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Research Article

Autonomous ships, port operations, and the challenges of African ports

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Abstract

The introduction of autonomous shipping (AS) into the maritime industry is bringing with it a great shift from conventional shipping to a digitalization mode. Expected benefits, which form the bases for conceiving and developing this innovation, include safety, security, and environmental protection. This innovation is not without some risks, such as non-navigation, cyber-piracy, and other issues which are always associated with new technology. This paper presents recent trends in shipping operations from the 18th century onwards, trends in autonomous system services, and the benefits and challenges of autonomous ships. The paper also navigates three (3) key potential challenges to Africa's adoption of autonomous shipping in the event of its adoption for commercial shipping. These challenges are Africa's trade level and trade facilitation, the state of infrastructural development, and piracy and maritime cyber-crimes in Africa. It is suggested that stakeholders in Africa's maritime industry and government should fashion holistic strategies for trade facilitation, rapid development of key trade infrastructures through investment, and intergovernmental capacities towards curbing piracy activities in the region's maritime routes.

1. Introduction

With increasing concern for global strategies for efficient ship operations that would impact positively on the environment and resource conservation, technology is evolving, and rapidly for that matter, at ensuring a shift from largely human-intensive ship operations to more autonomous maritime services. Advancement in innovations and technology development has in no doubt provided some levels of efficiency, especially when compared historically to the initial shift of the First Industrial Revolution (1800s), when mechanized power was introduced into shipping operations and vessels started using steam engines propelled by the use of coals; the Second Industrial Revolution (1900s), when diesel engines were invented to propel ships; and the Third Industrial Revolution, when computerized ship operations began. However, the advancement in technology to the level of autonomous shipping (AS) is expected to have an impact that has the capacity to reposition the shipping industry for a very long time. Apart from the impact on potential safety, efficiency, and effectiveness of operations, the eventual introduction and adoption of AS will have a considerable impact on supply chains and costs of operations (especially those accrued from manned operations), as well as on the environment. In other words, AS will transform elements of

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shipping, ranging from port facilities, the cargo handling process, including land-based logistics, and the transportation chain, with reduced negative externalities on the environment.

Since the conception of AS, and the various deliberations on its adoption, different projects and research have been carried out across the globe (Kim & Schröder-Hinrichs, 2021). Most of the projects and research have attempted to explore the economic, social, legal, regulatory, and technological considerations of the adoption of AS. For instance, Kretschmann et al. (2017) and Hogg and Ghosh (2016) analyzed AS from the perspective of its effect on employment, environment, and the reliability of operations and safety. According to them, low skilled labor is expected to be mostly replaced, whereas onshore employment is expected to increase, due to autonomous operations (Man et al., 2015). Other studies have also analyzed AS, mainly from a technical perspective (Wang et al. 2017; Wrobel et al., 2017; Campbell et al., 2012). However, given the potential benefits of AS, and the relatively wide array of studies on its potential adoption for full shipping operations, this paper aims to explore the challenges of the African maritime industry for the potential adoption of AS as part of shipping technology for global best practices. In spite of an array of research and projects on the feasibility of adopting AS innovation, no known study has been carried out in Africa and on Africa's ports in respect of any project, research, or preparedness to adopt AS. The study, therefore, explores Africa's readiness via critical consideration of three key issues that may pose potential challenges to the successful adoption and operation of AS. These issues are Africa's trade performance and trade facilitation; infrastructure capacity and capability; and piracy, cyber-attack, and other maritime crimes. The motivation for this study was from the understanding of the strategic importance of the African continent to global shipping operations. Apart from the fact that Africa depends on international trade via oceans for most of its imports and exports, some of the important global sea lanes pass through the continent. For instance, major sea routes navigate the Cape of Good Hope between the Atlantic and Indian Oceans via the Red Sea and east-west through the Mediterranean Sea, thus making Africa an unavoidable passage within maritime network. Also, Africa is home to Liberia-one of the world's largest shipping registries- with about 11 % of the world's ocean-going fleets. Thus, this study enriches the literature with information on existing challenges that may constitute barriers to the successful adoption of AS and the future development of ports in Africa.

The study is divided into five sections. After the introduction, Section 2 presents the literature review; Section 3 presents the potential challenges of adopting AS by Africa, while Sections 4 and 5 present the conclusion and recommendations of the study.

2. Literature review

This section provides sufficient information on historical shipping business operations from the First Industrial Revolution to the present Fourth Industrial Revolution and global trends in autonomous services, including the benefits and challenges as reported in various research studies.

