An Overview of Modern Technologies in Leading Global Seaports

Pavlić Skender, Helga; Ribarić, Elizabeta; Jović, Marija

Repository / Repozitorij:

Repository of the University of Rijeka, Faculty of Economics and Business - FECRI Repository

Helga Pavlić Skender
E-mail: helga.pavlic.skender@efri.hr
Elizabeta Ribarić
E-mail: elizabeta.ribaric@gmail.com
University of Rijeka, Faculty of Economics and Business,
Ivana Filipovića 4, 51 000 Rijeka, Croatia
Marija Jović
E-mail: jovic@pfri.hr
University of Rijeka, Faculty of Maritime Studies,
Studentska ulica 2, 51 000 Rijeka, Croatia

An Overview of Modern Technologies in Leading Global Seaports

Abstract

This paper provides an overview of the modern technologies used in selected global seaports, and their possible impact on future development of seaports. The research problem stems from inefficience of customs procedures, dispute information flow, unneeded container manipulation in port area, and time lost due to bureucracy procedures. Methods used in this paper are the descriptive method, method of analysis, classification method, and compilation method. Since the majority of leading global seaports are placed in China, the authors decided to analyze the most successful seaport from each country, in order to achieve heterogeneity and global insight into used modern technologies. In total, eleven seaports placed on Lloyd's list Top 100 Ports have been analyzed. Key findings in this paper are: (1) different level of development of a particular country affects different levels of implementation of new technical and technological achievements, resulting in different levels of development of each seaport; (2) future development of modern technologies in seaports leans towards autonomous technologies such as autonomous drones, and self-driving trucks. Modern technologies may improve the safety and efficiency of operations in and outside seaports.

Keywords: leading ports, modern technologies, transport, operations, challenges

1. Introduction

Seaports are the most common type of ports in the world [28]. „Ports are the primary interface in the import-export industry and play an important role in driving economic growth" [20]. Leading seaport can significanty affect the national income and

employment. According to the International Maritime Organization (2020) [19], almost 90% of global trade is done by sea. Consequently, seaports have a significant role in trade. Due to growth in trade, and the need for efficient seaport operations, seaports are reaching out for modern technological solutions. Some of the characteristics of modern technologies are the possibility of product personalization, service orientation, horizontal orientation, vertical orientation, smart product, real-time capability, virtualization, smart factory, and decentralization [14]. Modern technologies can reduce decision making time, increase the security, and efficiency of business operations.

The article focuses on following research question: What modern technologies have been implemented in leading seaports? Based on literature review authors decided to analyse following technologies: Radio Frequency Identification, Internet of Things, Cloud Computing, Big Data, blockchain technology and Location Detection technology.

Radio Frequency Identification can help in prevention of accidents, and consequently material damage of containers and goods. The main advantage of Internet of Things are real-time information that facilitate decision making. Due to availability of the needed information, regardless of location, Cloud computing reduces cost and increases the transaction pace. Location Detection technology reduces the time required to find (locate) goods, and thus increases the operability of the seaport. A feature of Big Data technology is the storage of large amounts of data, that enables faster decision making due to faster data analyse. Data in blockchain technology are chronologicali recorded, and each participant of particular blockchain can access to the data by itself. In that way trancations and document exchange are faster, reducing seaport costs. Due to reduction in cost, seaport can further investment in implementation of modern technologies.

The goal of this paper is to point out the importance of implementation of the modern technologies in seaports. This paper presents a review of relevant academic papers and official web pages of sellected seaports from the Lloyd's Top 100 Port list, to provide better insight into technologies used in the best performing global ports.

The paper consists of five parts. The Introduction provides a brief insight into the topic, the research question, research goal, and the paper's structure. In the second part of the paper, an explanation of the seaports and the modern technologies is given. The focus in the third part of the paper is placed on different modern technologies used in the selected global seaports. Future development of the modern technologies in seaports is presented in the fourth part. The final part of the paper is the conclusion.

2. Theoretical Overview

Seaports, being transport nodes, constitute basic links in the sea–land transport chains [24]. Seaports play a substantial role as a cluster of loading, unloading, and transshipment activities, shipbrokers, warehousing, and storage services [26]. As a determinant of the economic growth, seaports contribute to the development of

economic sectors and to the generation of economic benefits [21]. Seaports, as nodes in extensive global transport networks, create environmental impacts as well through their logistics function (i.e., transport, terminal, and warehousing activities) and industrial and semi-industrial function (i.e., goods and energy production, assembly, and recycling activities) [31]. Seaports involve numerous cargo manipulation procedures, involved stakeholders and data that need to be exchanged. Thererfore, seaports have to improve their operations continuously in order not only to optimize their business but also to achieve sustainable growth in cargo volumes [57]. Seaports and terminals have evolved and have entered into a fifth stage of evolution characterized by their digital transformation and alignment with Industry 4.0 practices [34].

