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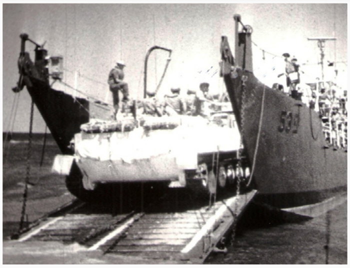

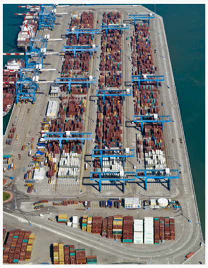

The Challenges in Operating Autonomous Vessels in an Era of Globalization –The Case of Autonomous Cargo Ships

Roi Naglar

Major technological changes in the world of shipping have in the past led to major transformations in the global economy. It may be that the shipping industry is currently confronting "disruptive"[1] technology in the form of autonomous technology,[2] which has the potential to change the global shipping market and to have a major impact on the global economy.

The goal of this chapter is to review the existing situation in commercial autonomous shipping and the challenges it faces, alongside the economic, social and political potential implicit in autonomous shipping.

Introduction – Society, technology and autonomy

The influence of autonomous technology on society, the ability to assimilate this technology and the implications of its introduction have been studied since the end of the 19th century, with the introduction of automization (in the form of machines that could do a predetermined number of actions without the intervention of an operator) in the textile industry and the replacement of workers by machines.[3] Already on the appearance of this technology, thinkers such as Adam Smith and Karl Marx pondered its implications for society. The main question that arose was what opposition there would be if the demand for labor declined and if the technology indeed would replace human beings. These questions highlighted the close connection between technology and society.

New technology is shaped by the society that develop it, but once the technology is introduced, it is the technology that shapes society.[4] The absorption of technology in society is the result of power struggles and negotiations between various groups

1 Disruptive innovation is a term that originated in the world of technology and it describes innovation that leads to the creation of a new market, and later on to the disruption of the existing one (the traditional market) until the new category becomes dominant and displaces the traditional category.

2 An autonomous system is one that carries out its task completely independently or semi-automatically or under supervision, when it operates under conditions of uncertainty. The system responds accordingly to the existing situation, which is in contrast to an automatic system that repeats the same action independently of its environment.

3 Moraes-Neto, Benedito. 2004. ‘Automation and Labor: Is Marx Equal to Adam Smith’. *Rethinking Marxism* 16(4): 407–22. https://doi.org/10.1080/0893569042000270898

4 Enduring, T H E, and Dilemmas of. 1995. ‘TECHNIQUE Langdon’, 67–72.

within society, where each group pulls in the direction that advances its own interests. The final result of the introduction of technology is that the group which managed to advance its interests in the most effective manner is the one that will shape the technology, rather than the technology meeting a real need that will generate efficiency and benefit for all.[5] Elements of nationalism, national security and the global economy are added to the mix, which increases the complexity of the interactions between the various players.

The shipping industry is an example of a socioeconomic structure with a large number of players with different interests and from different countries.[6] The socioeconomic structure of the shipping industry in unique in view of its high level of globalization, which involves an encounter between players on different types (nation-states, commercial players, regulatory authorities, etc.) within a changing regulatory environment (laws of flag state, ports, international waters, straits, etc.) and as such it constitutes a unique environment with respect to the manner in which it reacts to technological change.

Autonomous ships in the world of shipping

Commercial shipping is spread out all over the globe and is considered to be an important lifeline of global society. Currently, about 80 percent of all global trade is seaborne;[7] nonetheless, the rate of penetration of new technologies into the shipping market is slow relative to other domains.[8] During the past two years, the International Maritime Organization (IMO) has held discussions and conferences in order to determine whether to permit the use of autonomous commercial ships[9] and it has sought the opinions of the relevant players on this question.