2.1 Shipping operations from the First Industrial Revolution

Shipping is one of the truly global industries binding nations of the world together. In principle, trading and competition for trade between all states and nations is possible in maritime international trade due to the freedom of the seas and international regulations. In terms of making international shipping more efficient, several fields of innovation showed a rapid development in the recent past with the sole objectives of reducing the cost of doing business, increasing demand for shipping, providing more efficient service delivery, and overcoming shipping market turmoil (Yang et al., 2019). The initial innovation started with the First Industrial Revolution (1st IR) in the 1800s, when mechanized power was introduced and vessels started to be propelled by steam using coal as a fuel (Rüßmann et al., 2015). The vessel generally considered to be the first practical steamboat was launched in 1801. At this time, steamboat experiments were aimed primarily at building and operating passenger ships. The major drawback of these vessels was inefficiency in terms of available space for cargo and energy consumption, especially for long voyages. The next stage, represented by the Second Industrial Revolution (2nd IR), began when, in the early 1900s, the invention of diesel engines made vessels more efficient and reliable, using oil as a new fuel. Specifically, the first ocean-going diesel cargo liner was introduced in 1911. Although it was initially slow, expensive, and difficult to reverse, improvements brought about by the invention of light engines with reduction gears made it most efficient in terms of fuel economy. The computerized control of ships was introduced in the 1970s in the Third Industrial Revolution, represented by the internet-digital revolution. The Fourth Industrial Revolution, now referred to as The Industry 4.0 (Ling et al., 2020; Zhou et al., 2015), has been unfolding in the recent decade with the introduction and adoption of CyberPhysical Systems (CPS), Internet of Things (IoT), Big Data, Artificial Intelligence, Cloud Computing, and automation technologies (Emad et al., 2020; Imran & Kantola, 2018) (**Table 1**). The Fourth Industrial Revolution has the capacity of creating the opportunity for the maritime domain to improve connectivity between ports and ships. Such opportunity, in turn, has the capacity to raise the performance of ports and their relative significance in the global maritime community.

Table 1 Shipping revolution.

Shipping revolution	Timeline	Ship feature(s)	Operations
Shipping 1.0	Around 1800	Steam Engines	Fully man-operated
Shipping 2.0	Around 1910	Diesel Engines	Fully man-operated
Shipping 3.0	Around 1970	Automation and Computerized Systems	Man and computer
Shipping 4.0	Current	Digitalization	Unmanned, machine-control

Source: By Author (2022), based on some modifications of Emad et al. (2020).

2.2 Global trend in autonomous system services

Lisa (2020) has described autonomous systems as systems that include a wide variety of technologies: from thinking machines that can out-game humans in contests such as chess; to drones that enable the scanning of physical, natural, and social environments; to self-driving vehicles; to robots that work on manufacturing lines. Watson and Scheidt (2005) define autonomous systems as "…systems that can change their behavior in response to unanticipated events during operation" (p. 368). Fundamental to such systems is the incorporation of intelligence- the ability to perceive, process, remember, learn, and determine courses of action as a result of the integration of these processes. Recognizing Wiener's proposition that computing machines could reduce inefficient investments of humans in physical labor and amplify their effectiveness at knowledge work and the arts, while also averting the risks of subordination to machines (Wiener, 1950), different industries have been motivated to use autonomous systems as a springboard for a shift to the future global market. Some of the trends in autonomous systems can be found in the aviation, mining, nuclear power energy generation, and automotive industries (Li & Fung, 2019; Barabás et al., 2017). In the automobile industry, for instance, the latest trend is related to autonomous vehicles (AVs), otherwise known as self-driving cars, which is a product of the continuous revolution in technology, especially in computation and sensor technology (Alawadhi et al., 2020), which allow easy street navigation with the aid of charts, as well as vehicle-to-vehicle communication. This technology has received huge investment from some companies (Tesla, Volvo, Google) and countries (such as the UAE). Also, in airport services, autonomous technologies are being experimented with by airports around the world, especially in self-service gates, air taxes, virtual airports, autonomous shuttles, and others. In mining, there is what is known as autonomous mining systems (AMS) already being deployed and used in Australia and the USA, where hauling, drilling, crushing, excavation, and milling activities have been automated (Kansake et al., 2019). Gaber et al. (2021) posited that autonomous haulage systems (AHS), used in transporting ore without human interaction, is a significant advantage of the Fourth Industrial Revolution in the mining industry. In the manufacturing industry, autonomous technologies are now gradually addressing the challenge of short product lead times and competitive costing through digitization. The deployment of a careful blend of visual analytics, AI, and IoT can make supply chains more effective, with a lot of cost savings. Similarly, there are several cases in other industrial sectors, where robots and drones are being used to collect huge amounts of situational and other sensor data to understand and automate processes, predict the future, and adapt to complex environments. In the agricultural sector, autonomous technologies are now being used to optimally irrigate crops and enable the successful planting of high-density, efficient vertical gardens in areas with limited agricultural land. In all essences, the adoption of autonomous services in different industrial and social sectors have posed common goal-efficiency increases. Added to these are improvements in the consistency and scalability of operations.