The term Industry 4.0 originates from Germany. It was introduced at the Hannover Fair nine years ago [14]. According to Ghobakhloo [14], several technology trends are identified as a part of Industry 4.0: Internet of Things (IoT), Industrial Internet of Things (IIoT), Internet of Service (IoS), Internet of People (IoP), Internet of Data (IoD), Cloud Computing, Big Data, blockchain technology, Cybersecurity, Augmented Reality, Automation, and Industrial Robots, Additive Manufacturing, Simulation and Modeling, Cyber-Physical Systems, Location Detection technology (LDs) and Semantic Technologies. According to leading research papers the most significant impact on seaport performance have following technologies: IoT technology [14, 62, 32, 12, 13], RFDI [14, 15 ,12, 13, 52], Cloud computing [14, 52], Big Data [14, 32, 52], blockchain [14, 62, 32, 13, 52], and Location Detection technology [32], which will be explained.

According to Fang [12], four technologies are crucial in the development of the IoT system. These are Radio Frequency Identification (RFID), Dedicated Short Range Communication (DSRC), General Packet Radio Services (GRPS), and Wireless Sensor Network (WSN). The primary purpose of Radio Frequency Identification is the prevention of accidents and disastrous events by using the automatic transmission of information [62]. The DSRC is intended for short-distance mobile phone communication. The communication takes place between the onboard unit on the vehicle and the signal station fixed in one place. Implementation of DSCR technology in seaports provides better visibility and connection, but it also eliminates delays in information exchange between road haullers, port operators, and shipping lines [8]. According to Coronado Mondragon et al [8] „DSCR can affect key facilities in a port such as electronic logistics management systems, facilities to ensure and enhance safety and security, facilities to simplify administrative and customs procedures". The GPRS technology enables wireless data service, and WSN technology is made of a group of sensors that collect environmental information [2].

All of the above mentioned technologies create an effective IoT system. IoT connects real (physical) objects with a digital system; in other words, it represents real-time communication of people and machines [60]. It has been proven that IoT makes information and material processes more visible within an organization. The integration of IoT brings many benefits such as the reduction in delays in data collection, real-time information, data transparency, better control of the process, and the possibility

of predicting future market changes [15]. On the other hand, there are some challenges mainly connected with different technologies and data services used by other parties (e.g. financial institutions, shipping companies, freight forwarders, etc), worries regarding information security, requirements for a larger platform to store and secure data, significant financial investments in technology, etc [15].

Cloud computing is an Internet-based technology that enables information storage on servers. The advantage of this technology is that relevant customers and suppliers can access the information they need anywhere [11]. Cloud computing enables better control and management regarding resources, processes, transactions, and operations [17].

The purpose of the Location Detection technologies, as can be inferred from its name, is to determine the position of a person, vehicle, and/or freight while using electronic devices. In this way, LDs can reduce port congestion by reducing the time needed to locate goods in warehouses, the time for loading and unloading, and the number of accidents [32].

Big Data technologies represent a relatively new type of technology that helps organizations analyze numerous widespread data [14]. The advantage of Big Data technology can be structured in the 4V shape, which represents volume, variety, velocity, and veracity [61]. Volume implies a vast amount of data that are collected and analyzed; variety means that collected data have different purposes, and this can be found in every type and size, collected from business, government, population, organizations, etc. Velocity implies significant time savings because data are collected and analyzed quicker. Veracity means that all data should be accurate because companies are making data-based decisions.

Blockchain technology represents a growing chain of arranged information. Each part of the chain is called a block. Transaction in blockchain are recorded chronologically, cryptography is used to secure data, and transactions based on smart contacts are automatically activated. The most significant value of blockchain technology is real-time data. All information updated in the system are transparent and permanent, and all participants of specific blockchain can access the data without any need for third-party verification. Due to reduced transaction costs, quick, secure and effective distribution of information between participants, blockchain technology provides more effective, efficient, transparent, and sustainable business operations [5, 52].

3. Analysis of the Technologies Used in Seaports

Seaports as the open, complex and dynamic systems, must adapt constantly to contemporary business conditions in order to remain competitive in the global market [59]. In order to stay competitive, seaports increasingly invest in new technologies. In this paper, the emphasis is placed on technologies and their impacts in best performing global seaports. In the past, port authorities had the coordinator's role and were

mainly focused on loading and unloading operations, storage, intra-ports operations, and advancement of the superstructure and infrastructure for ship operations [55]. Nowadays, port authorities are linked with different logistics and transport operators to make higher value for the customers. The list of the world's leading global ports analyzed in this paper is shown in the following table.

Table 1 – Lloyd's List – Leading global ports

World Ranking	Country	Port
1	China	Shanghai
2	Singapore	Singapore
6	South Korea	Busan
10	The Netherlands	Rotterdam
11	United Arab Emirates	Dubai
12	Malaysia	Port Klang
13	Belgium	Antwerp
15	Taiwan	Koohsioung
16	United States	Los Angeles
17	Germany	Hamburg
20	Thailand	Laem Chabang

Source: [27]

In order to give a global overview and avoid homogeneity, only one seaport from each country is analyzed (11 seaports in total).

The Port of Shanghai had the largest trade in 2019 [27]. The seaport continuously invests in digital technologies and artificial intelligence, and plans to implement self-driving trucks to speed up the bridge traffic. The base for the implementation of self-driving trucks is 5G technology. This technology, along with an advanced navigation system, enables larger amount of cargo transport between the seaport and terminal/warehouse. Also, real data exchange tests between the seaport and the partner company - Cosco Shipping, that rely on the blockchain, are underway [27]. In 2019, seaport automated container terminal is put into use. Future investments in smart and green technologies remains important to reduce the negative impact of port operations and maritime transport on the environment [53].