As mentioned, changes in the world of shipping have led to a number of revolutions in the global economy.[10] The main ones have been the transition from ships propelled by rowing to large sailing vessels, which shifted control of the seas from the Ottoman Empire in the direction of Western Europe. The next transition was from sailing ships

5 Erez, Ram, the Hebrew University, "The politics of innovation: Networks as an area for change in Israel’s defense policy" (2009). [Hebrew]

6 Hannigan, John. 2017. ‘Toward a Sociology of Oceans’. *Canadian Review of Sociology* 54(1): 8–27. https://doi.org/10.1111/cars.12136

7 Review of Maritime Transport 2018, UNCTAD https://unctad.org/en/Pages/Publications/Review-of-Maritime-Transport-(Series).aspx

8 Rødseth, Ø. J., & Burmeister, H. C. (2012). Developments toward the unmanned ship. In *Proceedings of International Symposium Information on Ships–ISIS* (Vol. 201, pp. 30-31)

9 IMO: http://www.imo.org/en/MediaCentre/HotTopics/Pages/Autonomous-shipping.aspx

10 Fischer, Lewis R, and Even Lange. 2019. ‘Introduction’, 55–58.

to steamships propelled by coal and finally from steamships to ships propelled by fuel oil. These change brought with them the ability to transport large quantities of cargo of many types and led to the shift in center of gravity in global trade.[11] In recent years, we have been witness to a shift of global trade in the direction of East Asia, and with it dominance over the shipping market.[12] It may be that part of the interest that is driving the shift to autonomous ships is the attempt by interested parties in the European nations to maintain dominance over trade routes, by means of a technological revolution, namely the introduction of autonomous ships, in the domain of commercial shipping.

One of the main questions relating to the development of autonomous commercial shipping is whether this capability is the outcome of technological determinism, which the integration of technology simply because it exists or whether there is a real need filled by the autonomous technology. The answer to this is provided by examining the feasibility of developing autonomous ships and the main factors that justify the development of this technology, which are as follows:

Safety – Improving the safety level of shipping and cargo, reducing the number of maritime accidents and the severity of their outcomes.

Ecology – Transport of cargo that is more friendly to the environment, in terms of both direct pollution from ships (such as greenhouse gas emissions) and greater safety (see above) which reduces sea pollution incidents as a result of accidents.

Economic – Reducing the cost of transporting cargo and increasing its volume and greater efficiency in the supply chain (see below).

Social – Opening up the world of sea trade to additional sectors, raising maritime awareness and development in peripheral areas.

Political – Preserving political control of important trade routes.

Obstacles on the way to full autonomy

The ability to integrate autonomous ships must first be given a solid regulatory foundation. The regulation to be introduced can provide an indication of the technological hurdles that must be overcome in order to fill in regulatory lacunae. This will make it possible to better characterize the engineering needs of autonomous ships. The path to the integration of autonomous ships (given that the business model has been examined and found to be feasible, as will be described below) starts with mapping the regulatory lacunae.

11 Rødseth, Ørnulf Jan. n.d. ‘Developments toward the Unmanned Ship’, no. 314286

12 Ibid., UNCTAD.

Apart from the specific capabilities that exist on a ship, the regulations that need to be approved are influenced by a number of mutually dependent factors. The main factors that play a role in defining future regulation are as follows: [13]

Regulation of the legal domain – Unmanned ships are operated from control centers located in various countries; they sail in the sovereign waters of various countries; and they operate in the same environment as manned ships, all of which call for new legal regulation.[14]

Rules of Navigation at sea and prevention of collisions – The IMO is the UN committee that establishes regulations for ship traffic. It establishes laws and rules for ship safety and regulates sea traffic in order to ensure safe sailing and prevent ship collisions. These laws were formulated by a subcommittee called COLREGS (Convention on the International Regulations for Preventing Collisions at Sea). A reexamination of the rules of navigation at sea is necessary in view of the hybrid situation that will exist in the future (the simultaneous presence of manned and unmanned ships) and the expected behavior of unmanned ships. For example, there may not be the possibility of creating direct contact in the short run between two captains in order to prevent a collision, a possibility that does exist today, and it will be necessary to change the rules of navigation (such that there may be ship lanes in which only unmanned ships can sail).