DEGREE AND CHARACTERISTICS OF AUTONOMY OF AS			
Ship with automated process and decision support	**Remotely controlled ship with seafarers on board**	**Remotely controlled process with no seafarers on board**	**Fully autonomous operation**
Ψ Seafarers on board; Ψ Sometimes operations are automated and unsupervised, though seafarers are there to control	Ψ controlled and operated from another location; Ψ seafarers available on board to take control and operate	Ψ controlled and operated from another location; Ψ facilities for seafarers on board, but no seafarers on board	Ψ the operation and action of the ship is self-determined

Figure 1 Level of autonomy of AS.
Source: Author (2022), based on IMO MSC (2018b).

2.3 Autonomous ships- benefits and perceived challenges

Autonomous ships are defined as ships that can operate independently of human interaction to varying degrees of autonomy on single voyages. According to Rodseth (2017), they are ships which independently control their operations and actions while transporting goods from one port to another. Urciuoli and Hintsa (2020) and Porter and Heppelmann (2015) described AS as being part of a broader digitalization trend, capable of changing the conduct of business. These vessels consist of highly intelligent and adaptive functionalities, equipped with a variety of external sensors and actuators to gain situation awareness, automated control, and adaptive maneuvering for achieving more efficient and sustainable operations (Kim et al., 2022). AS are called next generation modular control systems and communications technologies that will enable wireless monitoring and control functions both on and off the board (MUNIN, n.d). Degree of autonomy of AS covers a wide range of gradation, from full human control of ships to complete self-operated ships with no human involvement. Based on this degree of autonomy, Rodseth (2017) and IMO (2018) classified autonomous ships into four key automation alternatives (**Figure 1**), depending on the level of human interference in their operational functions or the level at which human decision-making on board is replaced by computer-based solutions.

Autonomous ships, though not the first innovation in the maritime industry, began to gain more attention, especially in areas of research and development, in the 2000s, when the potential benefits of their adoption were being revealed (Hogg & Ghosh, 2016) (**Table 2**).

Table 2 Some projects on Autonomous Shipping.

Project	**Year**	**Objectives**	**Team location**
MUNIN- Maritime Unmanned Navigation through Intelligence in Network	2012	Develop and verify a concept for an AS	Germany, Norway, Sweden, Iceland, and Ireland
ReVolt	2013	Move more transport from land to sea; facilitate short sea shipping and build more maritime infrastructure	Norway
SSAP- Smart Ship Application Project	2015	Utilize smart ship concept to achieve optimal ship operation, safety, and energy efficiency	Japan
AAWA- Advanced Autonomous Waterborne Applications Initiative	2016	Produce the specification and preliminary designs for the next-generation advanced ship solution by exploring economic, social, legal, regulatory, and technological factors of its introduction.	Finland
YARA BIRKELAND	2017	Protect the planet with use of zero-emission electric ship	Norway
D4V- Design for Value	2017	Enable the best use of digital disruption for business growth through door-to-door supply chain with fully autonomous system-of-systems.	Finland
NOVIMAR	2017 - 2021	Optimize waterborne transportation for full use of short sea, sea-river, and inland waterways.	Netherlands
Zhi Fei	2020/2021	Undertake short sea operations	China

Source: Author (2022) (selected from various articles)

Part of the potential benefits that give incremental attractiveness to the development of AS as vessels for future shipping operations are the monetary savings from operational activities. These savings will accrue from the reduction in cost of employing and training of, and the payment of salaries to, seafarers, which ship operators have been recently facing (Björkroth, 2020; Ghaderi, 2020). Another saving would come from fuel cost (Kretschmann et al., 2017; Hogg & Ghosh, 2016), energy expenditure, and freight rate reduction as a gain from improved economies of scale. However, Kretschmann et al. (2017) and Stren and Kuipers (2018) pointed out that the estimation of such benefits will only be valid after due consideration of the cost associated with shore control centers (SCC).

