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Application of IoT Technologies in Seaport Management

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Abstract*— Seaports have a very important role in connecting freight by sea. Goods transported through seaports in the world are increasing day by day to meet human needs. This increases the pressure to apply more technologies for better port management. The world's seaports in the 4th generation, the generation in which seaports enhance connectivity to form a large network, have shown high efficiency when applying technology to port management. This optimizes port operations and connects port information into a network that improves productivity and reduces loading and unloading times. Today, the Internet of Things is the foundation for technologies to manage and optimize operations in various fields. It is considered by scientists to be a highly influential technology in the "4.0" era. The Internet of Things (IoT) technology directly affects the activities and processes of loading and unloading goods at seaports. Modern IoT-based port management technologies such as Radio Frequency Identification (RFID) and Dedicated Short Range Communications (DSRC) are contributing to the increased speed and safe movement of goods through seaports. The application of IoT in port management has become an inevitable trend and will be presented in this article. In the next generation, seaports tend to develop into smart ports based on rapidly developing technology platforms such as IoT, blockchain, and cloud computing. Smart port development also poses many issues to be resolved, including environmental issues. In this paper, the authors present some solutions to develop smart ports in an environmentally friendly manner.

***Keywords*— IoT; radio frequency identification; dedicated short range communications; seaport; port management; smart ports.**

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I. INTRODUCTION

In global trade, the maritime industry plays an important role in the logistics chain of the world [1–4]. Every year, the maritime field distributes 80% of the volume of cargo in the world, more than any other mode of transport in the world today although it is also reported to release the emission into the environment the most [5–8]. The seaport system was an effective role in marine transportation as well as the link between sea and land [9–12]. According to Tichavska et al. [13], this system supported to transport of goods effectively, this was shown via 1.4% of the goods that were increased each year. With this growth, the seaport system needed to solve the adaptability, optimize the activities in the seaport, and cut down on unnecessary activities [14][15]. In addition, roads also play a role in receiving and distributing goods, and current studies on transport routing and route selection are also very important for seaports [16–18]. In order to optimize the work of the seaport, IoT is considered an effective solution to resolve the seaport problem as well as effectively increase productivity [19][20]. According to Belfkih et al. [21], IoT was the next development step of Wireless Sensor Networks (WSN). A network of heterogeneous sensor types of equipment was deputized and connected via the Internet by the IoT system [22][23]. This system has the task to collect data and forward it to the collection center. Speeding up manufacturer operations while simultaneously reducing pollution was two of the primary goals of digitalization, which was governed by green regulations [24]. An IoT-enabled marine sector will see a dramatic shift in how it does business on a day-to-day basis: faults could be overcome; downtime can be minimized, and procedures and paper can be optimized, all of them transforming the conservative face of maritime business [25][26]. With the sensor available and the rapid development of IoT, the amount of data could collect from the land and sea area of the seaport would increase rapidly. These data could be collected from nature or human actions. In order to organize and control activities at seaports, the collected data from sources must be continuously observed [27].

Thanks to these activities, through the IoT system, the data were being a huge impact on trade, transport, people, and the environment at seaports [28].