A change in the composition of manpower operating a ship – The transition to unmanned ships will bring about a radical change in the composition of manpower and the number of crew members that will operate a ship. These changes will call for a change in the level of training and in salaries, as well as a transition period that may create opposition from unions and from developing countries whose citizens are employed on ships.[15] The transition period may arouse additional opposition as in the case of similar technological developments in the past.

Reduction in the environmental impact of sea transport – One of the justifications for the feasibility of developing autonomous capability should be the avoidance of much of

13 Chwedczuk, M. (2016). Analysis of the legal status of unmanned commercial vessels in U.S. admiralty and maritime law. *Journal of Maritime Law and Commerce*, 47(2), 123-170; IMO Committee, 2018: Committee, Maritime Safety, English Regulatory, Scoping Exercise for the, U S E of, Maritime Autonomous, and Surface Ships. 2018; Maritime safety committee 99th session Agenda item 5 MSC 99/INF.3 18 January 2018 regulatory scoping exercise for the use of maritime autonomous surface ships (MASS).

14 Chwedczuk, Michal. 2016. 'Analysis of the Legal Status of Unmanned Commercial Vessels in U.S. Admiralty and Maritime Law'. *Journal of Maritime Law and Commerce.*

15 Huang, C. Y., & Nof, S. Y. (2001). Automation Technology. Handbook of Industrial Engineering: *Technology and Operations Management*, 155-176

the maritime environmental damage caused by commercial ships. The IMO has defined the reduction of environmental harm originating from ships as one of the main targets of the shipping world, which is to be accomplished by reducing pollution from ships, the regulation of dumping of bilge water and ballast water at sea, etc. The changes in regulation in favor of autonomous capabilities must be part of this effort by the IMO.

Modifying port and ship infrastructures – The justification of autonomous capability is that ships will be able to sail without a crew. This will require a redefinition and modification of infrastructures in the ports, at port entrances (defining the arrival of the pilot) and of the ships themselves. For example, a solution will needed for the absence of technical crew members on a ship who can make repairs and as a result there will be a need to increase the reliability and redundancy of the main systems on a ship.

Responsibility and ship safety – Ship safety currently relies on meeting the IMO's regulatory standards for technical systems and also on the professionalism (seamanship) of the ship's crew. In the event of an accident, responsibility is determined on the basis of the crew's performance. The IMO's guidelines state that "…every ship will have certified officers on it who have appropriate training and on whom rests the legal responsibility to prevent accidents."[16] A fully autonomous system that makes decisions and maneuvers the ship based on those decisions will raise questions of responsibility in the event of an accident. For example, does the responsibility rest with the supervisor located in a far-off control room, on the developer of the algorithm that operates the ship, on the developer of the hardware and the physical equipment (such as electronic sensors) or on ship owners?[17] Such questions remain open as of now and need to be answered.

Cyber security – Currently, ships are not online most of the time, their navigation and maneuvering systems are isolated and the ability to damage the software of these systems is relatively low.[18] Autonomous ships that are remotely controlled will have to be constantly connected to an information system that will be vulnerable to attack. Currently, when a maneuver is carried out by a crew member, even in the case of a cyber attack, there is a crew member who can "take the wheel". In contrast, in the case of a cyber attack on an autonomous ship this crew member is not present and the ship's systems will have to be better protected than they currently are, including the network that supervises the autonomous ship and its degree of control. The various

16 IMO 94 4.B.

17 Chwedczuk, Michal. 2016. 'Analysis of the Legal Status of Unmanned Commercial Vessels in U.S. Admiralty and Maritime Law'. *Journal of Maritime Law and Commerce*.

18 IMO Committee, 2018

categories that need to be examined are interrelated and overlapping and there is no single category that stands alone. A change in the operating crew will require a change in regulations to prevent collisions and vice versa. All this will require cyber security and new legal and insurance frameworks. The relations between the categories can be seen in Figure 1 below. At this stage, the IMO is still mapping out all of the regulatory lacunae in the domain of autonomous ships, although it is still in the stage of finding solutions, whether regulatory or technological.

