPA) AND GYROSCOPIC COMPASS

3.1 *The ARPA System*

Obligations in Article 7(b) and other relevant provisions of the International Collision Avoidance Code refer to the observation of targets on a bridge deck or further corresponding systematic observation, performed via an automated printing system called automatic radar protection equipment (ARPA) [11, 12]. Current technology, especially in cases of multiple targets and situations of limited visibility, can lead to limited monitoring, an issue expected to be solved through ARPA. Many targets are accomplished with the help of the Automatic Radar Plotting Aid (ARPA), including reducing the minimum effort required to obtain more target information displayed on the radar screen. Also, the ability to evaluate situations accurately and continuously as the ARPA microcomputer equipment receives information on the target area and line of sight for radar equipment. Plus, the course and speed of the nearing vessels vessel are combined for sublimation, specifically the Closest Point of Approach (CPA) and the Time of the Closest Point of Approach (TCPA) in which the target will pass, giving the navigators the target's direction and speed the direction and speed of the target. The ARPA range is 16 nautical miles [13, 14].

3.2 *The Gyroscopic Compass*

The gyroscope is an instrument rotating around an axis, passing through its centre. Solids are rotary and symmetrical around this axis. Initially conceived by Foucault in 1851) and with the first gyroscopic compass constructed in 1908, the gyroscopic inertia proves that the Earth revolves around its axis [15].

Regardless of its specific subtype, each contemporary gyroscope requires frictionless action for one or two gyroscopic flywheels that are part of a three-phase motor. In addition, of course, the engine must have a unique power supply to rotate. A suitable control system is also necessary so that their axis of rotation or the component of the axis of rotation of a gyroscope or two gyroscopes looks for the meridian direction of the site. Finally, there must be a sufficient power transmission system, which the instructions of the wind turbine of the main compass to be electrically transmitted to their wind turbines repeatedly via an electrical supply [16].

3.3 *Free gyroscope and its properties*

A free gyroscope consists of a torsional mass, most of which is distributed on its periphery and is thin and balanced. The clamp has 3 degrees of freedom; that is, it can move three axes freely around its axis of rotation, the horizontal axis and the vertical axis. This is achieved by using the correct suspension. When the free gyroscope rotates around its axis, the gyroscopic inertia and transition are received, with the former being the free gyroscope that retains its properties. The transition is the property of the gyroscope. As a result, if a particular force is applied to the free gyroscope, a specific force will cause the axis of rotation of the moving gyroscope. Thus, the free gyroscope will become a controlled gyroscope, free for a short time yet controlled upon using the compasses. There are two methods for the free gyroscope to turn the Compass gyroscope: The Sperry method, with a northern part of the gyroscope and the Anschutz method, with weight at the bottom of a system of two round flywheels [17].

3.4 *Gyroscopic compass errors*

A regular series of inspections are needed to avoid multiple errors associated with the gyroscopic compass, including the (a) error of navigation, direction, and velocity, (b) depreciation error, (c) ballistic diversion error and (d) ship wall fault. The inspections include comparison with magnetic compass indications at least daily and checking the accuracy of the observations on the ground objects or celestial bodies [16].

4 THE RADIOGONIOMETER

4.1 *Radiogoniometer properties*

A Radio Direction Finder direction detector (RDF) is the oldest radio navigation aid used to identify the address of the station to which the received transmission was sent to the receiver of the device's signal. The basic principle of operation of a radiogoniometer is based on its antenna characteristics, providing the receiver with a variable power signal depending on the direction from which the signal reaches the transmitter. The simplest radiogoniometer antenna is a simple loop or frame antenna, which may have a circular shape, rectangle, triangle, etc. [18].

4.2 *Radiogoniometer errors*

Under ideal viewing conditions, the radiogoniometer can be highly accurate. However, this is often not the case. Indicatively, when the recipient determines the address from which he receives the transmitter's signal (beacon, ship, etc.), it is usually not the same as the corresponding signal. This difference is due to several factors affecting radio wave propagation and producing deviations from their regular route. These factors contribute to various errors in the radiogoniometer. They are errors due to meridians, polarities or nocturnal effects, coastal refraction or its effects due to ship bugs and square error, semicircle error, total error and radiogoniometer calibration [19].