In terms of reliability of schedules (Abaei et al., 2021; ITU News, 2018), it has been assumed that AS reliability may be better than conventional ships, because AS are data-driven and are designed to process both engine data and data related to the environment of transit. This potential creates positive inventory management of shipping companies (Vernimmen et al., 2007). In addition to positive inventory management, reliability of ship intelligence can enable preventive, and even predictive, maintenance (Tsvetkova et al., 2021; Lambert et al., 2019), thus reducing costs of maintenance in the long run. Also, there is increased transparency of ship operations, due to the bigger volumes of recorded data on vessel equipment operations and cargo conditions throughout voyages, and detailed logs of the surroundings.

There are also benefits associated with maritime safety, such as a reduction in fatalities (Rodseth, 2017), and a reduction or avoidance of collisions (Wrobel et al., 2017), due to constant and advanced situational awareness brought by ship intelligence and the reduction of the crew's fatigue by the taking over of routine tasks (Hogg & Ghosh, 2016). There is also a reduction in the likelihood of piracy (Arnsdorf, 2014), due to the mere fact that seafarers are transferred to the shore, and are not subject to operating vessels in harsh and dangerous conditions (Mooney, 2015).

Reduction in environmental impact of shipping includes zero emissions, which will accrue from the use of electric-powered AS and also from shifting load from road transport to sea, especially with the use of AS for short-sea shipping.

On the contrary, perceived challenges of AS include the initially high-capital costs of advanced new technology and the time it takes for its large-scale implementation, posing considerable investment risks (Karlis, 2018). There are non-navigational accidents due to fire or ship loss due to structural failure and loss of connectivity, as well as the risk of cyber-piracy (Wrobel et al., 2017; Streng & Kuipers, 2018). Though AS operations are expected to be based on a predefined set of rules which allow them to participate or function appropriately within the traffic that abides strictly by rules and standard information transfer, risk of collision is likely to be heightened, especially where they operate in a mixed environment. According to Perera and Batalden (2019), where AS and conventional ships share and operate at the same time within the same sea environment, decision making in such an environment can be complicated, since both humans and systems make decisions based on their own perspectives, thus compromising navigation safety, especially in ship collision avoidance scenarios.

In the case of cyber-attack and cyber-piracy, since autonomous ships will be relying on electronic navigation charts (ENC) which are regularly updated online or with mass storage devices such as USB, CD/DVD, etc. (Kos et al., 2013), any case of system infection by a malware may negatively impact the navigation chart images (Tam & Jones 2018). Such loss of navigation systems and loss of sensitive data due to malware or the activities of man-in-the-middle have already been witnessed in partially autonomous ships (Roberts, 2019; Svilicic et al., 2019). In addition, because of the increasing reliability of AS on networked ICT technology, Kessler (2019) opined that the vulnerabilities of AS navigation charts to cyber-attack and cyber-piracy may be heightened when malware is uploaded from the LAN of a ship or RADAR. Also, a cyber-attack may cause loss of data related to cargo characteristics, destination, and commercial value, with a severe financial impact on the shipping companies (Jensen, 2015).

In essence, the challenges of AS notwithstanding, multidisciplinary actions and stakeholders' engagements may be required to maximize the benefits of AS with minimal safety risk and negligible environmental impact.

3. Potential challenges of adopting AS by Africa

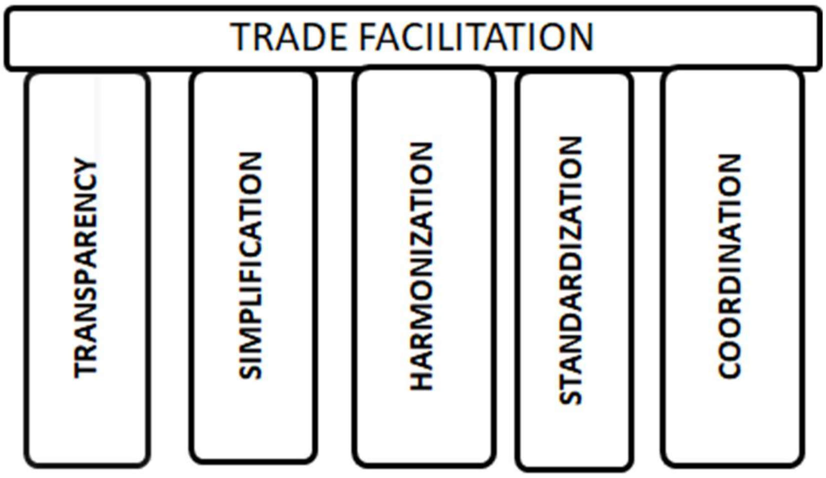
In this section, detailed information was provided on three (3) potential challenges of adopting AS by Africa. This information was based on the review of some literature relating to

Africa's economic and social development status. The potential challenges are Africa's maritime trade performance and trade facilitation; Africa's infrastructure capacity; and piracy, cyber-attacks, and other related maritime insecurities. Though there are other challenges hindering innovation adoption in Africa, these three are considered as central to maritime and related trading activities.