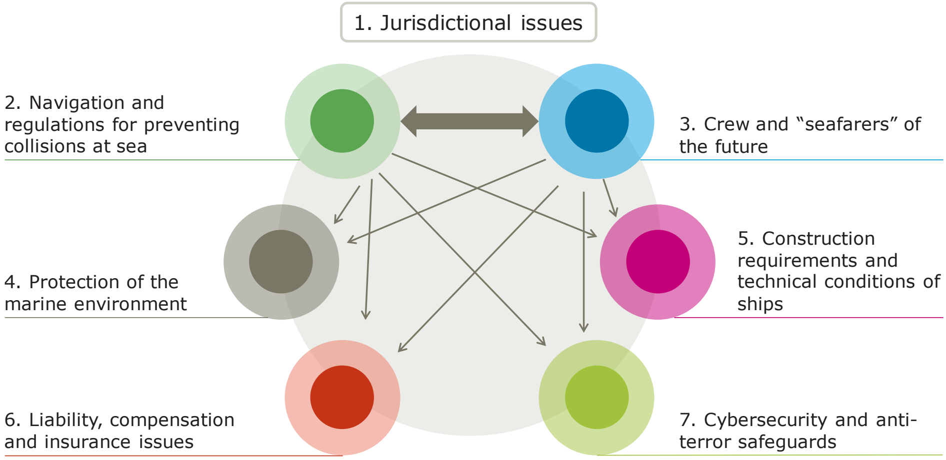

Figure 1: The categories and components of the required regulatory changes and the relations between them[19]

The feasibility of developing autonomous ships

Technology in general and autonomous technology in particular in the world of shipping lags behind other industries, such as air transportation and automobiles.[20] Artificial intelligence capabilities, including a system's ability to learn on its own, are path-breaking technologies that have the ability to bring about a technological revolution in many domains. The main question to be asked is whether the examination of the technology and the start of development of autonomous technology are the result of technological determinism? According to this approach, technological progress is an irreversible and inevitable process which has far-reaching implications for the social

19 ANALYSIS OF REGULATORY BARRIERS TO THE USE OF AUTONOMOUS SHIPS, Danish Maritime Authority Report, By Ramboll and CORE Advokatfirma. Denmark, December 2017 https://www.dma.dk/Documents/Publikationer/Analysis%20of%20Regulatory%20Barriers%20to%20the%20Use%20of%20Autonomous%20Ships.pdf

20 Ibid., Huang and Nof.

structure and the division of power between various groups in society. According to this theory, technological progress is what creates new technologies rather than social-sociological needs leading to technological progress.[21] A more sophisticated model is that of the competitive network, which explains the ability to introduce a technology into a social structure as the result of a power struggle between various players that make up the sociological structure.[22] Thus, there is a connection between the structure of the social-sociological body and the ability to introduce technology. According to the network model, there is a close relationship between the technological solution that in the end is attained, and the characteristics of the network that makes up the social structure.[23] The artificial intelligence technology that led to the autonomy of transportation vehicles such as drones has existed for a number of years, and there is a need to determine whether there is a real need to adopt it in the world of shipping or that its very existence led to the start of its introduction, as explained by the technological determinism model or whether the pace of its introduction is determined by conflicts between the bodies that determine regulation on the conceptual level (the IMO committees) as posited by the network model. It can be assumed that indeed there are socioeconomic needs that autonomous ships can meet and that there are a number of major advantages in the development of autonomous commercial ships that make the development of the technology worthwhile:[24]

Economic sustainability: Autonomous ships will make crews redundant and will save labor costs, which account for about one-third of a commercial ship's operating expenses (depending on the ship's size, its type and its age; see table 1).[25] The reduction in the size of a ship's crew less the additional manpower needed in the control room will result in a saving of about 10 percent of the total average cost of a voyage.