A port was considered intelligent when it is equipped with many 4.0 technologies like sensors, robots, Radio-frequency Identification (RFID), IoT, or Big Data accordingly for administration and analysis. These technologies would enhance the problem-solving ability of the port effectively. In brief, the port operation would be optimized, and the administration of the port will become easier with 4.0 technologies. For instance, in order to make a decision easier, faster, and better in real-time, the Automatic Identification System (AIS) was adopted, or the dataset will be more complete and stable by improving the relationship between program languages and seaport operation management system [29][24]. By collecting, analyzing, and managing data, this system has been very effective. The shipping companies have also benefited through decreased waiting time, and from then, the costs have been reduced. Besides, various types of weather-related data such as precipitation [30][31], tide levels [32] in wharves, and wind level [33] will also be collected to analyze and make the best decisions for ports and carriers. With collected weather data, the port can fully forecast extreme weather events and take remedial measures from the beginning, avoiding affecting operations. Mobile Cognitive Radio Base Station (MCRBS) was a suggested technique by Prihatiningtyas et al. [34] to temporarily restore network connections in disaster zones. This technology will help ensure the flow of information at the seaport in the event of bad weather. And an indispensable factor is the environment, thanks to adopting 4.0 technologies, a port could decrease the impact on the environment via energy management [35]. Especially in the context of the COVID-19 epidemic still leaving a lot of consequences with the participation from many sides, the seaport structure was considered complicated and difficult to manage [36–38]. In order to effectively manage resources and optimize the operations of stakeholders, they must work together in harmony. The safety and reliability were increased, and transaction costs and operational costs are reduced, which were some advantages when different parties combine sequentially and effectively [39]. Sensor applications in a smart port might develop with the help of the Internet of Things (IoT), but there are some drawbacks as well. The data collected from different sources would make the smart port that necessitated a system to store and analyze data. So, the drawback of data from sensors of the smart port was a big problem, in order to utilize this amount of data, they were needed to store, analyze, clean and visual. With a sequence of operations to make data usable, a system with the right foundation was essential to address the above requirements.

In recent years, the development of Machine Learning/AI-based technologies and digital technologies is impacting all industrial and service fields, energy, and management and this impact is increasing both in breadth and depth [40–44]. With the diverse impacts of digital technologies on all industries and service fields with the promise of the opportunity for creating value, from then, these technologies would receive recognition in transport fields in general and maritime transport fields in particular [45][46]. Set in the context of major seaports in Europe today, large ports such as Antwerp (Belgium) and Rotterdam (Netherlands) have applied these technologies to the seaport system and achieved great results. These ports seem to be familiar with technologies like blockchain and IoT, and from then, these technologies make port operations optimal, sustainable and promising high security. They are growing at a fast pace and combining to establish massive digital networks and portals. They can integrate and combine the digital and physical worlds in this way (i.e. machines, devices, and humans). The primary purpose of such revolutionary digital technologies is to maximize economic performance and optimize power demand, as well as to minimize resource and waste usage, as well as to improve the qualification of the service portfolio.

Improving the operations effectively was one of the main functions of IoT technologies, additionally, with IoT technologies, automation might help to facilitate inter-organizational integration [47]. Seaports, for instance, were very well instances of organizations whose activities and performances were significantly influenced by their information technology systems in the logistics field [48][49]. The rising intricacy and competitiveness of the port business necessitated the ongoing deployment of novel technology methods for managing port logistics operations and supply chain activities [50]. The definitions of the smart port were based on the IoT notions and IoT technologies around the world [51][52], and this title was becoming a popular topic, and many studies were studied and published that revolved around the application of technology in port management.

Some recent information communication technology (ICT) advancements in the seaport based on IOT technology are briefly presented in this document. Specifically, road and sea are presented as the two main modes of transport at seaports. The technologies including Direct Short-Range Communication (DSRC) and Radio Frequency Identification (RFID) are provided in this article as a means of satisfying the unique needs of port operations through vehicle transport. From then, it showed the need for smart technology to support seaport operations and the tripartite relationship between port operation, smart technology, and the environment. The conclusion shows that smart technology and environmental management in the seaport area have a close relationship and this is a direction for future research.

II. Material and Method

In this section, the authors will present the notion of port, IoT, and the relation. Additionally, in this chapter, the author will highlight the forefront of seaports for solving effectively problems in the way modern supply chains operate.