The Port of Singapore is in the second place. Until 2040, the plan is to settle the world's largest automated Tuas terminal. According to Lloyd's One Hundred Ports

[27], the terminal "will incorporate innovation such as an intelligent data-driven operation management system, wharf and yard automation, fully electric AGVs[1], smart engineering, and power management platforms." This terminal will also be one of the first terminals physically and virtually integrated into a broader supply chain network. The Port of Singapore, as well as the Port of Shanghai, are testing the implementation of 5G technology to enhance smart operations in the future [54].

The Port of Busan is in the sixth place of the largest seaports. South Korea plans to make a huge investment of 35,2 bn dollars into the seaport by 2040. The investment covers several parts – the port's infrastructure, an increase of the sea bottom depth, application of automation technology, and construction of the liquified natural gas terminal [27]. Last year, the seaport decided to use blockchain technology to track the movement of containers between the seaport terminals. Since containers are transported between terminals by a vehicle, drivers use a smartphone application. The purpose of the implementation of blockchain technology is to downsize the number of mistakes by giving real-time information to the shipping and trucking companies [25]. In 2019, laser-based software for Unremoved cone detection was implemented at the Port of Busan. It is used to determine if the twist locks are connected to the container when it is lifted by yard cranes [51]. This technology reduces (eliminates) possibility that the container cones stay attached to the container after being unloaded from the ship. This is important because unconnected container cones can connect with other containers, and at some point, when the crane picks up the container, it will carry two containers instead of one. While carrying two containers, other containers could be hit and pulled down. This leads to delays in delivery, damages outside of the container, and damages in goods placed in containers.

The Port of Rotterdam, as the largest seaport of Europe, is positioned in the tenth place in the world. In contrast to Asian ports, which decided to contract other companies for technological solutions (outsourcing), the Port of Rotterdam formed an in-house team of 70 programmers. This resulted in the Pronto system, which has positive effects on several participants – carriers, pilots, terminals, and shippers [27]. Other services that are offered in the Port of Rotterdam are: Portscan – software which provides information about port statistics and movement in and around seaport [47], Optimised Dredging – provides information about depth of water for the boat, information about dreading activity, it takes into account global safety margins related to the depth and length around vessel, and it decreases CO_2 emission [44], Time to Port – software which provides specific information about the location and arrival of vessel [49], Port Information API – provides information about a specific port; API provides data about searched port (based on name or location of port) [45], Boxinsider (Cargo Tracker) – provides timely information about container transportation [43], Portcalls API – provides information about ships (arrival and departure time) from port calls

---

1   Automated guided vehicle

[46], Ship Events API – provides real-time information about arrivals and departures of ships worldwide [48], Vessel Traffic Service – enables route prediction based on previous sailing and predicts possible collisions. Also, a translation support system is implemented [50].

The Port of Dubai (also known as Jebel Ali Port) has one of the world's largest semi-automated terminals. It has 19 automated quay cranes, 50 automated rail-mounted gantry yard cranes, and is capable of handling ultra-large container vessels [10]. In 2017, RFID-based technology was installed at the seaport terminal [1]. There are plans for the implementation of autonomous vehicles and supported technology into daily operations [9].

The Port of Klang is making large investments into increasing the capacity of container terminals. In addition to the infrastructure, the seaport is investing in information technology. Fast track has been set up at the entrance to the terminal. By using the mobile platform, the cargo owner can complete all certifications and customs clearance procedures. In that way, when the truck arrives, it can pass and unload the cargo. The port implemented a new operating system in 2017. The main advantage of this technology is that the vehicle enters and unloads goods from the container and loads the goods that need to be transported. In the future, the seaport is planning to introduce electric driverless truck technology to the terminals [7]. In 2013, the Port Authority of Klang implemented a digital information-sharing platform that connects relevant participants included in seaport and trade operations [4].

The Port of Antwerp is the second-largest port in Europe. Much effort is put into the development of the smart port and smart transport. In the field of smart seaports, solutions had been found in several fields. With the help of little plastic tags, it is possible to inspect the whole seaport infrastructure in a shorter time. A digital twin of the seaport is created; a digital 3D map of the seaport, which provides real-time data about the position of the ship, situation on the docks, etc. Blockchain technology is applied in the field of exchange of the phytosanitary certificates needed to import goods from New Zealand. The use of blockchain technology enables safe exchange of documents and speeds up the data exchange process leading to more efficient inspections and faster transit. In the future, the seaport is planning to do the same with certificates for organic products. Intelligent wharf walls project is based on digital cameras and sensors that are installed in the seaport. Therefore, when entering the seaport, each captain knows where to dock the ship. The seaport has more than 600 cameras installed whose purpose is to make the seaport safe and secure. Besides, there is an application that identifies in detail objects located in the seaport [36]. In the future, the seaport plans to build a network of autonomous drones. The seaport already presented a depth-sounding boat, which is used for regular control of the seabed in the seaport. An autonomous depth-sounding craft is developed to measure sea depth of hardly available places in the port [37].

