Maritime Research and Technology
MRT
ISSN 2812-5622
http://dx.doi.org/10.21622/MRT.2022.01.2.059

Challenges and Smart Opportunities in Maritime Fields on Effects of 4IR and COVID-19 Pandemic

Hossam Eldin Gadalla [1], Ahmed Wael Shetewy [2] and Mohamed Essallamy [3]

[1] Head of Quality Management and Int. Accreditation Unit, MSI, AASTMT
[2] Deputy Dean, Maritime Safety Institute, AASTMT
[3] Head of Marine Accident Investigation Center, IMO Compound, AASTMT

Emails: hossameldin1@gmail.com, ahmedwaelshetiwy@gmail.com, messallamy@gmail.com

Received on: 12 September 2022 Accepted on: 04 December 2022 Published on: 15 December 2022

Abstract

Purpose: *The COVID-19 pandemic affected world trade, and the economy in addition to public health i.e. adding additional challenges and perhaps opportunities for the maritime industry and the importance of novel technologies. Novel technologies and high levels of automation in maritime transport imposed by the Fourth Industrial Revolution (4IR) are expected to contribute significantly to the changing of maritime operations sooner than expected. Ports are already facing enormous challenges in coping with recent trends including autonomous and mega-ships, and smart concepts such as cyber risks.*

Design/Methodology/Approach: *This paper focuses on a key aspect, i.e. how the maritime industry should adapt to accommodate and interface with 4IR i.e. accelerated after the pandemic. By an inductive and deductive approach, the research demonstrates the challenges facing shipping and ports in preparing for different 4IR challenges. The Suez Canal Economic Zone (SCZone) ports are taken as a case study, which should cope with these 4IR developments and overcome any future pandemic effects.*

For rationality, analyses are done for SCzone, as an example of how to remain competitive in international transport.

Findings: *Findings of the research found that developing countries should be eager to invest in capacity building and legislative adaptation before investing in infrastructure to cope with the latest technologies. Technical cooperation programs under international bodies e.g. IMO, inter alia, can play an important role in these required adaptation developments.*

Key-words:
Pandemic, Autonomous Ships - Ports, 4IR, Challenges, Opportunities.

1. INTRODUCTION TO THE PANDEMIC EFFECT ON MARITIME ACTIVITIES

The COVID-19 epidemic has dramatically impacted global trade. Many countries totally or partly shut down in successive waves; in effect, many trade transactions are slowed down, and maritime activities are significantly affected. Demand for ships for trade in a particular period resulted in a drop in fuel consumption, i.e. led to a significant prompt and instant drop in oil price. Many ships, as a result, found the longer path around the Cape of Good Hope cheaper than using the Suez Canal (SC) route. On the other hand, many oil tankers have been converted to storage tankers for the shortage of land-based storage in a stockpile market. Seafarers as well are dramatically affected, crew changes were banned in many countries, putting more additional burdens on seafarers, which may affect the safe operations of ships one way or another and triggered the need to accelerate autonomous ships applications. Technology advancements definitely induce challenges but can also create multiple opportunities.

The challenges of the Fourth Industrial Revolution (4IR) were considered burdens for developing countries. The 4IR is characterized by the adoption of artificial intelligence (AI) and increased levels of automation throughout industries. Automation and novel technologies are changing the economy, politics, community, and commerce. Consequently, jobs will become more demanding or shift to different economic sectors. In this regard, research can provide opportunities for making digital technology an effective instrument for positive transformation. Regional changes in transportation patterns are anticipated and the pace of incorporating AI into maritime transport sectors both onboard and onshore will have a significant influence (Schröder-Hinrichs, et al., 2019).

Developing countries, e.g. Egypt, should benefit the most from the introduction of 4IR technologies to overcome the market withdrawal of some mega-companies and encourage new foreign investments in its ports. For example, Piraeus port in Greece has attracted Chinese Shipping Line investments after becoming the most interconnected port within the Mediterranean Sea in 2019 (Heleinic Shipping News, 2019). In this regard, the authors of this study believe that Egypt is an example of good investment returns for its promised maritime trade markets thanks to the establishment of the Suez Canal Economic Zone (SCZone).

This study discusses the possible effects of the 4IR on different aspects of maritime transport, particularly, port challenges to survive the effects of the COVID-19 pandemic by using the recent high-tech era as a cure. Autonomous and mega-ships, sustainability, and cyber security are some of the challenges. The research illustrates two fronts of these challenges. First, the move towards digitalization and second, the introduction of mage and autonomous ships; the research exhibited a plan to deal with autonomous ships.

Egyptian ports, among other developing countries, are advised to cope with the research recommendation for developments in international shipping technology. Ports will need to adapt to interface with autonomous ships from one side, and on the other hand, to deal electronically with shippers, consignees and carriers.