5 THE AUTOMATIC RUDDER

5.1 *Automatic rudder*

Autopilot is an advanced electromechanical and electronic system. It is connected to the gyroscopic transmission system through ship repeaters to know that the ship deviates from its steady course, and with a turn of the rudder blade, the vessel may return to its course. An alternative automatic rudder also exists, which uses separate magnets and a compass to automatically follow the correct route in case of a vessel's gyroscopic compass failure [20].

5.2 *Automatic rudder function*

When the ship leaves its course, the sailor must turn his steering wheel to the opposite to reestablish the system. This depends on how many times the number of degrees the ship is off course has, so it should be placed at a right angle. Its rudder is usually small enough to bring the boat back into orbit. On its bridge is a deck control unit in which a repeater (relay motor) is operated by a gyroscopic compass on board, activating the entire autopilot mechanism [21].

5.3 *Double unit rudders*

Transmission of electrical signals from the deck control unit to the steering wheel of a double unit to the power unit of the stern turns into a mechanical or hydraulic drive. Of course, one should follow the operating schedule as accurately as possible. The stresses of the ship, the rudder, the automatic rudder, and the automatic rudder must also be reduced. This also depends, of course, on the sea conditions and the towing capacity of the vessel. Finally, the autopilot is nowadays equipped with a computer unit that can plan the entire trip and automatically performs the required course changes during this time [22].

6 THE NAVIGATION SONAR

6.1 *The sonar technology*

The sonar is an electronic naval instrument that informs sailors of the ocean's depth under a ship's keel. The operation of the device is based on the emission of sound waves under the keel perpendicular to the bottom. The emitted sound waves travel to the bottom, face it, and then are absorbed, diffused or reflected in different directions. Most of the reflected sound energy will return to the source as an echo. With a properly programmed operating cycle, an audio device changes its operation from an audio transmitter to a receiver. The device accurately measures the time elapsed between the onset of a sound wave and its reflection is received and determines the depth of the sea by calculating the speed-space-time ratio [23].

6.2 *Principe of operation of sound instruments*

The operation of the sonar is based on the constant speed at which it moves. Ultrasonic waves in seawater where their reflections when they hit the seabed or other solid objects from which they return to the reflected waves form echoes. Unique grooves in the area of the keel are in place to prevent its destruction. At the same time, a particular oscillator has been installed that can receive pulses and ultrasonic waves of high power of a very short duration perpendicular to the bottom. Part of the energy of each ultrasonic pulse as it hits the bottom is also reflected in the form of echoes at the same frequency as the ultrasonic pulse returning to its keel and being taken from another sensitive oscillator. After the frequency propagation, the time from the launch time to the launch time of the ultrasonic wave is constant, but the return time is also constant from projection time to projection time. The return corresponding to each echo pulse will be proportional to twice the distance from the ship's keel. The propagation rate of ultrasonic waves is constant [24].

7 LORAN – C PRINCIPLES OF OPERATION & ERRORS OF THE LORAN SYSTEM – C

Loran-C is a long-range positioning system whose position lines are determined by time difference measurement and phase comparison. The location of the corresponding chain is used to determine the location in the zone. A Loran-C station chain consists of a primary station, M and two, three or four secondary stations denoted by the letters X, Y, Z and W, which are located around the central station in the centre of the area. Each station emits a long-distance pulse signal at a frequency of 100 kHz. To determine the position, the system receiver on board measures the time difference it receives from the central station. Each master-slave station determines the position line above and the ship's position by the intersection of the two unnecessary position lines. In practice, the seafarer identifies the Loran-C position in one of the ways: by using unique Loran-C maps on which the excessive position lines corresponding to the measured time differences are drawn, or by measuring matrices, or even directly by the indications of width and length provided by certain modern receivers [25,26].

The points identified by the Loran-C system are some that are divided into systematic and random. According to some physicists, systematic errors or mathematical laws lead to the same result in all measurements—errors due to the Loran-C signal propagating on land [27].