The Port of Kaohsiung is part of Taiwan International Port Corporation. The Corporation has installed a wireless network in several seaports. In this way, access to the Internet and Cloud computing is ensured. The technology used in seaports includes

Radio Frequency Identification (RFID), Vessel Traffic Services (VTS), Automatic Identification System (AIS), International Ship and Port Facility Security (ISPS), and Closed-Circuit Television (CCTV). To accelerate procedures, they made a smart platform consisting of software such as SAP enterprise resource planning integration, computer, and automated terminal operation system (CATOS), and Taiwan Port Net (TPNet). In the future, the seaport plans to implement Big Data technology [59]. In 2020 new automatic gates have been installed. The system is based on incorporation of artificial intelligence and smart-impact analysis functionalty. The system enables verification, comparison, recording, and management of people, vehicles, and cargo entering and leaving the seaport. System simulates human-decision making and deductive reasoning in order to provide real-time information on the main characteristics of each vehicle. As a result, there is a significant raise in accuracy of logic-based comparison, and the accurancy and efficacy of customs release decisions. Due to enormus amout of generated records, the system can be easily searched by customs and police authorities [56]. The smart environment network has been implemented. Users can see a 3D map of the port in real-time [42].

The Port of Los Angeles is the leading seaport for international trade in North America. The seaport is continuously working on implementing new technologies to improve digital information flow [38]. In 2011, the seaport initiated a project which should reduce air pollution by cutting ship emissions. The device is called a seawater scrubber, and it uses seawater to filter pollutants from ships engines [40]. Port of Long Beach and Port of Los Angeles developed the Cargomatic Free Flow program which optimizes container movements. In 2013, the Cargomatic mobile app was launched as an online marketplace to connect trucks with less than a truckload and those who have more than full load. In 2014, Cargomatic was implemented in the field of port drayage [39]. In 2020, the seaport introduced a new data tool – The Signal. It contains all data about the ships and cargo that will enter the seaport in the next three weeks. It represents a cloud-based solution [41].

The Port of Hamburg is the most important seaport in Germany. Real-Time Navigation is implemented in the seaport area. It provides information on traffic in and around the seaport. Also, a GPS sensor – mobile app is being introduced. It provides different types of information, from an emergency vehicle's positions to the flow of the river Elba. The implementation of a Virtual Depot resulted in cut downs in unnecessary movements of empty containers. Also, the smartPORT logistics app for trucks was introduced. This app informs drivers about a free place in the parking lot [16]. In 2020, a test of 5G technology started in the Port of Hamburg area [29].

The Port of Laem Chabang is one of the youngest seaports analyzed in this paper. Significant investments in technologies have been made. The seaport uses Radio Data Terminal System (RDT), which provides real-time information on containers – where they are placed at a terminal, whether they are loaded or unloaded, information on whether the containers passed customs procedures, etc. The CTCS software provides data on each container in seaport, from customers booking, through gate operations to

management reporting and communication. The COREBIS software is also being used at the terminal. According to data collected from CTCS, the COREBIS automatically makes invoices for customers [3]. Remote-control technology is used to improve efficiency, safety, and working environment for crane operators. The nGen system, which is developed in-house, is used to control and to optimize operations at the container terminal. It improves planning and accelerates the movement of cargo in seaports. The HPT General Cargo, Ro-Ro, and CFS Management System (HPT GCMS) enables real-time information on the status of cargo (loaded/unloaded, location of cargo, and engaged equipment). Electronic data interchange (EDI) is implemented. It reduces the need for human labor and the possibility of human errors in order to increase efficiency and service quality [18].

An overview of the technologies used in the seaports is provided in the following table:

Table 2 – Identified Technologies Used in Seaports

Port	Country	Technologies	Source
Shanghai	China	Self-driving trucks, 5G, blockchain*	[27], [53]
Singapore	Singapore	5G, Automated Taus terminal*	[27], [45]
Busan	South Korea	Blockchain, Unremoved Cone Detection	[27], [25], [51]
Rotterdam	The Netherlands	Pronto system, Portscan, Optimised Dredging, Time to port, Port information API, Boxinsider, Portcall API, Ship events API, Vessel Traffic Service	[27], [47], [44], [49], [45], [43], [46], [48], [50]
Dubai	United Arab Emirates	RFID, Autonomous vehicle*	[10], [1], [9]
Klang	Malaysia	Fast track, digital information-sharing platform, Electric driverless cars*	[7], [4]
Antwerp	Belgium	Plastic tags, 3D port map, blockchain technology, Autonomous drones*	[36], [37]
Kaohslung	Taiwan	Cloud computing, RFID, VTS, AIS, ISPS, CCTV, CATOS, 3D map, automatic gates Big Data technology*	[59], [56], [42]
Los Angeles	USA	Cargomatic mobile app, The Signal	[38], [40], [39], [41]
Hamburg	Germany	Navigator in real-time, smartPORT logistics app, 5G	[16], [29]
Laem Chabang	Thailand	RDT system, COREBIS, CTCS, HPT GCMS, EDI, nGen	[3], [18]

planned implementation in the near future

Without continuous investments in new technologies, seaport activities cannot be managed successfully and efficiently. According to Song and Panayides [55], "the investment in technology is merited by the resulting higher performance (in terms of service quality), which is an important parameter for the selection as well as evaluation of the services of the port."