In addition, an unmanned ship will make it possible to reduce the ship's speed and thus to increase its efficiency (since one of the constraints that dictates a higher speed on a voyage is to arrive as quickly as possible in order to save on the payment of the high salaries of crew members during a sea voyage). The reduction in speed will reduce the consumption of fuel and will increase profitability.

21 Ibid., Erez.

22 Enduring, T H E, and Dilemmas Of. 1995. 'TECHNIQUE Langdon', 67–72.

23 Erez, Ram, "The politics of innovation: Networks as an arena for change in Israel's defense policy (2009), the Hebrew University of Jerusalem, n.d. [Hebrew]

24 Rødseth, Ørnulf Jan. n.d. 'Developments toward the Unmanned Ship', no. 314286.

25 OPEX- ship operating expenses.

Table 1: Percentage of manpower costs according to type of ship, in millions of dollars[26]

	Daily operating costs in US$ per day						
	Handysize	Handymax	Supramax	Panamax	Post Pmax	Capesize	VLCC
#Ships (2010)	2963	2124	n/a	1412	387	921	197
#Crew	18	18	18	19	20	20	22
Manning	1.779	1.779	2.247	2.359	2.366	2.648	2.662
Insurance	655	720	770	785	790	1.030	1.190
Stores/Lubes	610	625	650	770	780	875	1.010
M&R	1.590	1.634	1.837	2.099	2.370	2.622	2.765
Admin	651	651	700	749	793	837	833
Total OPEX	**5.285**	**5.409**	**6.204**	**6.762**	**7.099**	**8.012**	**8.460**
Man/OPEX	34%	33%	36%	35%	33%	33%	31%

Ecological sustainability: Pollution and harm to the maritime environment and the coasts due to the human element is particularly serious. This is the result of mistakes in the pumping of liquids within the ship and dumping out at sea. Other causes of pollution are the bilge water created by crew members which is dumped at sea and garbage (such as food leftovers) that are thrown overboard during a voyage.[27] The saving in time on a voyage and the reduced speed will also result in a significant reduction in emissions of air pollutants. Unmanned ships will lead to the optimization of sailing speed, a reduction in the amount of dumping and the prevention of maritime pollution as the result of human error.

Social sustainability: The world of shipping is perceived as a man's world, since most of the positions on a ship are filled by men. This is a result of the need to leave one's family for long periods while the ship is at sea. The nature of the work has prevented large number of women from working on ships. An autonomous ship will be operated from a control room, which will be manned according to normal shifts, thus allowing operators to be with their families at the end of a shift. The change in the character of ship operation will facilitate the integration of women as ship operators. In addition, and in view of the large communication distances between the control room and the ship, there will be no need to locate the control room near a port or even near the coast. It will be possible to locate control rooms in peripheral locations and thus to encourage higher-skilled employment in these areas, as well as increasing maritime awareness.

Prevention of collisions: According to a 2012 report published by the German Marine Insurance Association, between 75 and 96 percent of maritime collisions are the result human error, which is often due to fatigue.[28] It is estimate in the automobile industry

26 Rødseth, Ørnulf Jan. n.d. 'Developments toward the Unmanned Ship', no. 314286.

27 Ibid., IMO Committee, 2018

28 Porathe, Thomas. 2016. 'Autonomous Ships PPT', http://onlinepubs.trb.org/onlinepubs/mb/2017Spring/Porathe.pdf

that close to 92 percent of accidents are the result of human error.[29] In view of the accumulation of experience in the operation of autonomous automobiles starting from 2007 it is expected that casualties in vehicular accidents will be reduced by 90 percent[30] thanks to the increased use of decision-supporting autonomous systems (see Figure 2). Maritime collisions cause casualties, they result in air pollution and they lead to high insurance premiums. Reducing the number of maritime collisions will have an impact on other aspects of the environment (such as prevention of huge oil spills as a result of collisions), the economy (reduction in insurance premiums that will reduce shipping costs) and of course personal safety of the crew. The removal of the human component from the decision-making process in the remote control of autonomous ships is expected to significantly reduce the number of maritime collisions.[31]