3.1 Africa's maritime trade performance and trade facilitation as determinants of adoption of AS

The African economy has witnessed a considerable annual growth of about 4.7 % between 2000 and 2017 (UNCTAD, 2018). This makes Africa one of the fastest growing continents in the world. Nevertheless, Africa's share in world merchandise trade remains very low, at 2.7 % in 2018, and its share in world exports declined from 3.5 % in 2008 to 2.5 % in 2018, though this does not represent uniform growth experienced by the countries in the continent, because of varying levels of economic development, and other socio-demographic and political indices. However, the record of international trade with Africa shows a tripled increase when compared with the rest of the world. Nevertheless, this is a marginal proportion of the global trade. The relatively low level of trade in and out of the bounds of Africa is an indication of the fragmentation of the African market and the dominance of African exports by raw materials and agricultural products. With the introduction of container technology as a means of moving goods some six decades ago, global maritime trade and supply chains have been greatly impacted (Watson et al., 2017). Specifically, terminals and port operators have to invest in new cranes, dredging equipment, reinforced quay walls, and extended berths to accommodate now ever-increasingly large vessels, which are a product of the introduction of containerization into maritime trade (Saxon & Stone, 2017). This has introduced stiffer competition for trade among nations. Thus, major players in the shipping industry are constantly looking forward to more innovative ways of gaining prominence, and also to increase productivity with minimum cost. As a result, shipping companies are considering exploring new trade routes, new forms of alliance, and other strategies with the view to further facilitate trading. These strategies may have long-run costs and risk implications for conventional ships. However, the recent development of AS as the 'next generation' ship is identified as having the capacity to solve these problems. The degree with which AS can achieve these objectives is dependent on the existing globalization and trade liberalization. Meanwhile, trade liberalization can be enhanced by trade facilitation, which in turn is hinged on trade components of individual economies and the efficiency of its ports as drivers of economic and reliable ways of moving goods over a considerably long distance (Munim & Schramm, 2018). Unfortunately, it is worrisome to note that Africa's ports are among the least efficient around the world (Abdourahamane, 2015) recording low port traffic flows due majorly to poor ports and port-side infrastructure, low logistic performance, lengthy trade procedure times, and congestion. This unimpressive trade performance has remained, despite Africa's enormous natural resources and trade potential.

Though increased trade flows, both among African countries and between Africa and the rest of the world, have the capacity to shore up some significant economic gains and expansion for Africa, this would only be achieved through trade facilitation. According to Seck (2017), trade facilitation would spur economic gain through the reduction in trade costs. Reduction in trade costs would further spur the productivity growth of domestic firms and induce increased trade volume and the continent's capacity to export. Indeed, Seck (2016) confirmed that trade facilitation increases the chances of firms' participation in international trade. According to UNECE (2012) trade facilitation rests on the transparency of regulations to stakeholders; the simplification of essential trading processes; the harmonization of trading procedures, and documentations among trading partners; and the standardization of global best practices (**Figure 2**). All these principles are not duly applied in trading process in Africa. For instance, trade facilitation in Africa has been hampered by certain critical factors, such as undue customs delays and poor administration, insufficient/inefficient transport and telecommunication systems, too much documentation and too many bureaucratic procedural activities, inadequate coordination between government agencies, corruption (Portugal-Perez & Wilson, 2012; UNECA, 2013; Shepherd, 2016; Sakyi et al., 2018; Kingsland, 2020), and poor design and execution of trade policies (World Bank, 2006). All these are part of the reasons why the cost of doing business is inordinately higher in Africa compared to other regions in the world. According to the World Bank's Ease of Doing Business (2019a), it takes more days than in any other region to import and export goods in Africa, thus making Africa lag when compared with other regions of the world, especially in terms of customs, infrastructure, competence in trade-related logistics, and timeliness of exports and imports (World Bank's Logistics Performance Index, 2019b). Since the goal of trade facilitation is to help improve controls and offset the additional burden on legitimate traders, a huge threat is posed at welcoming autonomous ships at various ports in Africa, because more cost incurred at ports due to delay and other associated issues will take a toll on the profitability of the shipping companies, and also negate the purpose of autonomous shipping. Also, African countries may be grossly affected in their participation in global supply chains with other regions. This is because extra time spent at ports translates to a loss of profitability. For instance, Hummels and Schaur (2013) estimated that a delay of three days can reduce the probability of export by 13 % and, according to Thien (2019) and Sebastian (2019), every hour of port time saved by ships translates into savings in port infrastructure expenditure for ports, ship capital costs for carriers, and inventory holding outlays for shippers.