Random errors due to unbalanced factors are generated, and it is not accidental since they are not even observed, so it is impossible to calculate the corresponding correction [28].

8 THE GLOBAL POSITION SYSTEM (GPS)

The Global Position System (GPS) system is a second-generation satellite system. Its development began in the early 1970s and was completed between 1992 and 1995. It can give sequentially to any area on Earth (a) High precision placement in three dimensions (width, length and height of the sea) (b) Accurate World Time U.T.C. (c) Ship speed data [29].

GPS positioning is based on the measurement of the distance of the receiver from three satellites whose positions are determined at the intersection of three spheres focused on the position of the satellite, with the measured distance as a radius, accurately identifying the location of any part of the earth. The computer which controls and coordinates all the functions of the receiver shall be selected by the most appropriate available satellite, applying corrections, and calculating the position and speed as well as the location of the vessel and the dispersion to be followed to reach the destination and the distance from the given point [30].

9 AUTONOMOUS VESSELS

9.1 *Introduction to autonomous vessels*

Maritime transportation faces tremendous challenges in our time, such as a significant increase in transport, environmental and institutional requirements, and expected reductions in human resources. The development of technology led to the development of new navigation equipment solutions, a gradually but steadily advancing wave of automation. This development may improve shipping operations by promoting the adoption of a more sustainable mode of navigation by reducing the time of seafarers' onboard engagement and the subsequent elimination of seafarer fatigue, stress, and errors [31].

The terms "autonomous" and "unmanned" can be used several times to identify the same thing. At this point, it would be reasonable to give the full definition of the above words. Referring to the word "autonomous", we explain that the ship can then carry out some defined operations with little or no care by the guard officers of the bridge. It does not close the possibility that there may be a human being. Contrary to the term "unmanned", we mean that there is no one in the cockpit of the bridge to supervise any action. Apart from that, however, the crew may still be on board. With the term " Maritime Autonomous Surface Ship " (MASS), it has already been proposed by the IMO to characterise as a term an autonomous ship. MASS was established as "ships which have varying degrees of autonomy and can operate independently of human interaction" [32].

The Maritime Unmanned Navigation through Intelligence in Network (MUNIN) organisation carried out a preliminary Conception and Research for the Implementation of Unmanned Ships in the shipping industry; however, several difficulties and doubts prevent unmanned ships from being widely adopted by the industry, involving, indicatively, loss of control while the ship is at sea, accidental damage to the ship and during the voyage, and insufficient monitoring in dangerous areas [33].

The absence of a human element is not the only difference between traditional and autonomous ships. An essential difference between the two is the formulation, management and implementation of individual decisions made by the crew and the master on conventional ships. Unmanned ships can be achieved through a combination of remote, automatic and autonomous control, according to the IMO [34].

An autonomous vessel is a vessel controlled by automated systems for navigation, including its engine. These systems will be pre-programmed as we can now have a pilot who follows the prescribed route plans. However, autonomous ships are not necessarily uncrewed. The maintenance team may be involved during the voyage to maintain or repair systems on board, as described above, where ships are expected to be manned as they approach and leave the port. A reliable communication system will be one of the challenges of the system; if the autonomous systems cannot cope, such systems will be retained as a last resort. An increase in autonomy is expected to reduce the need for the crew on board [35].

The IMO proposed the following four degrees of autonomy [32, 36]:

- Ship with automated processes and advanced decision-making functions. The crew should be on board and control and operate all its systems and functions.
- Remotely operated ship with a crew on board. The ship is controlled and operated from some remote location, but the crew is still on board.
- Remote-controlled ship without crew on board. The ship is controlled and operated from some remote location, with no crew on board.
- Fully autonomous ship. The ship's operating system can make decisions and handle all situations without human intervention.