4. Future Development of Technologies in Seaports

The emergence of technologies changes the competitive landscape and provides new opportunities for business transformation. Although some seaports have already implemented blockchain and Big Data technologies, for some of them they are near future. The challenges of implementation of blockchain technology could be: large investments, inability to integrate all relevant participants, distrust in the entire system (cyber security), legal barriers related to personal data protection, unequal level of development of seaports [30]. Prewett, Prescott, and Philips [35], indentified several barriers to blockchain technology implementation. The first barrier could be scalability, which represents the limited capacity of the system in processing large amounts of data at a given time. Another challenge could be differences in the legal system. For now, blockchain technology is designed according to the needs of particular company. However, new difficulties could arise when participants from different companies decide to cooperate. In that case, the most important part is to determine bottlenecks, data security, and system diversity. These platforms require programming language encoding, which requires additional use of time and human resources. The basis of blockchain technology is decentralization. However, "the lack of standardization also prevents blockchain participants from being able to collaborate and communicate effectively" [35]. Ultimately, the most critical role could be the lack of adequate human resources and the complexity of setting up the blockchain technology itself, from programming and testing to the implementation in the system. Nevertheless, "by reducing bureaucracy and paperwork, blockchain could improve international trade efficiency and facilitate business transactions" [33]. Blockchain technology could enhace collaboration and cooperation between, for example seaport and carriers, it could provide tracebility of containers in and outside of seaports, it could reduce human errors and possibility of losing documents, it could reduce unethical behaviour between employees and other included parties (shipping companies, seaports), and it could reduce energy consumptions due to reduction in unnecessary movement of containers [25].

Challenges could arise in the implementation and application of Big Data as well. They could be primarily related to the costs associated with longer-term storage and management of collected information. Another challenge could be the lack of properly information sharing. According to Jović et al. [22] "unauthorized individuals can wilfully insert, delete or update information in order to reach economic advantages or

to diguise illegal activities". Due to fast development of new devices, the challenge of inadequte workforce can appear. Despite the existence of the aforemention challenges, Big Data technology can bring significant benefits, such as increased security in seaports, cost savings, faster detection of errors, reductions in containers manipulations, faster information exchange, reductions of negative impact on the environment, the possibility of more precise planning regarding the arrival of the ship in port [22]. Although numerous challenges exist, seaports increasingly invest in modern technologies that provide various benefits such as reduced costs and improved security.

Future development of technologies in seaports leans toward further automatization of seaport operations and implementation of autonomous technologies based on 5G network. More efforts can be made to reduce or eliminate administrative procedures by using sophisticated programs. Due to the advancement of technologies, the possibility of human errors can be further reduced, and consequently the need for routine workers. Intentions of larger and more influential seaports lean towards making in-house solutions that can be offered (or better said impose) to their business partners.

In the year 2020, new challenge have emerged. For the majority of seaports, the COVID-19 situation further complicates the implementation of new technologies. Because of the slowdown in container throughput, investments in modern technologies are under review. There is a possibility that some plans will be postponed [32].

5. Conclusion

Seaports represent the main links in the sea-land transport chains and have important role in the global trade. As a determinant of economic growth, seaports contribute to the development of economic sectors. Leading seaports can significantly affect national income and employment. Seaports include a number of cargo manipulation procedures, stakeholders and data to be exchanged. In order to stay competitive and achieve the growth in the cargo volume, seaports must continuously improve their operations and invest in technologies.

In this article theoretical overview of significant modern technologies used in seaport is given. Modern technologies that have significant impact on seaports development are Radio Frequency Identification, Internet of Things, Cloud computing, Location Detection technologies, Big Data, and blockchain technology. One thing that is common to Internet of Things, Cloud computing, Location Detection technologies, Big Data, and blockchain technology are real-time information. Having the real-time information, seaports can prevent and/or reduce amount of accident in and outside of the seaport area, make reliable predictions about capacity utilization, react faster to unpredicted situations. Big Data technology accelerates decision-making process due to reduction in time required to analyze data. Blockchain technology reduces bureaucracy and paperwork, and it could accelerate international trade.

The authors analyzed the best performing seaport from each country to provide a global overview. In total, eleven leading seaports are analyzed. Majority of seaports is

placed in Asian area, followed by Europe and North America. The analyzed seaports put significant focus on the future implementation of modern technologies. Some of the seaports have already implemented Big Data and blockchain technology in everyday operations, while for others they represent the near future. Port of Roterdam and Port of Antwerp have put more emphasis on implementation of technologies that increase safety in the seaport area, for example plastics tags, Portscan, Optimised Dredging, etc. Also, European seaports are oriented in generation of in-house solutions, in comparison with Asian seaports. Future development and implementation of technologies in seaports lean toward autonomous technologies such as self-driving vehicle, autonomous vehicle, autonomous drones, etc. In future, majore challenge could be a lack of adequate (skilled) workforce, that could form new technological solutions. The technology incorporated so far has accelerated, facilitated, and made container-related manipulations faster and easier. Although the seaport's survival lies in the technology that constitutes the fourth industrial revolution, the incorporation of technologies is a time-consuming and financially demanding process.