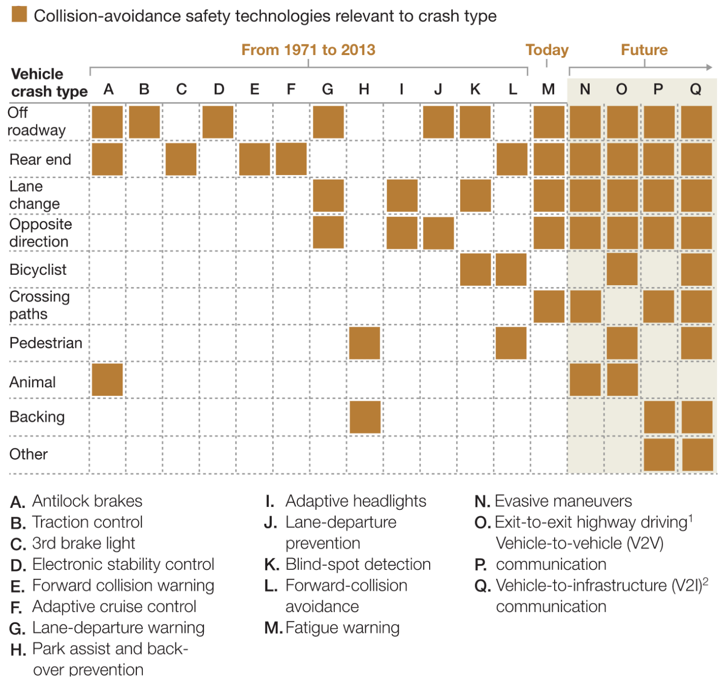

Figure 2: Decision-supporting systems for vehicular accident prevention[32]

29 Frey, Carl Benedikt. The Technology Trap . Princeton University Press.2019 p 309.

30 Jean-François Bonnefon, Azim Shariff, Iyad Rahwan, The social dilemma of autonomous vehicles, Science Vol 352, Issue 629 24 June 2014.

31 Chwedczuk, Michal. 2016. 'Analysis of the Legal Status of Unmanned Commercial Vessels in U.S. Admiralty and Maritime Law'. *Journal of Maritime Law and Commerce*; IMO Committee, 2018.

32 P. Gao, R. Hensley, A. Zielke, "A roadmap to the future for the auto industry," McKinsey Quarterly (October 2014); www.mckinsey.com/industries/automotive-and-assembly/our-insights/a-road-map-to-the-future-for-the-auto-industry.

In sum, it appears that from a feasibility point of view there are significant elements that an autonomous ship will improve and they may constitute an advantage for many population groups around the world and in a number of ways, including preserving the environment and reducing shipping costs.

In addition to economic and environmental sustainability, there is also the issue of political-economic sustainability, particularly in the case of Western countries. In recent years, Western Europe has become less dominant in maritime commerce. This is the result of a decline in maritime awareness among the population in these countries. This process began with the reluctance in these countries to work on ships.[33] Ships' crews originate, for the most part, from Asia and Eastern Europe and this pool also provides ship captains who later in their career become managers in the shipping companies. Another stage in this process occurred as the shipping companies came under Asian ownership, such that Western European countries were no longer owners of the ships or operating the shipping routes. Autonomous capability together with the operation of ships from control rooms on dry land will require trained manpower that will work under more convenient and more technologically advanced environment. These control rooms will make it possible for crews in Western Europe to operate the ships and in this way the dominance of Western Europe in shipping can be maintained. Maintaining control of the shipping routes creates a clear interest among the Western European countries to support and advance the shift to autonomous ships, in contrast to the interest of developing countries, such as India, the Philippines, Ukraine, etc., who currently provide the crews for ships.

The current status of autonomous ships worldwide and in Israel (the Mediterranean) in particular

As of today, there are no local or international regulations that relate to the use of autonomous ships.[34] Nonetheless, there is progress in research and testing of autonomous ships being carried out by private companies and navies. Most of the information in this essay was gathered from the publications of commercial companies rather than from academic articles.