A fast development of automation in ports is witnessed especially when compared to the introduction of autonomous ships on a commercial basis. This could be reasoned by the freedom of non-applying international law in port operation sectors versus shipping (Schröder-Hinrichs, et al., 2019). Ports are normally applying national laws, on the other hand, shipping is mostly governed by international requirements, which makes the applicability of innovative technology less flexible.

For example, the "East Container Delta Terminal" located in Maasvlakte in Rotterdam has become the world's first automated container terminal in 1993 (Schröder-Hinrichs, et al., 2019). On the other side, the agenda of Maritime Autonomous Surface Ships (MASS) was expected to be in place before 2035 as per the IMO (DNV-GL, 2018) i.e. accelerated due to the pandemic. Ships should be developed in parallel, not to ignore or resist the escalated development in ports.

MRT
ISSN 2812-5622
http://dx.doi.org/10.21622/MRT.2022.01.2.059

2. 4IR AND PORT OPERATIONS

With highly increased automation levels, the 4th IR is driving dynamic changes to industries i.e. will continue to impact all transport systems. Containerization, for example, brought us in the 1950s-1960s major changes in all means of transport profiles, e.g. cargo gear, ship design, port structures, and shortened turnover durations in ports. This section of the study provides illustrations of current and upcoming technological trends.

Maintenance activities could be carried out remotely from the shore side, for example, software updates by specialized crews may be dispatched on-demand when maintenance service is required on-site, (Schröder-Hinrichs, et al., 2019). Maintenance robots would help the crew in carrying out several repair tasks, especially in areas where it's difficult to reach the equipment; in these cases "drones" can undertake multiple potential hazardous inspection activities (Schröder-Hinrichs, et al., 2019). Furthermore, drones are used as an aid to future shore-based pilotage and optimizing port of calls, inter alia (Danish Maritime Authority & IALA, 2019).

Beyond screens, operators should also shift to utilize innovative methods of training and education. In this regard, Simulation, Augmented Reality, Virtual Reality and Mixed Reality are the upcoming future trends in maritime education and training institutions (Schröder-Hinrichs, et al., 2019).

Autonomous systems in vehicles and infrastructure operations would become a basic desire to catch the ride. Before the pandemic, the application of autonomous ships that are supervised by humans was anticipated to achieve an adoption rate of 11-17 % by the year 2040, it was also expected that the operations will be limited to domestic and specialized trades only (Schröder-Hinrichs, et al., 2019) but this scenario is accelerated after the pandemic. In the 100th meeting session held in 2018, the IMO's Maritime Safety Committee (MSC) approved the regulatory scoping exercise's framework for the use of autonomous ships as described below, and as illustrated in figure (1):

- **Degree one – Manned Ship:**
  The traditional way of working: A Ship with decision-support and automated processes but seafarers are present on board to run and manage shipboard systems and operations. Although seafarers on board are ready to take charge, some activities might be automated and occasionally run unattended.
- **Degree two – Remote Ship:**
  Increased sensors and decision-support: A Ship that can be remotely operated but has crew members on board. The ship is managed and operated from a remote location. on board, seafarers are ready to take command and control ship systems and operations when needed.
- **Degree three – Automated Ship:**
  Human-assisted autonomy: A Ship that is remotely operated and has no crew on board. There are no seafarers aboard as the ship is fully managed and operated from a remote location.
- **Degree four – Autonomous Ship:**
  Full autonomy: A Ship with Full autonomy where the ship's operating system is capable of decision-making and can determine required actions by itself. (MSC 100, 2018; UNCTAD, 2019).