The Five Pillars of Trade Facilitation

Figure 2 Source: National Board of Trade, Sweden; ADB (2013).

3.2 Africa's infrastructure capacity as determinant of adoption of AS

Infrastructure not only contributes to economic growth and development, but is also an important input to human development (Agenor et al., 2006; Palei, 2015; Muhia et al., 2019). More importantly, infrastructure plays a significant role in achieving trade improvements, particularly in developing economies (Olarreaga, 2016; Gurara et al., 2018; Muhia et al., 2019). However, the relationship between trade liberalization, improvement in trade, and infrastructural development is determined to a large extent by the free flow of technology, innovation, and productivity. Africa's economic growth and development are intrinsically linked to infrastructure development, yet its top developmental challenge, in terms of the achievement of greater economic activity, enhanced efficiency, and increased competitiveness, has been the shortage of physical infrastructure. There is no doubt that Africa is facing a monumental task in scaling up the provision and development of quality infrastructure, especially given the estimated increase in both urban and workforce population. This challenge explains the low transaction in trading activities in the region, especially with the other trading regions outside the continent. Specifically, the infrastructure challenge varies greatly by country type. While fragile economies within Africa face a critical infrastructure burden, resource-rich countries also suffer, despite their wealth. Nevertheless, the cost of addressing Africa's infrastructure needs is around $93 billion a year between 2016 and 2026, about one-third of which is for maintenance.

Going by the description of AS as a ship equipped "with modular control systems and communication technology to enable wireless monitoring and control, including advanced decision support systems and the capabilities for remote and autonomous operation" (Waterborne TP, 2011) Hassani et al. (2017) opined that the amount of technology required to operate an autonomous ship will substantially increase compared to the current situation. Key infrastructure required for the seamless operation of AS are digital infrastructure and hardware infrastructure. The development of key port infrastructure is required to accommodate AS for full functionality. The digital infrastructure includes technologies like lasers, radar detection, video content analysis, and electronic sensors, which will create full environmental and situation awareness and enable safe autonomous operations. This is because a lot of communication between shore and ship is required, and the technology on the ship itself will also increase and become more complex. A constant data flow is needed for the control and monitoring of the ship and multiple systems with different failure rates. According to AUC/OECD, (2019), Africa needs significant investments to boost universal access to digital infrastructure, which is a key driver of AS. The cost of closing the digital gap in Africa has been estimated to be approximately USD 9 billion annually (ITU/UNESCO, 2019). This estimated cost includes the cost of laying about 250,000 km of fiber across the African region. In addition, the need for the vertical integration of operations will also require the consideration of the future development of autonomous ports and port-side infrastructure. For instance, infrastructure for automated rail, automated aerial vehicles, and road vehicles, as well as other infrastructure required for the loading and unloading of cargoes, will need to be integrated into a shipping hub of operations to enhance seamless freight movement at each stage of the supply chain. The robustness and availability of these technologies should be very high and most modern, since ships are becoming totally dependent on these technologies.

However, considering the state of development of African infrastructure, the uptake of AS may be slow, if not retarded. This is due to the level of development of both the digital and hard infrastructure in Africa when compared to other rapidly developing economies and the developed economies of the world. Africa's infrastructure networks increasingly lag behind those of other developing countries, and are characterized by missing regional links. According to the World Bank, achieving universal, good-quality internet access across Africa will require investments of US$100 billion, 80 percent of which is needed for core infrastructure to establish and maintain broadband networks.

Power, which is the fulcrum on which digital infrastructure rests, is the largest infrastructure challenge in Africa, as the majority of countries on the continent face power shortages, even with high tariffs. Poor supply, which includes low accessibility, high costs, and shortages, is a major draw-back for industrial activities to thrive with maximum productivity. Since contemporary maritime trade requires exportable manufactured products for balance of trade, low productivity occasioned by power shortage may hinder the development of full industrialization in Africa, thus negatively impacting export-orientation of business in the continent.