The Rolls Royce company together with the Kongsberg company have published a roadmap that emphasizes the importance of autonomous ships and the path to achieving that capability.[35] The document describes the process by which they intend to develop an autonomous ship, including a detailed specification of such a ship. The

33 Rødseth, Ørnulf Jan. n.d. 'Developments toward the Unmanned Ship', no. 314286.

34 Ibid., IMO committee 2018.

35 Levander, O. (2017). Autonomous ships on the high seas. IEEE Spectrum, 54(2), 26-31

Company, together with Finnferries, a Finnish-owned ferry company, demonstrated the first autonomous ferry in 2018 which operates in an archipelago south of the city of Turku.[36] The Company has also developed an advanced research facility at Turku with the goal of developing the technologies necessary for a future autonomous shipping industry.

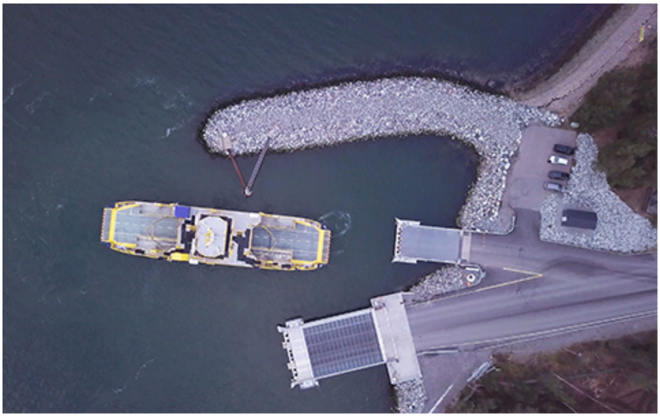

Figure 3: An autonomous ferry of the Kongsberg and Rolls Royce companies operating in Finland[37]

According to reports, the US navy has successfully sailed a Medium Unmanned Surface Vehicle (MUSV) from San Francisco to Pearl Harbor and back (on the way to Pearl Harbor a technical intervention became necessary in order to repair piping).[38] The EU has published its multi-year R&D plan (Horizon 2020) which includes the development of autonomous ship technologies[39] while the IMO has already held a number of conferences on the subject and has issued a work plan for developing regulation in this domain.[40]

China is currently at the forefront of research in autonomous ship technology, together with the Scandinavian countries and the US. This can be seen in the testing, research

36 ROLLS-ROYCE and FINFERRIES demonstrate world's first fully autonomous ferry' https://www.oneseaecosystem.net/rolls-royce-and-finferries-demonstrate-worlds-first-fully-autonomous-ferry

37 Ibid.

38 Sea Hunter Unmanned Ship Continues Autonomy Testing as NAVSEA Moves Forward with Draft RFP, https://news.usni.org/2019/04/29/sea-hunter-unmanned-ship-continues-autonomy-testing-as-navsea-moves-forward-with-draft-rfp

39 Autonomous Shipping Initiative for European Waters, https://trimis.ec.europa.eu/project/autonomous-shipping-initiative-european-waters

40 Ibid., IMO committee 2018.

and articles being published in China on this topic.[41] China's project to develop an autonomous ship reached an important milestone with the launch of the country's first autonomous cargo ship, the Jin Dou Yun O Hao, which at the end of 2019 completed its first trial voyage. The Chinese company Yunzhou Tech (which specializes in projects involving the use of unmanned vessels to carry out surveys) began the project in 2017, together with the Wuhan University of Technology.[42] In collaboration with the port of Shanghai, a simulator was built to test the decision-making system which is based on a database of decisions made at sea.[43] The city of Zhuhai is currently developing a special testing area for autonomous ships, as part of its plan to develop an industrial platform for this new sector. The maritime testing zone, called Wanshan, will cover an area of 77.6 square kilometers and will become the largest testing area in China and the world for autonomous ships.[44]

Figure 4: The autonomous ship Jain Doui Yun O Hao[45]