MRT
ISSN 2812-5622
http://dx.doi.org/10.21622/MRT.2022.01.2.059

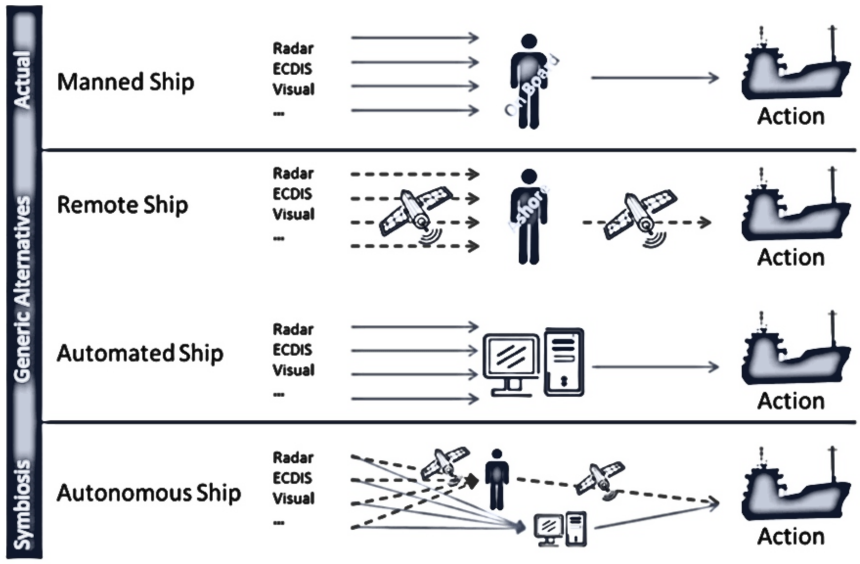

Fig. 1. Illustration of the 4 degrees of the autonomous ships.
Source: (MUNIN, 2016).

On the other hand, technological port infrastructure in developing countries should be examined with care for AI compatibility. New players would appear in the market to develop innovative types of services and platforms that can satisfy customers' demands and port service providers' assessments (MaaS, 2020). For less human interaction and port dues, new port technologies have been created, as in the case of the port of Rotterdam container terminal, to account for a sizable proportion of increased trade flows during the 4IR (Bernhofen, et al., 2016). As an ultimate benefit, Ducruet, et al., 2019, found a positive correlation between the effects of advanced port technologies and the attraction of investment and less use of land i.e. offering a new solution for land scarcity in some ports e.g. Port-Said west.

In the 4IR era, data will be the new role player since many services will have to emerge and cope with data management (EU Horizon 2000 Program, 2018). However, the inflexible flow of data may be witnessed for national security reasons. Horizon 2000 program – EU, 2018, depicts that knowledge sharing and feasible technology investments provide opportunities for the removal of existing operational problems and capacity constraints.

For example, Holm, (2019) presented Sea Machines' current projects. The project retrofitted a vessel with the equipment to merge sensors; through this, the crew will be able to see a centralized display. The pilot as well does not board the vessel but is fed data from the ship, including cameras and radar sensors that utilize the 4G network; 5G would be an added value. The benefits of the project are reduced transit risk, enhanced productivity, and increased operational data. The cons may be crew culture and worries including job losses (Holm, 2019).

However, technology incompatibility is a problem in the maritime industry; different regions of the world have developed their own digital solutions that might be incompatible with the technologies utilized in other regions. This could be a barrier to maintaining the safe and sustainable global movement of vessels and ultimately reducing the efficiency of the transport chain. Container ships waste an average of 6 % of their operation time at anchorage areas because of ports' delays which result in extra costs and risk of accidents (Rostopshin, 2019).

As a response to this issue, there are basic steps that need to be carried out to achieve the global harmonization of technological solutions:

- Define and publish the basic and unified solutions;
- Guide how contemporary technology can be utilized to apply solutions;
- Create an obligation to follow solutions;
- Publish how solutions have been implemented in any given geographical area.

This process should then be examined for e-navigation applicability with the proper security and share of natural resources (Eriksson, 2019).

In this regard, the national authorities can play a more active role in the implementation of e-Navigation technologies (Ismagilov, 2019). For example, E-navigation has been introduced in Russia through a range of state programs which have included the introduction of a new Vessel Traffic Service and an automated hydrographic trawling system. This carries a better solution to port congestions, which optimizes a ship's speed to coincide with the time schedules of the ports' terminals, enabling a substantial reduction in fuel consumption and better emission control. For example, a 10% decrease in the global fleet's speed would reduce 19% of CO2 emissions. The use of an IT solution based on real-time synchronization enables the optimization of a ship's speed with navigational routes for precise arrival timings (Rostopshin, 2019).

2.1. Future Scenarios and Impacts

Enhanced ship autonomy opens up opportunities for improved, safer, and more cost-effective operations with much less engagement of the human element, the primary cause of accidents. Many business impacts may be expected e.g. automated sailing without the intervention of humans, which could lead to fewer crew members and reduced ship operation costs (Negenborn, et al., 2018; Smart Port, 2019) since several occupations on ships will shift to shore side. In order to locate their berths, vessels will communicate their precise location and status to a lock or bridge entrance of ports (Smart Port, 2019). Furthermore, docking, lock, and bridge decisions should be taken automatically, taking into consideration the implications of all surrounding vessels' intentions when headed towards the same destination.

A Port Control Center (PCC) should be effective in monitoring, navigating, and controlling autonomous ships to investigate ports' impacts. The PCC's design could potentially pose a significant influence all over investment and operational expenses and present a serious challenge to stakeholders (Smart Port, 2019). Responsibilities and job description for a harbour master should be defined properly including levels of interventions and their timing. Repair docks should be also developed to host automated ships; investment in such services would need highly intensive and dynamic capital.