3.3 Piracy, cyber-attacks, and other related insecurities as determinants of adoption of AS in Africa

With respect to ship and port operations, piracy, terrorism, and smuggling have been identified as critical security threats (Germond, 2015). Maritime transport and maritime piracy seem to be in a historically inseparable wedlock. Maritime piracy is an organized, violent, and acquisitive crime that has posed a threat to all states' maritime interests for nearly as long as people have sailed the ocean (Haywood, 2011). The International Maritime Bureau Piracy Reporting Centre (IMB-

PRC) has described piracy as an act of boarding any vessel with the intent to commit theft, or any other crime, and with the intent or capability to use force in the furtherance of such act (IMB-PRC, 1998). Piracy has posed a huge threat to human safety, as well as to political and commercial interests. Specifically, the risk of pirate attack has been a primary concern for ships carrying explosive cargoes, such as liquefied natural gas (LNG) (Geng et al., 2017). Global records reported about 2,000 pirate incidents between 2012 and 2017, with 17.6 % taking place in 2017 alone. Most of these incidents happened in and around some of the busiest trading routes in the world. These include the Gulf of Aden (between East Africa and Western Asia), the Gulf of Guinea (Cape Lopez in Gabon and Cape Palmas in Liberia), and the Malacca Straits (the main shipping channel between the Indian and Pacific Oceans). However, it is noteworthy that maritime piracy has been combated by the combined efforts of different national and international governments, agencies, and security organizations. Nevertheless, several consequences of disruptions occasioned by maritime piracy have been noted. These include additional costs incurred by shipping companies on rerouting their ships in order to explicitly avoid hazardous zones and protect ship crew. This also has further implications for local economies and revenue. For instance, rerouting may force a ship to use different ports and waterways. In addition, further expenditure is incurred where shipping companies choose to provide security and defense equipment on board a ship to deter pirates. Also, piracy adds to the cost of shipping, where shipping companies opt to increase their insurance coverage as a proactive way of providing a broader safety net for the company in case of eventual pirate attack. In all, the cost of doing business becomes unbearably high, and these costs are passed on to consumers in the form of increases in the prices of goods.

Africa is reliant on maritime trade, with an estimated 90 % of all African trade passing through the sea and, because sixteen of Africa's countries are landlocked, big ports typically service whole regional markets and the national economic interests of neighboring countries. However, significant to Africa is the Gulf of Guinea, which is a region along the West African coast spanning about 4,000 miles (6,000 km). This region is an important maritime route which links Europe and America to West, Central, and South Africa; accounts for about 25 % of African maritime traffic and is home to about twenty commercial seaports; and boasts a high concentration of hydrocarbons and sources of appreciable crude oil to countries around it and good international fishing grounds. However, the region has been a hotbed for the majority of maritime insecurities (e.g., armed attacks, vessel boarding, hijacking, kidnapping, and even the assassination of crew members), especially in the last one and a half decades. For instance, Nigeria, which is one of the countries in the Gulf of Guinea, is a hotspot for incidents of piracy, robbery at sea, and other criminal acts such as kidnapping. In 2018, the Gulf of Guinea accounted for more than 40 % of the global incidents of maritime piracy. In 2020, 130 out of 135 global maritime kidnapping occurred in the Gulf of Guinea. In 2021, 43% and 95 % of all reported global piracy incidents and kidnapping, respectively, took place in this region. Most of the piracy and maritime related crimes around the Gulf of Guinea has been attributed to disorder surrounding the regions with oil industries and high incidences of institutional corruption.

In a similar vein, cyber-attack is gaining ascendancy, due to the fact that today's global maritime business is increasingly becoming reliant on digitalization, operational, integration, and automation (DiRenzo et al., 2015; Jensen, 2015). Ship builders and stakeholders constantly innovate their operations by utilizing the most modern technologies and innovations for greater shipping efficiency. These technologies include advanced remote control, communication, and connectivity capabilities (Alcaide & Llave, 2020). Autonomous ships, which rely heavily on these technologies, contain a fleet, or what is called a conglomeration, of complex automated systems. Some of these technologies include radio detection and ranging (radar), light detection and ranging (LiDAR), high-definition cameras, thermal imaging, sonar, Automatic Identification Systems (AIS), etc., and many other operational technological capabilities, which will enable them to traverse the high seas unsupervised, partially operated, or partially autonomous, depending on the level of automation. Thus, the adoption of modern information and communication technology (ICT) increases the risks of cyber-attack and the introduction of new risks. This makes the safety and security of an autonomous ship be uncertain. According to the European Directive “EU 2016-679”, autonomous ships which are cyber-enabled are among the most critical infrastructures which rely heavily on digital services, but whose operations can be disrupted by malicious acts from cybercriminals (Halgamuge, 2015), causing catastrophic financial and environmental damage. In recent times, there have been records of several cybercrime cases in the maritime industry (Boyes, 2015; Roberts, 2019). For instance, there were records of cyber-attacks which struck all four of the world's top shipping firms; the attack on the Mediterranean Shipping Company (MSC), which caused a network outage due to a malware assault in April 2020; and CMA CGM SA (a French container transportation and shipping company), which was targeted by a ransomware attack in September 2020. Thus, maritime cyber-attacks now constitute an added complexity to already existing traditional maritime threats such as piracy, illegal activities, maritime terrorism, and accidents at sea.