9.2 *The importance of technology for autonomous vessels*

Recently, the strengthening of satellite communications and the continuous improvement of other transport aids/systems, such as the AIS, The

GMDSS Risk and High Identification and Monitoring System, or the scope of LRIT, is a reality. All these have laid the technical foundations for the advancement of the shipping industry, being strongly related to its group of remote-controlled ships. Therefore, the concept of unmanned vessels presents many vital concepts, such as advantages in the design and construction of ships, in the reduction in operating costs such as fuel and labour and, finally, the environmental impact associated with conventional vessels. However, the implementation of such autonomous systems focuses on long-distance commercial maritime transportation and is still limited to passenger vessels. Naturally, the autonomous operation of unmanned ships requires as much possible navigation and control with high reliability, error detection and a high safety rate [37].

This requirement, however, includes an inherent need to provide basic information such as the position of the ship in real time to avoid allisions and collisions with other vessels or other obstacles. Contemporary technology offers automatic collision avoidance and critical reconnaissance systems, sensors such as radars and cameras to identify and sweep the vessel's environment, and sea navigation and support for passenger services [38].

Future needs must also focus on the interaction between manned and unmanned vessels and autonomous ship control centres. The IMO defines electronic navigation as a unified collection, integrity, exchange, visibility and separate analysis of marine information on board and on land by electronic means to improve navigation, anchorage and improvement services responsible for safety and development, marine protection and protection of the marine environment. The international conventions lay down rules for the prevention of collisions with ships and regulations for the prevention of maritime collisions, the so-called COLREGS by the International Maritime Organization IMO. While the COLREGS Convention mainly focuses on manned vessels, the main objective is that these regulations also apply to automation regulations and systems [39].

On an autonomous ship, the implementation of the system has requirements imposed by the COLREGS Convention for information provided by the sensor system and the correct actions in dangerous situations. Both autonomous and conventional ships must have an automatic AIS system specifying that radio waves contain helpful information about the available position, speed and vessel, such as the type of cargo. Furthermore, given the necessity for communication with lights and sound instruments, one should expect the implementation of a relevant protocol expanding radio communications to support autonomous operations. Vessels deploy 400 to thousands of sensors collecting data for various functions. The transition will not reduce the number of sensors used, as the data must be reported to a shore control centre to check the vessel's condition effectively [32, 40].

An up-to-date example comes from Rolls-Royce, which recently announced its development of a centre of autonomous operations with remote control in 2015. This joint research program between production, education and research, entitled Autonomous Floating Application (AAWA), presents the idea of autonomous vessels controlled by minimal human resources through a land control centre. The program currently runs a series on Finferries' 65m double-ended ferry Stella, trying to determine how to implement possible combinations of current communication technologies in unmanned ships to achieve navigational autonomy [41].

9.3 *Future technological applications in autonomous vessels*

The spearhead of the Fourth Industrial Revolution's current wave is information technology, which performs human-like advanced information processing activities (cognitive, inferential learning and decision-making). More recently, this technology was reintroduced as ICBMS, signifying the collaboration in IoT, Cloud, with Big Data, Security and more, as follows [42]:

9.3.1 *Internet of things*

According to Shancang Li & Li Da Xu & Shanshan Zhao (2020), the Internet of Things (IoT) means that everything is connected to the internet now; there is no point in relating physically or conceptually to each other. Therefore, although there are many values, it is essential that the interconnection of things produces valuable data and that the price used is for the user's benefit [43].

9.3.2 *Big Data and Analytical Services*

Big data has the opportunity to store and process the traffic data that create a post for in-depth analysis support; these are all called the data platform. The innovative autonomous architecture of ships and Big Data platforms are divided into two types. There is, for a start, a large data platform inside the ship, an in-memory analytics platform (Edge Analytic Platform); the information generated can be collected and stored, made equal to it in real-time on and off-board, allowing for the data to be processed in detail in seconds, using various relevant application services. The next type is a comprehensive analytics platform that collects and stores information on the status of selective vessels and other information systems onshore [44].

9.3.3 *Security – IoT & Security*

According to Cabbar (2022) in Shipbuilding Industry, technology has introduced automation and-enabled services of vessel information for efficiency. At the same time, IT expansion exploits its vulnerabilities in the data hubs of ground transportation of IT equipment which is widely implemented, such as information leaks, attacks on infrastructure and systems, malware, cyber-attacks, personal attacks such as data spoofing, etc. Firstly, identity control and data protection by preventing damage to information equipment where ships are currently being built onboard ships. Communication between autonomous vessels and land, e.g. (Satellite, LTE) data centres. Finally, the coverage in terms of user identification, the protection of existing data and the prevention of intrusion by foreign users [45].