2.2. Smart Concepts and Cyber Security

'Working from home and online operations may solve some COVID-19 consequences but cyber security should be considered at all levels of companies.' Based on the cyber-attack on Maersk in 2017, inter alia, research has shown that 69% of Danish shipping companies have been attacked in 2018 (Steffensen, 2019). The IMO is a bit behind in maritime cyber security; only on 1st, Jan. 2021 cyber security embeds in the safety management systems of shipping companies.

In an automation era where many organizations' missions and fundamental tasks rely on IT, the capability to manage this technology and ensure information security, availability, and reliability is crucial (Secretary of Defense Office, 2017).

Many challenges are to be solved at the level of 'port' authorities and the relevant stakeholders on a global scale in terms of standardization of legal schemes and sharing data and information security under a sustainable cooperation scheme. To solve that, it is essential to identify challenges and find solutions to the applicability of digitalized maritime sectors in the most beneficial way by linking smart ports and autonomous shipping (Hong, 2019) under the best security practice. Electronic Navigation (E-Navigation) is lacking a mechanism to ensure the security of communication.

Cyber Security in e-navigation needs identification and authentication mechanisms; the Maritime Connectivity Platform and blockchains can contribute to cyber security in e-Navigation (Hahn, 2019). IACS and BIMCO, inter alia, have made recommendations on building cyber resilience and have been issuing guidelines for maritime cyber security. The most important pillars of effective cyber-resilient ships are:

1. Equipment software should be designed with cyber risks in mind;
2. Ships should be built in a cyber-resilient way.

To do so, **BIMCO** advises that:

1. *"The risks involved in cyber security are real and must be tackled at every stage;*
2. *To safeguard ships against potential cyber-attacks, cyber security should be in-built into the safety management system;*
3. *A cyber resilient ship is one where the software, hardware and operational practice are all designed to deter an attack;*
4. *Having a robust cyber security clause will protect the interest of ship-owners in the business arena." (Srinivasan, 2019).*

2.3. Mega-ships and Port Operators' Challenges

In a very dynamic market, the economy of size has changed dramatically i.e. adding a new concept to maritime economics. Mega ships would lead to larger peaks in ports and a need for bigger yards and larger demand for hinterland transport (International Transport Forum, 2015). 'Nearly 50% of the existing shipbuilding requests are concerning ships with a capacity of more than 12,000 Twenty Equivalent Units (TEUs'). Many ports in the USA have planned to invest billions of dollars to accommodate mega-ships, even though there isn't any assurance that mega-ships would include these ports in their potential destinations (Hacegaba, 2014).

With the estimated escalation in world trade i.e. expected to grow by 3.2% before 2022 (UNCTAD, 2018) port operators should be ready for activities impacted by innovations. Nowadays, some mega-ships can hold over 20,000 TEUs. Ports and Terminals must invest money in new cranes, extended dredging capabilities, strengthened jetty walls, and longer berths to be prepared for the upcoming era of mega-ships (Saxon & Stone, 2017; Smart Port, 2019).

Both developments in liner shipping and ports face technological races and challenges. A 24,000 TEU container ship would be difficult to host and manage from processes of cargo planning to stowage. The technological application may standstill in some developing countries to host and handle such mega-ships i.e. to be promoted in the industry race towards escalated technology compatibility.

Moreover, capacity building and fiscal and administrative factors should be considered in development to remain competitive. Consortiums should be invited to invest in developing countries (Baik, 2017). Furthermore, Baik, (2017) argued that cargo handling rates need to increase by 3 – 17%, depending on the increase in vessel size, to keep operational costs at the same levels. This could be difficult for some developing countries and SCZone without aid from industry tycoons.

Safety is another scope to be considered in ports and coastal seas; the larger the ship, the more costly it is insured, for the consequences of accidents on capital and environmental risks. In order to survive, shipping companies merged, and others made acquisitions or at least cooperated under some sort of alliance (Baik, 2017) to survive. Ports may also do the same: consolidation, alliances, merging or acquisition; technology should offer some solutions for bonding ports, which would be useful in cost reduction, slots and berths reservation and reducing waiting times. Under these solutions, members of a port alliance would share ship routing and schedules including terminals vacancies, operate under singular unified networks and share information on ports of call.

SCzone shapes a good opportunity for a regional port consortium. With their combined volume, Global Terminal Operators (GTOs) would have more favourable conditions for shipping liners, particularly mega-ships, and improved attraction for new companies. Mega ships and shipping alliances' growth means less ocean carrier product differentiation and more competition among ports. For better business attraction, GTOs will retain service differentiation by way of factors such as service levels, infrastructure, location, and inland connectivity. Moreover, the size of alliances allows SCZone to negotiate better cargo handling tariffs if proper networks are applied. SCzone offers a great opportunity to use 24/7 hinterland transport i.e. a great competitive advantage, assuming that customs and legislations are to cope with these smart port demands.