References:

1. Alawaba 2017, ENOC enhances technology at Jebel Ali Port to boost fuelling efficiency, viewed: 23.09.2020, online: https://www.albawaba.com/business/pr/enoc-enhances-technology-jebel-ali-port-boost-fuelling-efficiency-945592
2. Anowar, T., Khan, N. H., Kabir, M. A., Hossen, D., Alam, M., Sunny, M. R. & Hasan, M. M., 2016, 'Application of Dedicated Short-Range Communication within M-Commerce and Intelligent Transportation Services, and its Global Adaptation Using RFID technology', *Imperial Journal of Interdisciplinary Research*, vol. 2, no. 7, pp. 764-771, viewed: 15.09.2020, online: https://www.researchgate.net/publication/303988727_Application_of_Dedicated_Short-Range_Communication_within_M-Commerce_and_Intelligent_Transportation_Services_and_its_Global_Adaptation_Using_RFID_technology
3. APM Terminals 2020, viewed: 25.09.2020, online: https://www.apmterminals.com/en/laem-chabang/about/our-terminal
4. Aziz, A. 2017, Port Klang Authority to implement digital platform initiative on March 1, The Edge Financial Daily, viewed: 23.09.2020, online: https://www.theedgemarkets.com/article/port-klang-authority-implement-digital-platform-initiative-march-1-0
5. Bajwa, N., Prewett, K. & Shavers, C. L. 2020, 'Is your supply chain ready to embrace blockchain?', *The Journal of Corporate Accounting & Finance*, vol. 31, pp. 54-64, viewed: 15.09.2020, online: https://onlinelibrary.wiley.com/doi/full/10.1002/jcaf.22423
6. Chauhan, C. & Singh, A. 2019, 'A review of Industry 4.0 in supply chain management studies', *Journal of Manufacturing Technology Management*, viewed: 11.09.2020, online: https://www.emerald.com/insight/content/doi/10.1108/JMTM-04-2018-0105/full/html
7. Container Solution System 2020, Port Klang: Malaysia's largest port is expected to rank among the top ten in the world, viewed: 23.09.2020, online: http://www.usacss.com/port-klang-malaysias-largest-port-is-expected-to-rank-among-the-top-ten-in-the-world/
8. Coronado Mondragon, A. E., Lawani, C. S., Coronado Mondragon, E. S., Coronado Mondragon, C. E. & Pawar, K. S. 2012, 'Intelligent transport system inmultimodal logistics: A case of role and contribution thorugh wireless vehicular networks in a sea port location', Int . J. Production Economics, vol. 137, pp. 165-175, viewed: 20.11.2020, online: https://www.sciencedirect.com/science/article/pii/S0925527311004683
9. Davis, A. 2020, Autonomous Container Terminal Vehicles start work at Jebel Ali Port, Highways today, viewed: 23.09.2020, online: https://highways.today/2020/06/10/aitv-jebel-ali-port/

10. DP World, The largest Port in the Middle East, viewed: 23.09.2020, online: https://dpworld.ae/our-portfolio/jebel-ali-port/

11. Etro, F. 2009, 'Economic Impact of Cloud Computing on Business Creation, Employment and Output', *Review of Business and Economics*, vol. 2, pp. 179-208, viewed: 17.09.2020, online: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.368.2358&rep=rep1&type=pdf

12. Fang, W. 2020, 'An Exploratory Study on the Logistics Supply Chain of Maritime Port', *Journal of Coastal Research*, vol. 107, Special Issue, pp. 5-8, viewed: 11.09.2020, online: https://doi.org/10.2112/JCR-SI107-002.1

13. Federico, G. F., Garza-Reyes, J. A. Anosike, A. & Kumar, V. 2020, 'Supply chain 4.0: concepts, maturity and research agenda', *Supply chain: An International Journal*, vol. 25, no. 2, pp. 262-282, viewed: 13.09.2020, online: https://www.emerald.com/insight/content/doi/10.1108/SCM-09-2018-0339/full/html

14. Ghobakhloo, M. 2018,'The future of manufacturing industry: a strategic roadmap toward Industry 4.0', *Journal of Manufacturing Technology Management*, vol. 29, no. 6, pp. 910-936, viewed: 11.09.2020, online: https://www.emerald.com/insight/content/doi/10.1108/JMTM-02-2018-0057/full/html

15. Haddud, A., DeSouza, A., Khare, A. & Lee, H. 2017, 'Examining potential benefits and challenges associated with the Internet of Things integration in supply chains', *Journal of Manufacturing Technology Management*, vo. 28, no. 8, pp. 1055-1085, viewed: 10.09.2020, online: https://www.emerald.com/insight/content/doi/10.1108/JMTM-05-2017-0094/full/html

16. Hamburg Port Authority 2020, viewed: 24.09.2020, online: https://www.hamburg-port-authority.de/en/hpa-360/smartport/

17. He, W. & Xu, L. 2015, 'A state of the art survey of cloud manufacturing', *International Journal of Computer Integrated Manufacturing*, vol. 28, no. 3, pp. 239-250, viewed: 17.09.2020, online: https://www.researchgate.net/publication/271669733_A_state-of-the-art_survey_of_cloud_manufacturing

18. Hutchison Ports Thailand 2020, Modern technology, viewed: 22.11.2020, online: https://hutchisonports.co.th/technology/

19. International Maritime Organization 2020, viewed: 25.09.2020, online: https://business.un.org/en/entities/13

20. Irannezhad, E., Hickman, M., Giacomo Prato, C. 2017, 'Modeling the Efficiency of a Port Community System as an Agent-based Process', Procedia Computer Science, vol. 109C, viewed: 4.12.2020, online: https://www.researchgate.net/publication/317546478_Modeling_the_Efficiency_of_a_Port_Community_System_as_an_Agent-based_Process