In Israel, there a number of programs to develop an autonomous ship but all of them are for military purposes. These vessels carry out maneuvers and missions in the Mediterranean and some are even operational. The Protector USV, developed by Raphael, is a 15-meter long patrol boat that is already in service with the Israeli

41 Department of Maritime Operations, University of South-Eastern Norway, Horten, Norway.

42 https://www.marinetechnologynews.com/companies/company/yunzhou-tech-200990

43 Xue, Jie Van Gelder, P.H.A.J.M. Reniers, Genserik Papadimitriou, Eleonora Wu, Chaozhong Elsevier Ltd 2019 Multi-attribute decision-making method for prioritizing maritime traffic safety influencing factors of autonomous ships' maneuvering decisions using grey and fuzzy theories.

44 https://www.port2port.co.il/article/ הובלה-ימית/ספנות-קווית/סין-אנייה-אוטונומית-ראשונה-סיימה-הפלגת-מבחן-בהצלחה

45 "China: The first autonomous ship successfully completed a test voyager", port2port, December 16, 2019.

navy and has participated in a number of NATO exercises.[46] The Elbit company has launched a similar ship called the Seagull, which is the same size as the Protector and has capabilities for towing arrays such as sonar, for surface protection and for mine detection. It is already in service with the Israeli navy.[47] A similar ship, called the Katana, was launched by Israel Aircraft Industries[48] and has similar abilities to the ships developed by Raphael and Elbit. In the underwater domain, Elta has developed an unmanned diving vessel with the ability to replace sensors and to carry out operational missions. It appears that Israeli industry is well advanced in the development of autonomous vessels but this is being done only in the military domain.

As of today, the development of autonomous maritime capability is concentrated among a small number of technological companies, in contrast to the regulatory issues which are receiving much wider attention in the IMO committees.

Figure 5: From left to right: The Protector developed by Raphael,[49] the Katana developed by Israel Aircraft Industries[50] and the Seagull system developed by Elbit[51]

Conclusion and Recommendations

The survey of the advantages and disadvantages of autonomous ships indicates that there is a genuine need for this technology. Nonetheless, the current regulation of the domain is far from providing a solution to the introduction of this capability, particularly in the hybrid stage when there are both manned and unmanned ships in the same environment.

46 https://www.rafael.co.il/worlds/naval/usvs

47 Seagull™, Elbit Systems' USV Performed Live Remotely Operated Anti-Submarine Warfare Mission, https://elbitsystems.com/pr-new/seagull-elbit-systems-usv-performed-live-remotely-operated-anti-submarine-warfare-mission/

48 KATANA USV System https://www.iai.co.il/p/katana

49 see footnote 46.

50 see footnote 47.

51 see footnote 48.

The solution to the regulatory lacunae and the ability to apply the technology should be multilayered, with regard to both the levels of autonomy to be introduced and the environment and situation in which they will be introduced. This guideline is based on the idea that the more crowded an environment is, as in the case of narrow straits and harbor entrances, the lower the level of autonomy that should be implemented in that environment (at least in the initial stages). Over time, with the improvement in technologies and the increasing level of reliability of the systems, the level of autonomy that can be introduced in complex and crowded environments can be raised. In view of the regulatory processes needed to achieve international consensus, it is possible to begin with local operation of autonomous ships in an environment that does not span any international boundaries, as in the case of the Finnish ferry described above. As mentioned above, Israel has proven abilities in the domain of unmanned ships, primarily for military use. In view of the commercial potential and the huge size of the global shipping market, it is worthwhile encouraging the commercialization of these military technologies by means of various industrial development measures, such as support from the Innovation Authority on various tracks (grants, technological incubators, etc.), the establishment of commercialization bodies and arenas for testing the feasibility of new technologies to be operated by Israeli players in the maritime domain, such as the ports of Haifa and Ashdod, and also dealing with regulatory aspects, such as defining a maritime zone for testing the technologies.

In conclusion, developing autonomous capabilities appears to be worthwhile and feasible and will bring about significant improvements that will benefit shipping and society in general, although a multi-faceted plan is needed for the implementation of this technology.