3. CASE STUDY: SCZONE

The SCZone is recognized as a trade hub and a world-class free zone of 461 km^2, about two-thirds the size of Singapore, where more than 10% of the world trade is passing through each year; The zone comprises:

- Two linked and integrated regions include two ports each; "Ain-Sokhna" with "Ain-Sokhna Port" & "East Port Said" with "East Port Said Port".
- Two development areas; Al-Qantara West, and East Ismailia.
- Four ports: West Port Said Port, Al-Adabiya Port, Al-Tor Port, and Al-Arish Port (SCZone, 2016).

The SCZone has been developed in 2016 to attract operators from all kinds of maritime, industrial, and commercial businesses all over the world to invest in Egypt under new economic incentives. SCZone gives a big opportunity to generate a competitive advantage against mega-ship owners, shipping liners, and other rival ports. Increase in efficiency and a reduction in turnover times, GTOs can effectively merge several terminals and operate as if they were one. The (6) ports of SCZone may cooperate with a GTO under one consortium.

SCZone ports are actively competing with other neighbouring countries' ports e.g. Piraeus in Greece under Chinese control and Jabbal Ali in UAE.

Fortunately, some SCZone ports have avoided a consistent decline in domestic container market share vis-à-vis container transit (Pallis, et al., 2017; Notteboom, 2016). The market share of at least East Port-Said demonstrates long-term progressive growth in the east Mediterranean (SCZone, 2016; SCA, 2017). Shipping liners indicate a preference to use a variety of ports rather than putting all volume at a single mega-port; SCZone introduces (6) ports against one in Greece, and another in UAE i.e. another competitive advantage.

Giving rise to the unique location, Africa and Middle East market access, feasible use of Egyptian labour, business-friendly process requests, better infrastructure and logistics hopes, and privileges offered to companies operating within the SCZone such as:

- A 100% company foreign ownership,
- A 100% foreign control of importing and exporting operations,
- All imports are free from sales tax and customs fees,
- Customs fees on exports to Egypt are only on the imported components but not the final product,
- Services of fast-track visa issuance (SCZone, 2016).

Suez Canal introduces a huge competitive advantage by being capable to host the largest container ship ever built (SCA, 2017; Essallamy, et al., 2019). However, investing in such a promising region still need some legislative, taxation, automation and networking adjustments for better attraction. Moreover, as SCZone depends mainly on investors to develop the infrastructure, investors are still in fear to put huge capital on land. Perhaps it would be better for SCZone to develop the basic infrastructure of business development to attract operators. Gap analyses may be a good approach for investor needs and the offered services particularly for the next generation of mega-ships, in order to end up with a win-win situation.

SCZone would leave a carrier fewer options to find a cheap port and less time to find direct calls, and it would remove some individual ports from the competition. Furthermore, it gives a shipping line less bargaining power against SCZone. If failed to react properly, it would be removed from the shipping schedule. Therefore, it should work on the development of abilities and its terminal capabilities including automation of services to survive. Figure (2) shows the SCZone integrated ports' locations, cargo service specialities, and the estimated transit time to linked Airports.