21. Jouili, T. A. and Allouche, M. A. 2016, 'Impacts of seaport investment on the economic growth', *Promet - Traffic - Traffico*, vol. 28, no. 4, pp. 365–370

22. Jović, M., Tijan, E. & Gebhard, B. 2019, 'Big Data Management in Maritime Transport', *Journal of Maritime & Transportation Sciences*, vol. 57, pp. 123-142, pogledano: 3.12.2020, online: https://hrcak.srce.hr/232669

23. Jović, M., Tijan, E., Zgaljic, D. & Aksentijević, S. 2020, 'Improving Maritime Transport Sustainability Using Blockchain-Based Information Exchange', *Sustainability*, vol. 12, no. 21, viewed: 2.12.2020, online: https://www.researchgate.net/publication/344903650_Improving_Maritime_Transport_Sustainability_Using_Blockchain-Based_Information_Exchange

24. Kotowska, I., Mankowska, M. & Plucinski, M. 2018, 'Inland Shipping to Serve the Hinterland: The Challenge for Seaport Authorities', *Sustainability*, vol. 10, no. 10, viewed: 4.12.2020., online: https://www.mdpi.com/2071-1050/10/10/3468

25. Ledger Insight 2019, Korea's Port of Busan to use blockchain in production, viewed: 22.09.2020, online: https://www.ledgerinsights.com/port-of-busan-blockchain-in-production-korea/

26. Li, X. K., Park, T.-J., Lee, P. T.-W., McLaughlin, H. & Shi W. 2018, 'Container Transport Network for Sustainable Development in South Korea', *Sustainability*, vol. 10, no. 10, viewed: 4.12.2020., online: https://www.mdpi.com/2071-1050/10/10/3575/htm

27. Lloyd's List One Hundred Ports 2020, viewed: 19.9.2020, online: https://lloydslist.maritimeintelligence.informa.com/one-hundred-container-ports-2020/Digital%20edition%20ebook

28. Marine Insight, 2020, 'What are Different Types of Ports For Ships', viewed: 1.12.2020, online: https://www.marineinsight.com/ports/what-are-the-various-types-of-ports/

29. Mouncer, B. 2020, Hamburg Port rolls out initiative with Deutsche Telekom and Nokia, Supply Chain, viewed: 24.09.2020, online: https://www.supplychaindigital.com/technology/hamburg-port-rolls-out-5g-initiative-deutsche-telekom-and-nokia

30. Mukherejee, S., Carter, C. & Koh, S. C. L. 2018, 'Blockchain Disruption in Transport', viewed: 30.11.2020, online: https://www.researchgate.net/publication/333809102_Blockchain_Disruption_in_Transport

31. Notteboon, T., van der Lugt, L., van Saase, N., Sel, S. & Neyers, K. 2020, 'The Role of Sraports in Green Supply Chain Management: Initiatives, Attitudes, and Perspectives in Rotterdam, Antwerp, North Sea Port, and Zeebrugge', Sustainability, vol. 12, no. 4, viewed: 4.12.2020., online: https://www.mdpi.com/2071-1050/12/4/1688/htm

32. Parola, F., Satta, G., Buratti, N. & Vitellaro, F. 2020, 'Digital technologies and business opportunities for logistics centers in maritime supply chain', *Journal of Maritime Policy & Management*, viewed: 17.09.2020, online: https://www.tandfonline.com/doi/full/10.1080/03088839.2020.1802784?scroll=top&needAccess=true

33. Pavlić, Skender, H. & Zaninović, P. A., 2020 'Perspectives of Blockchain Technology for Sustainable Supply Chains', In Kolinski, A., Dujak, D., & Golinska-Dawson, P. (eds) *Integration of Information Flow for Greening Supply Chain Management*

34. De la Pena Zarzuelo, I., Freire Soeane, M. J. & Lopez Bermudez, B., 2020, 'Industri 4.0 in the port and maritime industry: A literature review', Journal of Industrial Information Integration, vol. 20, viewed: 4.12.2020., online: https://www.sciencedirect.com/science/article/abs/pii/S2452414X20300480

35. Prewett, K. W., Prescott, G. L. & Phillips, K., 2020 'Blockchain adoption is inevitable – Barriers and risk remain', *Journal of Corporate accounting & finance*, vol. 31, pp. 21-28, viewed: 30.09.2020, online: https://onlinelibrary.wiley.com/doi/abs/10.1002/jcaf.22415

36. Port of Antwerp – Smart Port 2020, viewed: 23.09.2020, online: https://www.portofantwerp.com/en/smart-port

37. Port of Antwerp – Smart Transport 2020, viewed: 23.09.2020, online: https://www.portofantwerp.com/en/smart-transport-en-industry-40

38. Port of Los Angeles 2020, viewed: 24.09.2020, online: https://www.portoflosangeles.org/about

39. Port of Los Angeles 2015, Port of Los Angeles embraces technology to increase supply chain efficiency, viewed: 24.09.2020, online: https://www.portoflosangeles.org/references/news_060415_cargomatic

40. Port of Los Angeles 2011, San Pedro Bay Ports Clean Air Action Plan, viewed: 24. 9. 2020, online: https://kentico.portoflosangeles.org/getmedia/b4a3b04b-5d3b-447b-b914-087c549dd2ce/news_010611_scrubber