9.3.4 *Mobile Technology*

According to Ken Dulaney(Dulaney, n.d.) on an unmanned autonomous navigation ship, mobile service providers exchange information (messages, voice, video) with the visitor and with the ground data centre to resolve any potential problem with the equipment of the ship. This information is managed in real-time as the maintenance history and is used as data for preventive maintenance analysis [42].

9.3.5 *Artificial Intelligence*

The term Artificial Intelligence (AI), according to B.J. Copeland (Copeland, n.d.) , refers to intelligence that machines have created. From a philosophical point of view, artificial intelligence is divided into Powerful (Powerful AI) and Weak (Weak AI). the weak part is not about intelligence but about imitating specific steps; a prepared set of rules is used. Numerous vessels are associated with weak AI due to the use of computer development programmes for risk assessment while learning security is based on accurate data [46].

9.3.6 *Intelligent autonomous ships and land services*

For ships to be autonomous in the ocean, they must consist of operational and essential data. In addition, the ship can be controlled according to a crisis outcome of an autonomous nature. In contrast, the existing state of emergency of the ship is spread in real-time from the land centre if necessary. A function designed to perform remote control by land through the collection of operational checks from the ship to the land control centre when passing through the port area [47].

9.3.7 *Automatic navigation system*

The automatic navigation system mentioned in the AAWA report will include various features such as route planning (PR), critical recognition unit SA case, CA collision avoidance unit, and the Ship Status Detection Unit (Ship Status Detection Unit) SSD module (Ship status detection). Each unit combined will have its system function with a dynamic positioning system and operator data connection system in the control centre. Then, a complete set of autonomous navigation systems will be used, such as SSD Ship Status Detection Unit and Unit Virtual VC Captain having the highest priority because they collect information from all other systems and decide under what conditions the ship operates. According to other systems, the VC unit determines whether the vessel should operate autonomously, remotely or if it failed in safe mode. Situational awareness is an integral part of the safe navigation of ships. Understanding unmanned ships must be at least as good in condition as conventionally manned. The CA then assesses and avoids the risk of a collision. In contrast, the RP route planning unit is used as a tool, and when programming, the CA unit is always active and real-time, according to current conditions [48].

9.3.8 *Land Control Center*

Communication with Shore Control Center (SCC) should always be available. If the computer system fails to deal with the dangerous situation, the operator must, with the possibility of remote control, solve the danger immediately and effectively from the ferry. Not all data need to be transferred while you find the boat in fully autonomous mode, but it should be immediately available when necessary. A quantity of data will have to be assigned as the number of sensors currently used on board increases. Lidar and HD cameras will be used as blind parking spot detection aid and for light and range detection. Vessels will, in most cases, operate autonomously from the control centre, receiving the minimum data rate for effective vessel surveillance. However, different ways of data transmission, fast connections that are usually available near land, where ships may use a 4G connection or another reliable network sailing close to land, must be considered along with offshore connection and other alternatives, such as satellite or VHF frequencies [32].

9.3.9 *Artificial Intelligence (AI)*

Current growth dynamics in artificial intelligence synthesis in areas such as automation can often be controversial, especially in the shipping sector. However, Artificial intelligence provides enormous opportunities for all sectors of society, including the shipping industry, which will benefit greatly and move on to automated processes on and off-board, increasing the reliability and efficiency of global shipping [46].