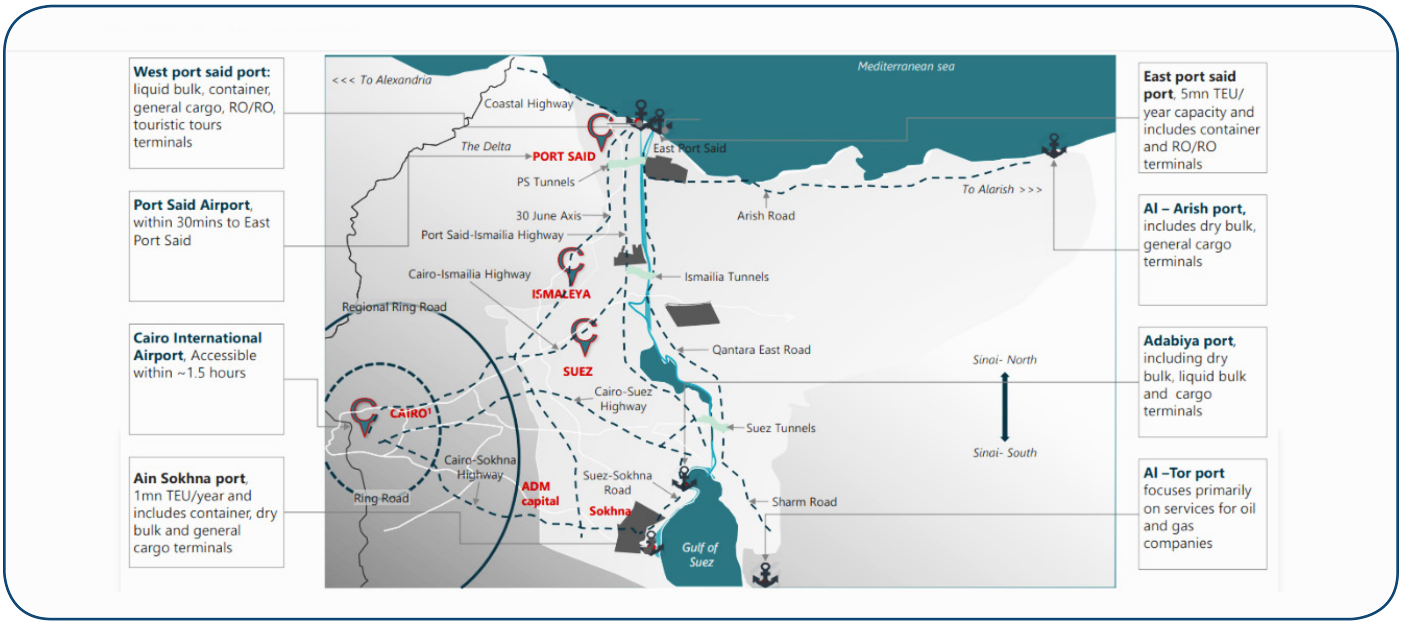

Fig. 2. SCZone ports
Source: (SCZone, 2016)

3.1. Sustainability and Smart Concepts

Environmental sustainability has recently turned into a major concern of the global maritime shipping strategy where multiple environmentally-related legislation and rules are influencing the dynamic nature of the shipping market (UNCTAD, 2019). In this manner, the SCZone ports should provide valuable services to its customers while maintaining a minimum of adverse effects on society and the environment. Considering the use of green fuel can be significantly essential for achieving this objective. For example, methane (or CH_4) is a fossil fuel that will most likely be a bridge technology towards the more intense use of green energy (EU Horizon 2000 Program, 2018) i.e. expected to show significant growth in the long run.

Sislian et al, (2016) described three primary perspectives that comprise the concept of port sustainability as follows:

1. *An economic perspective that considers the investments-returns, effectiveness of using the port area, and the infrastructure provision for improved companies' efficiency.*
2. *A social perspective that considers the contribution to increasing employment opportunities in multiple companies and operations related to the port operations and indirect employment created by the interaction and relationship between the port and the city, in addition to the contribution to the development of knowledge/education, and ultimately the livability of the geographical regions around the port.*
3. *An environmental perspective that considers the performance and management of multiple environmental aspects including pollution prevention, noise control, low emissions, minimized effects of dredging activities, and adequate disposal of wastes.*
(Sislian, et al., 2016; UNCTAD, 2009).

Digitalization would make shipping easier and more efficient: paperless bills of lading, e-certificates, and similar smart contracts improved trade flexibility and robust intelligent systems both onboard and onshore. Many of these technologies are currently being trialled in many countries. Therefore, governments, such as in the UK, work with industry and academia to develop a 'port innovation hub'. This hub could be a physical location provided in a port to generate opportunities for networking across sectors, creating industry partnership opportunities thus helping to develop expertise in maritime autonomy research and development (Department for Transport UK, 2019).

Another example can be given in communication scope i.e. necessary for the cargo owner, shipper and consignee including the carrier and the necessary port interface to deal accordingly. Intelligent Ship Reporting Gateway systems such as "I-Ship", which is a cutting-edge software application, have been created to assist ship representatives in fulfilling their reporting duties to some ports in Europe and international maritime and custom authorities (Maritime Europe Strategy Action, 2013). In other words, ports of SCZone are required to pursue innovative technologies and seek to catch up with the industrial revolution in parallel with developed countries and shipping companies.

4. CONCLUSION

In conclusion, seafarers and port operators should adapt to survive through innovative techniques of education and promotions of skills to cope with the automation and 4IR revolution and to reduce infection probability. The maritime industry is now evolving in two aspects; becoming a furtherly digitalized industry and preparing itself to host autonomous vessels technology. The first aspect is in deep need of cyber security for the protection of ship/port transactions e.g. cargo handling and delivery, while the second requires significant development in all ship-port operations to deal with mega and autonomous ships.

In this regard, AI and automation give rise to better investment and development opportunities. Accordingly, GTOs consortiums and SCZone authorities should work on gap analyses to cope with investors' needs such as the next generation of mega-ships.

Applying cyber security requirements in safety management systems are good chance for the industry to adapt to recent challenges and better data protection, however, it may be better to link with ports.