Seaport

In recent years, many notions of seaports have been announced via many studies. Notwithstanding, economy and geography were the two main field that was researched in many studies related to the seaport [53][54]. Nowadays, the definition of seaport has changed because of expanding of the supply chain. Many industries and fields have been affected significantly by globalization. It drove firms to transfer the production locations and commodities flows, develops new needs to invest in infrastructure development projects, and creates a higher emphasis on environmental safety and energy efficiency. Requests about safety and security with the process integration brought dramatic alter in the management of the supply chain [55][56]. These developments required terminals of containers that had to change and enhance activities significantly [57]. From a geographical perspective, the seaport was a point that connected land and sea, but from a global supply chain management perspective, the seaport was a place where a link between all modes of transport. So, to evaluate the effectiveness of the seaport nowadays, the modes of transport were utilized as evaluation factors [58]. A seaport was considered an efficient connection if it could connect all transport modes. According to Bisogno et al. [59], the seaport was a complex combination, and to optimize activities, the integration between activities and actors involved in operations was necessary. With the increase of factors that took part in the operation of the seaport, researchers believed that applied information technologies would be the development step, and it would bring opportunity for enhancing efficiency, decreasing costs [60], and increasing manpower [61][62]. Currently, seaport management systems were utilized for simultaneous processes on terminals, some very famous examples of these systems were Portnet in Singapore, Dakosy in Hamburg, and Port Base in Rotterdam [63–65].

According to Arbia et al. [66], the development of the current seaport can be divided into 4 distinct phases. For the first generation, the seaports were primarily connectors between the land and the sea in commodities transit. Their responsibilities were then limited to the following activities: the loading and unloading of ships, the storage of products, and the delivery and receiving of commodities. Seaports in the second generation were considered hubs in the field of transportation, industry, commerce, and manufacturing of a country. Service providers play an important role in the function of seaports. So, the seaport of this gen could provide industrial or commercial services indirectly via the port's logistical infrastructure without being associated with the port's traditional loading and unloading operations [67][68]. With globalization, containerization, and the development of multimodal transport, the third-generation port was extended significantly with the increase in international trade. In this generation, the viewpoints related to management, operation, and development of seaport administration had different compared to previous generations. In the global manufacturing and delivery system, the seaport played an important and active role. Their behavior has changed as a result of this. Based on internationalization and diversification, the fourth-generation ports were born with a network system for enhancing the connectivity between ports in the region. This system allowed many seaports to connect and incorporate to develop the seaport system in a country and larger areas [69–71] Network ports were the name given to this system. As part of a worldwide transport logistics network, these ports worked hand in hand with other logistics companies operating in numerous different geographic regions. Fig. 1 below showed the development of the port via period.

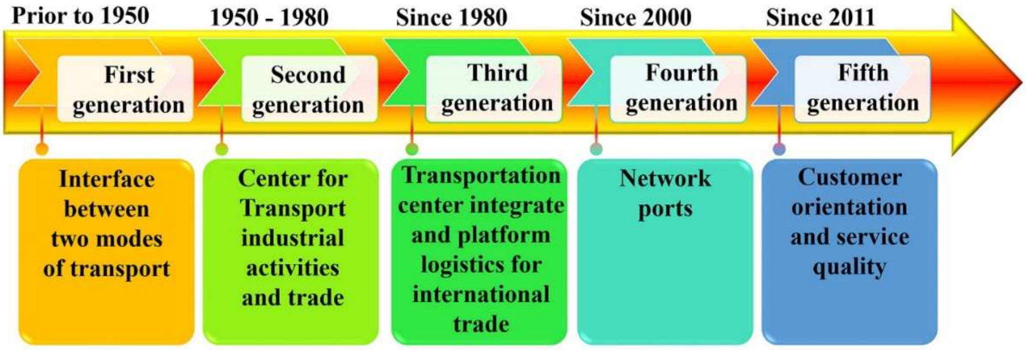

Fig. 1 Evolution of the seaport concept [66]

Along with the snappy development of information technology, digital innovation in the 4.0 period was a tendency that reshape the maritime supply chain structure [72][73]. Among the many advantages offered by digital technologies of Industry 4.0 for maritime supply chains' logistics centers, which include transport hubs, distribution centers, intermodal stations, and inland container depots, improved operational efficiency and reduced costs were two of many effects of information technologies as well as improved stakeholder relationship management (SRM) [74–77]. With many types of research were published, scientists agreed that IoT, blockchain, and cloud computing would the most influential technologies in the 4.0 era [73]. With these above technologies, the seaports had outstanding advantages in management ability and make-decision based on the collection and handle data ability via high technologies, toward becoming the smart port system. With intelligence, efficiency, and automation, it can be considered that this was the 5th generation of seaports. However, these generations of seaports all face a problem which is the environment. Most countries in the world are very interested in this issue because transportation is inherently one of the major causes of emissions. Seaports or shipping are also part of the cause. A large number of studies have been carried out on the green and clean technological solutions for seaports and shipping such as toxic emission management [78–84], and utilization and application of clean energy relating to toxic emission and clean energy management become extremely important [85–89], ballast water treatment in seaport [90–92], treatment and management for oily water and polluted water sources by heavy metal caused by maritime activities [93–101].