9.3.10 *Electric propulsion*

In the areas of power and propulsion, energy production in the shipping industry will rapidly change in the coming years. There is evidence regarding the creation of alternative fuels, energy-saving equipment, renewable energy sources and hybrid power generation systems, and this will play an essential role in the development of the system. The developments foreseen in GMTT 2030 include dual-fuel engines running on alternative fuels. Common rail and other technologies will be redesigned to harmonise and accommodate them as a new fuel. Of course, the GMTT report states that in the future, the central propulsion unit will include larger, more powerful two-stroke internal combustion engines; ergo, the automation will allow autonomous monitoring of the current state of essential and non-essential components, the monitoring of new engine heat flows, and its operating parameters will be redefined as well as an integrated combustion quality control. The overall performance of the propulsion unit will be significantly enhanced with new materials, such as graphene and alloys, in piping alternators and condensers. This will dramatically improve the overall thermal efficiency of the engine while maintaining maintenance costs [49].

9.3.11 *Sensors*

The ability of the vessel to operate remotely, thus allowing them to sail independently, is based on the use of sensors for wireless monitoring. A new wave of sensor technology will automatically collect data and transmit this information in real-time to the land control centre's of respective shipping companies. This data will allow shipowners to improve the overall ship maintenance cycle, including more efficient, targeted, predictive and cost-effective monitoring of the vessel's condition. The relevant emerging trend of the innovative "biosensor" technology provides a biological component that can create sensitive sensors that are extremely fast and easy to use. However, these exciting detection methods require intelligent use of sensor integration technology robust and data processing capability. Then smart innovation can transform vast amounts of sensory data into proactive, helpful information not only for practitioners but also for regulators and authorities, i.e. in the case of environmental data collection [50].

9.3.12 *Cybersecurity*

Cybersecurity and adaptive security architecture solutions will be required to support flexible digital ecosystems. The construction of ships and intelligent, innovative technology infrastructure independent of the human factor will create further exposure to potential risks. An effective communication platform, and a strong level of data encryption, when transmitting and receiving data from the vessel to the land control centre, combining dynamic and efficient to prevent cyber-attacks, satellite navigation systems will help in uninterrupted and fully efficient operations on autonomous ships and therefore are expected to provide robust reliability and efficiency, in a new era of autonomous shipping [51].

10 ANALYSIS

10.1 *Advantages of autonomous vessels*

Autonomous transportation has the potential to bring many benefits to transport in the shipping industry, the most prominent of which are the elimination of human error, the minimisation of operating costs, and the avoidance of environmental degradation [32].

As mentioned above, human error is the leading cause of maritime accidents. Replacing the crew with automatic navigation and surveillance systems will undoubtedly result in its elimination. Likewise, naval transportation safety will be significantly improved. These developments may also provide a more enjoyable working environment where factors such as stress and fatigue will no longer affect the operators of ships on land to the same extent as they would be involved in onboard conditions. Further reasons behind maritime accidents, indicatively incorrigible or incorrect map calculations or weather conditions, will also be eliminated [52].

In addition to protecting human life, another potential benefit is that fuel costs are practically eliminated by reducing the introduction of productivity gains. Furthermore, crew costs – including catering costs, equipment, crew accommodation and other amenities, and their salaries where seafarers can achieve 10 – 44% of the operating expenses the owner saves by the nature of the ship a significant profit. On the one hand, it is evident that the cost savings associated with the operation of autonomous vessels lie in the elimination or reduction of the crew in it; on the other hand, additional features that allow the vessel to operate autonomously and additional staff will be housed in the land control centre to attend autonomous trips, which certainly need a significantly increased amount. However, unmanned ships should be able to operate more efficiently, thanks to a more efficient energy management system and improved navigation and routing systems. Most importantly, it makes sense for the boat to be more aerodynamic without the superstructure, such as decks and accommodation spaces. This will reduce the overall resistance of the vessel, thereby increasing efficiency and reducing fuel consumption and operating costs [53, 54].

Last but not least, autonomous transport will reduce fuel emissions as automation allows unmanned ships to sail more efficiently and consume less fuel, thus reducing the environmental pollution. Due to the integrated accommodation infrastructure, the vessel's smaller deadweight is the same. Furthermore, the cost may be reduced if the various actors in the shipping and port industry cooperate in time. All interested parties can coordinate their schedules, depending on how the goods are shipped, and exchange the information they have. The alternative fuel use is the slow use of steam, which is an essential solution in times of falling demand and the ample supply of ships for economic reasons crisis. Its use reduces carbon dioxide emissions and fuel costs by reducing consumption, and, as a result, unmanned ships are expected to be less polluting than conventional ships. This mode of transport can make ships more environmentally friendly thanks to the slow steam. Slow vaping is the practice of operating cargo ships, especially even if the speed of the container ship is significantly lower than its maximum speed [55, 56].