The world after the pandemic is less resistant to change to new methods of working; digitalization is now the highest priority. More expected support from the government and digitalization of processes in the supply chain, particularly administrative ones.

The new normal seeks new requirements including health, social and transport considerations and how these can be incorporated.

Moreover, SCZone hinterland connections facilities should adapt to the growth of mega container ships that will cause the port congestion problem, which is against the reliability of service. Adaptations would take ages and need huge capital investment for the port and hinterland. Investing in capacity building and legislative adaptation is essential before investing in infrastructure to cope with the latest technologies. Technical cooperation programs under international bodies can play an important role in these adaptation developments.

REFERENCES

Baik, J. S. (2017) The Study on Impacts of Mega Container ships on Ports. *Pan-Pacific Journal of Supply Chain Management*, 1(1), 22-40.

Bernhofen, D. M., El-Sahli, Z. & Kneller, R. (2016) Estimating the effects of the container revolution on world trade. *Journal of International Economics*, 98(NA), 36–50.

Danish Maritime Authority (DMA) & International Association of Marine aids to navigation and Lighthouse Authorities (IALA) (2019) *International e-Navigation Underway Conference – Report*, M/S Pearl Seaways ferry: DMA & IALA.

Department for Transport UK (2019) *Technology and Innovation in UK Maritime: The case of Autonomy: A Maritime 2050 Route Map*, London: Department for Transport.

Det Norske Veritas & Germanischer Lloyd (DNV-GL) (2018) *A Global Energy Transition Outlook*, Oslo: DNV-GL.

Eriksson, O. F. (2019) *Harmonization is the key: M/S Pearl Seaways ferry. e-Navigation Underway International 2019 Report.* Copenhagen: IALA. Available from: https://www.iala-aism.org/content/uploads/2019/03/e-Navigation-Underway-International-2019-Report.pdf [Accessed: August 2, 2022].

Essallamy, M., Abdel Bari, A. and Kotb, M. (2019) Spectral fatigue analyses comparison study: Suez Canal vs. Cape of Good Hope. *Journal of Marine Engineering & Technology*, 19 (4), 257–265. Available from: https://doi.org/10.1080/20464177.2019.1572703.

EU Horizon (2018) *Port of the Future concepts*, Brussels: Horizon 2000 program of the EU.

Hacegaba, N. (2014) *Big Ships, Big Challenges: The Impact of Mega Container Vessels on U.S. Port Authorities*, California: Port of Long Beach.

Hahn, A. (2019) *Identity, Authentication and Blockchain Technologies for Maritime Systems*, M/S Pearl Seaways ferry. E-Navigation Underway International 2019 Report. Copenhagen: IALA. Available from: https://www.iala-aism.org/content/uploads/2019/03/e-Navigation-Underway-International-2019-Report.pdf [Accessed: August 2, 2022].

Heleinic Shipping (2019) *Hellenic Shipping News Worldwide: Shanghai is rated the world's best-connected port.* [Online] Available at: https://www.hellenicshippingnews.com/shanghai-rated-worlds-best-connected-port/ [Accessed 18 Jun. 2022].

Holm, P. (2019) *Enhanced Operational Awareness and Remote Pilotage, M/S Pearl Seaways ferry. e-Navigation Underway International 2019 Report.* Copenhagen: IALA. Available from: https://www.iala-aism.org/content/uploads/2019/03/e-Navigation-Underway-International-2019-Report.pdf [Accessed: August 2, 2022].

Hong, S. (2019) *Strategies for the establishment of a SMART Maritime Logistics System*, M/S Pearl Seaways ferry: e-Navigation Underway International 2019 Report. Copenhagen: IALA. Available from: https://www.iala-aism.org/content/uploads/2019/03/e-Navigation-Underway-International-2019-Report.pdf [Accessed: August 2, 2022].

International Transport Forum (ITF) (2015) *The Impact of Mega-Ships: Case-Specific Policy Analysis.* Paris: OECD/ITF. Available from: https://www.itf-oecd.org/sites/default/files/docs/15cspa_mega-ships.pdf [Accessed: August 10, 2022].

Ismagilov, M. (2019) *The first e-Navigation testbed in Russia*, M/S Pearl Seaways ferry, e-Navigation Underway International 2019 Report. Copenhagen: IALA. Available from: https://www.iala-aism.org/content/uploads/2019/03/e-Navigation-Underway-International-2019-Report.pdf [Accessed: August 2, 2022].

MaaS (2020) *Mobility as a Service [MaaS].* [Online] Available at: https://maas-alliance.eu/ [Accessed 22 July. 2022].