In general, piracy and other maritime crimes stand a chance of posing a huge challenge to Africa’s adoption of AS due to the fact that these criminal activities are deeply intertwined with government failure or weakness. The great challenge this poses for Africa in the adoption of AS is viewed from the perspective of its trade relations with other global countries. From the words of Raj Aggarwal in his book “Technology and Globalization as Mutual Reinforcers in Business: Reorienting Strategic Thinking for the New Millennium”, technology enables globalization, and globalization makes technology more profitable; therefore, they comprise a mutually reinforcing cycle (Aggarwal, 1999). It can further be said that technology drives international trade which, in turn, drives globalization, which is fueled by technology. So, for the African continent, this process could be hindered by pirate activities because, when smooth trade is hindered or disrupted by the nefarious activities of pirates, trading with other countries outside the continent could become too costly.

4. Conclusions

The shipping industry in the recent decade has entered the digitalization arena with the advancement in the technologies of sensors, computers, and data processing. This advancement is paving the way for the introduction and commercialization of autonomous ships. Though the potential benefits of the transition to autonomous ships have been highlighted to include a reduction in ship operating costs, an increase in navigational safety and securities, as well as environmental protection, concern about non-navigation risks, and cyber-security have been raised. However, understanding the potential challenges for Africa to the adoption of AS is central to the continent’s level of preparedness required to welcome the innovation if it moves from the experimental stage to the implementation stage, thus becoming the viable commercial means for maritime cargo transfer. This study is limited by the lack of adequate data on the trend of adoption of innovation in the maritime industry in Africa. However, for further studies, an in-depth consultation with stakeholders in the port industry in Africa should be made, for more rigorous understanding of the state of maritime innovation development for the continent.

5. Recommendations

Based on the competitiveness of market and environmental pressures, this study recommends that Africa, with cooperation among its countries, must be strategic in embracing trade facilitation procedures as part of trade development agendas. For instance, simplification of customs procedures must be encouraged, regulations and guidelines for trade must be transparent, and corruption and red tape must be eradicated. Also, stakeholders in the maritime industry in Africa need to embrace and develop strategic planning mechanisms for investments in requisite digital and hard infrastructural technology in order to be efficient and sail smoothly with innovation drift in global maritime business affairs. Because ICT is increasingly becoming part of the maritime space, and the port and shipping sectors are set to become completely dependent on automation, Artificial Intelligence, Big Data, the Internet of Things, and blockchain in the future, Africa's investment in digitalization infrastructure, for instance, will allow for operational efficiency, improve effectiveness, and increase profitability. In addition, smart digital solutions improve public administration of trade and boost efficiency in export, import, and transit operations. In terms of infrastructure, African leaders and economic stakeholders must build the requisite physical infrastructure for more integrated transport systems and efficient energy, with the central goal of regional and intercontinental economic integration. This is necessary because access to effective ports, interconnecting infrastructure, and effective operations to deal with changing demand occasioned by new innovations in shipping will cater for current demand and future growth which will, in turn, lead to reduced costs of doing business and improved overall freight logistic efficiency and reliability. For piracy, cyber-attacks, and other related crimes at sea, Africa must catch up with understanding global awareness and new strategies on mitigating crimes at sea, especially cyber-attacks. Though conscious efforts have been made by the African Union (AU), especially when considering its adoption of the recommendation of the Convention on Cyber Security and Personal Data Protection (held in Malabo, 2014), the AU must take a proactive leading role in pursuing a collective approach at facilitating improved capacities in maritime security across all member states. Africa must take quick advantage in order to learn from the experiences of developed economies to mitigate future maritime cyber threats and to address potential vulnerabilities. In addition, it is essential that African governments and all stakeholders follow global best practices and ensure compliance with the latest International Maritime Organization guidelines for cyber security for vessels in order to ensure the achievement of cyber security and the safety of their port infrastructure.

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