10.2 *Disadvantages of autonomous vessels*

The main disadvantages associated with autonomous vessels are attributed to the cost of construction, the on-shore management of the vessels, safety issues, and macro-economical consequences related to the changing pattern of employment in shipping [57].

To begin with, the construction cost of building a ship with the technology required to be remote or independent can be significantly higher than a regular vessel. Moreover, the automation systems required for these ships have nothing to do with regular ships. Now, today's shipyard workers cannot cope with the new conditions. Most likely, they need further training - which means augmented costs - and recruitment of new ones with specialisation and knowledge of autonomous ships, which means increased labour costs since the salaries of shipbuilding units will increase. In conclusion, the shipowner bears the improved maintenance services and fees [58, 59].

Proceeding with the vessel's management, an autonomous vessel's control lies with the pilot in charge of the Shore Control Center. The pilot will monitor the ship from its embarkment until it reaches the port, where it will be temporarily manned until the loading and unloading process is completed. The pilot's idea raised many questions about the safety of the ship because the remote control can be lost at any time in there and the boat will thus remain unattended until the control centre regains access, which is very dangerous, not only for the ship itself but also for other ships that happen to be sailing nearby. Staff members will carry out active activity on the high seas to be alert daily and solve problems. It will participate, for example, in very active to less active tasks, so monitoring ships from the coast can perhaps facilitate other types of human errors [60,61].

Although unmanned vessels are expected to be safer, several safety, regulatory and legal issues must be resolved before fully adopting autonomous navigation in shipping. This process will take a long time as maritime law and conventions are revised and adapted to meet the needs of autonomous ships to adapt to the new chain of responsibility. Also, as mentioned above, vessels are designed to eliminate human error, which is the leading cause of marine accidents. The relevant research results show that the accident rates, such as collisions and others, will be significantly reduced. However, scenarios involving extreme cases, i.e. fire or structural damage to the vessel, or cases where partial or total loss of control occurs as a result of a maritime disaster, have yet to be thoroughly analysed and processed, leaving a gap in risk management-wise [32, 62].

Finally, the demand for active seafarers will gradually decline. Consequently, it should be expected that many existing crews will lose their jobs, which will increase over time. This phenomenon can cause massive socioecononomical issues, as this changing employment pattern must be addressed internationally; the positive externalities that seafarer income has for the immediate and broader social environment are undoubted, and the impact of its reduction will be tremendous [58].

11 CONCLUSIONS

In the last decades, many navigational systems have been introduced, changing the face of the maritime industry. In the Fourth Industrial wave, new technologies based on innovation, such as the Internet of Things or AI, have made fully autonomous vessels feel closer than ever. The adoption of unmanned vessels will reshape maritime transportation, excluding the physical interaction of human elements initially the physical and any exchange in the final stage of their operation.

Currently, the importance of human interaction for the efficient operation of those systems and the proper assessment of the relevant information is undoubted. However, unmanned vessels are primarily expected to redefine maritime transportation by minimising or eliminating human error, possibly leading to substantial economic, ecological, safety, and security benefits. Potential hazards (e.g., fire, structural or mechanical damage, etc.) and obstacles (e.g., responsibility, building and control centre functions, etc.) must be identified. Furthermore, changes in construction and communication technology costs will be counterbalanced by more cost-effective routes, using Big Data, and eliminating crew costs. However, the need for the human factor will remain for some time, as autonomous vessels will require human surveillance, control and intervention through an on-shore control centre.

While a highly crucial issue for the condition and development of the shipping industry, and despite the various challenges which might logically emerge as a result -indicatively, safety, regulatory, and monitoring-only the industry-wide deployment of those vessels will allow for the extraction of more safe conclusions regarding the adoption of those new technological innovations. One thing is certain: the shipping industry will never be the same.

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