Maritime Europe Strategy Action (2013) *MARITIME INNOVATIONS FOR THE 21ST CENTURY: Success stories from EU Research*, Brussels, Belgium: WATERBORNE TP Secretariat.

Maritime Safety Committee (MSC) (2018). *Maritime Safety Committee (MSC), 100th session*, London, UK: IMO.

MUNIN (2016) *The Autonomous Ship.* [Online] Available at: http://www.unmanned-ship.org/munin/about/the-autonomus-ship/ [Accessed 15 July 2022].

Negenborn, R. et al (2018) *Autonomous Ships in the Port of Rotterdam, Report of Smart Port, projectTET-SP, Smart Ships and the Changing Maritime Ecosystem.* SmartPort. Available at: https://www.researchgate.net/publication/327704347_Smart_ships_and_the_changing_maritime_ecosystem [Accessed: August 7, 2022].

Notteboom, T. (2016) The adaptive capacity of container ports in an era of mega vessels: the case of upstream seaports Antwerp and Hamburg. *Journal of Transport Geography*, 54 (June 2016), 295-309. Available from: https://doi.org/10.1016/j.jtrangeo.2016.06.002.

Pallis, A., Parola, F., Satta, G. & Notteboom, T. (2017) Private entry in cruise terminal operations in the Mediterranean Sea. *Maritime Economics & Logistics Journal*, 20 (1), 1-28. Available from: https://doi.org/10.1057/s41278-017-0091-7.

Rostopshin, D. (2019) *Just in Time Arrival: benefits for ships and ports, M/S Pearl Seaways ferry. E-Navigation Underway International 2019 Report.* Copenhagen: IALA. Available from: https://www.iala-aism.org/content/uploads/2019/03/e-Navigation-Underway-International-2019-Report.pdf [Accessed: August 2, 2022].

Saxon, S. & Stone, M. (2017) *Container shipping: the next 50 years*, NA: Whitepaper McKinsey.

Suez Canal Authority (SCA) (2017) *Suez Canal Authority news.* [Online] Available from: https://www.suezcanal.gov.eg/English/Pages/default.aspx [Accessed 11 Jun. 2022].

Schröder-Hinrichs, J.-U.et al. (2019) *Transport 2040: Automation, Technology, Employment - The Future of Work*, Malmo, Sweden: World Maritime University.

Suez Canal Economic Zone (SCZone) (2016) *Suez Canal Economic Zone news.* [Online] Available from: https://www.sczone.eg/English/Pages/default.aspx [Accessed 28 June 2022].

Secretary of Defense Office (2017) *Unmanned Systems Integrated Roadmap 2017-2042*, Washington: USA Secretary of Defense Office.

Sislian, L. A., Jaegler, A. & Cariou, P. (2016) *A Literature Review on Port Sustainability and Ocean's Carrier Network Problem*, NA: Research in Transportation.

Smart Port (2019) *Smart ships and the changing maritime ecosystem*, NA: Port of Rotterdam Authority, Deltalinqs, Municipality of Rotterdam, TNO, Deltares, Erasmus, Delft University of Technology.

Srinivasan, A. (2019) *Cyber security-tackling the risks involved, M/S Pearl Seaways ferry: e-NAVIGATION UNDERWAY INTERNATIONAL 2019 REPORT.* Copenhagen: IALA. Available from: https://www.iala-aism.org/content/uploads/2019/03/e-Navigation-Underway-International-2019-Report.pdf [Accessed: August 2, 2022].

Steffensen, A. H. (2019) *New Technologies – New Opportunities, M/S Pearl Seaways ferry: e-Navigation Underway International 2019 Report.* Copenhagen: IALA. Available from:https://www.iala-aism.org/content/uploads/2019/03/e-Navigation-Underway-International-2019-Report.pdf [Accessed: August 2, 2022].

United Nations Conference on Trade and Development (UNCTAD) (2009) *Review Of Maritime Transport 2009 Report.* No. E.09.II.D.11. Geneva: UN Publication. Available from: https://unctad.org/system/files/official-document/rmt2009_en.pdf [Accessed: August 5, 2022].

United Nations Conference on Trade and Development (UNCTAD) (2018) *Agenda Item 3a. Challenges faced by developing countries in competition and regulation in the maritime transport sector, Intergovernmental Group of Experts on Competition Law and Policy.* Geneva: UN Publication. Available from: https://unctad.org/system/files/non-official-document/ciclp17th_c_compcomsa_mar_en.pdf [Accessed: August 5, 2022].

United Nations Conference on Trade and Development (UNCTAD) (2019) *Review of Maritime Transport 2019 Report.* No. E.19.II.D.20. Geneva: UN Publication. Available from: https://unctad.org/system/files/official-document/rmt2019_en.pdf [Accessed: August 5, 2022].