41. Port of Los Angeles – The signal 2020, viewed: 24.09.2020, online: https://www.portoflosangeles.org/references/news_090320_signal

42. Port of Kaohsiung 2020, Rollout of AI-enabled Image Analysis System at Port of Kaohsiung's Automated Gate Sentry Posts Aims to Raise Vehicle Transit Safety and Efficiency, viewed: 22.11.2020, online: https://kh.twport.com.tw/en/News_Content.aspx?n=9C9076824CE61A04&s=9B986B287A951A78&SMSU=7886AF6A805074BD

43. Port of Rotterdam – Boxinsider 2020, viewed: 23.09.2020, online: https://lab.portofrotterdam.com/boxinsider-api/

44. Port of Rotterdam – Optimised Dredging 2020, viewed: 23.09.2020, online: https://lab.portofrotterdam.com/optimised-dredging/

45. Port of Rotterdam – Port Information 2020, viewed: 23.09.2020, online: https://lab.portofrotterdam.com/portinformation/

46. Port of Rotterdam – Portcalls API 2020, viewed: 23.09.2020, online: https://lab.portofrotterdam.com/portcalls/

47. Port of Rotterdam – Portscan 2020, viewed: 23.09.2020, online: https://lab.portofrotterdam.com/portscan/

48. Port of Rotterdam – Ship Events API 2020, viewed: 23.09.2020, online: https://lab.portofrotterdam.com/events-api/

49. Port of Rotterdam – Time to port 2020, viewed: 23.09.2020, online: https://lab.portofrotterdam.com/timetoport/

50. Port of Rotterdam – Vessel Traffic Service 2020, viewed: 23.09.2020, online: https://lab. portofrotterdam.com/vts/
51. Port Technology 2019, Busan Port Rolls Out Container Cone Innovation, viewed: 22.09.2020, online: https://www.porttechnology.org/news/busan-port-rolls-out-container-cone-innovation/
52. Sanders, N. R., Boone, T., Ganeshan, R. & Wood, J. D. 2019, 'Sustainable Supply Chains in the Age of AI and Digitalization: Research Challenges and Opportunities', *Journal of Business Logistics*, vol. 40, no. 3, pp. 229-240, viewed: 18.09.2020, online: https://onlinelibrary.wiley.com/doi/full/10.1111/jbl.12224
53. Shiphub – Port of Shanghai 2020, viewed: 22.09.2020, online: https://www.shiphub.co/port-of-shanghai/
54. Shiphub – Port of Singapore 2020, viewed: 22.09.2020, online: https://www.shiphub.co/port-of-singapore/
55. Song, D. W. & Panayides, P. M. 2008, 'Global supply chain and port/terminal: integration and competitiveness, *Journal of Maritime Policy and Management*, vol. 35, no. 1, pp. 73-87, viewed: 22.09.2020, online: https://www.tandfonline.com/doi/full/10.1080/03088830701848953
56. Taiwan International Ports Corporation Ltd. 2020, Smart Sea and Airports – Forging the Future, Revolutionizing Global Gateways, and Interfacing Intelligently with the World, viewed: 22.11.2020, online: https://www.twport.com.tw/en/News_Content.aspx?n=9C9076824CE61A04&s=826C29C330B9D145&SMSU=D9FE4A4404E76D64
57. Tijan, E. 2012, 'ICT Enablement of Administrative Processes in Croatian Seaports', in Proceedings of the Graduate Student Consortium–25th Bled e-Conference, Maribor, Slovenia, 17–21 June 2012
58. Tijan, E., Jović, M., Jardas, M. & Gulić, M. 2019, ' The Single Window Concept in International Trade, Transport and Seaports', *Pomorstvo*, vol. 33, no. 2, pp. 130-139, viewed: 29.11.2020, online: https://www.researchgate.net/publication/338063431_The_Single_Window_Concept_in_International_Trade_Transport_and_Seaports
59. TIPC 2019, Taiwan's Ports Linking Asia to the World, viewed: 24.09.2020, online: https://kh.twport.com.tw/Upload/A/RelFile/CustomPage/1/b8181d54-8fbd-4197-ab6d-ae9402d80050.pdf
60. Tomanek, D. P., Hufnagl, C., & Schröder, J. 2020 'Determining the Digitalization Degree of Information Flow in the Context of Industry 4.0 Using the Value Added Heat Map' In Kolinski, A., Dujak, D., & Golinska-Dawson, P. (eds) *Integration of Information Flow for Greening Supply Chain Management*
61. Wright, L. T., Robin, R., Stone, M. & Aravopoulou, E., 2019, 'Adoption of Big Data Technology for Innovation in B2B Marketing', *Journal of Business-to-Business Marketing*, vol. 26, no. 3, pp. 281-293, viewed: 17.09.2020, online: https://www.tandfonline.com/doi/full/10.1080/1051712X.2019.1611082
62. Zelbst, P. J., Green, K. W., Sower, V. E., & Bond, P. L., 2019, 'The impact of RFID, IIoT, and Blockchain technologies on supply chain transparency', *Journal of Manufacturing Technology Management*, vol. 31, no. 3, pp. 441-457, viewed: 19.09.2020, online: https://www.emerald.com/insight/content/doi/10.1108/JMTM-03-2019-0118/full/html