IoT system

Nowadays, to meet the requirements of life, the development of the Internet was inevitable. In 2017, by the testing database of Web of Science, Jang Hyun Kim and his colleagues [102] conducted a study that kept an eye on academic study trends, especially on the Internet of Things

(IoT). Linguistic networks from 2015 to 2017 have revealed numerous clusters, such as intelligent and digital home networks, sensor systems, general linear models, tracking and environmental protection, cloud computing, and huge data. In fact, the discussions for adopting IoT in seaport activities took place widely earlier. The implementation of IoT in seaports has been the subject of many of research, including those on the technical scope, working system, and supporting system. In the study of Dong [103], the information development in international seaports had been interpreted in detail. The next-generation Smart Port deployments' technological needs have been gathered and examined. Detailed plans have been drawn up for core technologies such as IoT devices and Smart Port Solutions. The study drew to a close with forecasts about the direction that Smart Ports would take in the future. IoT technologies' applicability in fields industry was very large. Transportation and logistics were two of many industrial fields that could apply IoT [104][47]. Integration of multiple commercial processes and requirements from a wide variety of firms was the IoT applied basis for logistics and supply chain management [105]. Through automation, IoT technologies could enhance operational efficiency and help activities integration processes between organizations to become smooth [47]. Shipping ports were very well examples of businesses whose activities and profitability are heavily reliant on their IT structures in the supply chain management industry [48][49]. To manage logistics operations in the seaport, the seaport requested to apply and improve continuously the information technologies system for meeting the complexity and competition in the maritime industrial field [50]. The Internet of Things (IoT) may also enable the re-engineering of the processes of complicated seaport-centered networks such as dry ports, and inland intermodal terminals which are directly connected to seaports and utilized by clients as logistic sites for container pick up or departure from the port [106].

According to Fang [107], four technologies were crucial in the development of the IoT system such as RFID, Dedicated Short Range Communication (DSRC), General Packet Radio Services (GRPS), and Wireless Sensor Networks (WSN). The above technologies would make the IoT system effective. The Internet of Things (IoT) was a network that connects physical objects to a digital system, allowing people and machines to communicate in real-time [108]. The information would become clear in an organization with IoT and this was proved. Data collection, transparent data, real-time information, process control, market forecast, and decreased delay were advantages that IoT brought to an organization [75]. For the seaport, the IoT technologies would directly affect the activities and processes of cargo handling. With the great potential of IoT technology, it would bring optimization to each exploitation process at the seaport. Fig. 2 will show the basic functions of a port that are applied to IoT technology.

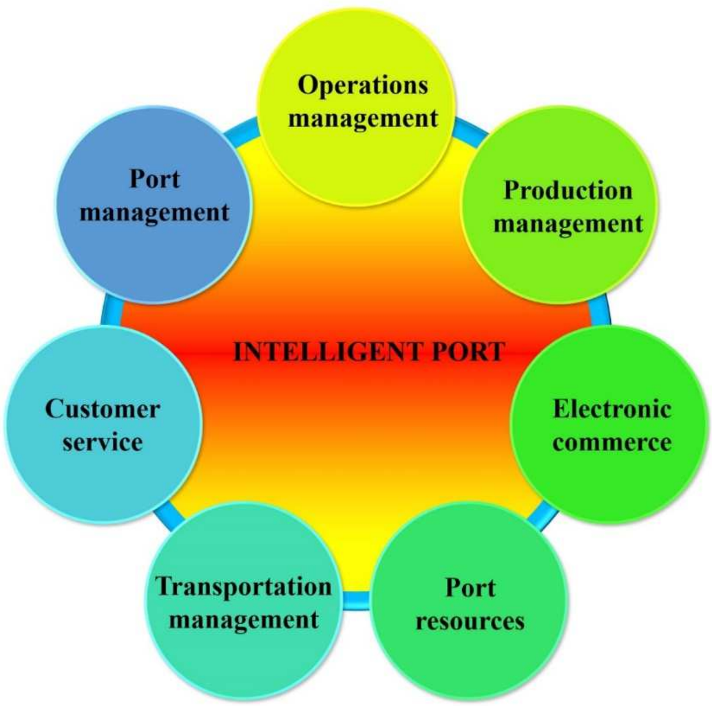

Fig. 2 Basic functional modules of intelligent port [52]

According to Wu et al. [52], as with any other port, the smart port also has unique characteristics that must be tailored. However, high efficiency, high security, and high-quality service were general features that the smart port provided services for the customer. As a result, a smart port system should focus on modules such as customer service, the port production administration system, the port activities administration system, e-commerce, the combined transportation administration system, the port resources administration system, and other functional systems. For the sea environment around the seaport, researchers and government officials have talked a lot about the marine environment in a world where the economy and society are always changing. Traditional systems for keeping an eye on the ocean's environment, such as ocean research fleets, are expensive [109]. With these traditional methods, it took a long time to collect and analyzed data, and the data that was collected isn't very reliable [110]. IoT technologies were born as a solution to solve these problems directly at a cheaper cost. Also, new models for intelligent process planning by deep learning solutions have been suggested that could be used to manage marine ecosystems smartly [111]. More interestingly, evaluating the relationship between real-time big data analysis and setting up merchandise decision-making data systems based on formula modeling platforms was thought to be possible for marine environment monitoring applications [112]. This is one of the steps needed to make industrial revolution 4.0 a reality [113]. However, the most obvious IoT concerns are safety and security-related issues. The statistics are very worrying about the problem of attacks on the internet. According to TechRepublic [114], malware targeting Internet of Things devices grew by 600% from 2016 to 2017. Another research by SiaPartner [115] about applying IoT applications in transportation showed that things connected to the internet increased the risk of data theft dramatically [116].

III. Results and Discussion

IoT could link and connect physical objects through the sensors system. As a result, it enabled managing the environment, reporting on the status of physical entities, and even acting on the information received. So, the source of information could be taken from any physical entity according to theory. Supply chain management tools provided by the Internet of Things (IoT) have revolutionized the transportation and logistics industry. Virtual manufacturers serviced real productions in real-time which was a particular example of the change because of IoT in supply chain activities. Real-time data exchange and real-time data collection help make the smart port's everyday tasks run more smoothly. To enhance the factors in applying IoT in the logistics and transport industry, Rey et al. [117] investigated and gave 5 hypotheses. There were five assumptions underlying the study, each relating to a different aspect of a logistics organization or seaport's size, innovation capability, absorption capacity, and perceived benefits or costs of connected technology.

In this article, technologies to manage and optimize seaport operations based on IoT systems will be presented. These technologies have been studied and presented in previous studies. With the two core RFID and DSRC technologies, practical applications can come from one technology or a combination of technologies.

A. Radio Frequency Identification

When a Radio Frequency Identification (RFID) tag or label was affixed to an entity and read by a reader, data from the tag or label could be read and then used to identify and track the object. For RFID, all modes of transport and supply chains were acceptable. To track and identify the property of an organization, RFID deployment would support and associate the property with activities in a facility, The deployment would help to automatize processes, and enhance activities capacity, in addition, for the seaport, RFID implementation supported assure for port workers as well as containers security. In fact, in addition, to improving security for port workers and containers, this technology is still utilized to improve quality, containers determine location and tracking as well as access control. With this technology, up to 70% of errors because of people and 50% of transaction time could be decreased in port [118]. Interactive optimization using RFID real-time data results in improved planning, increased efficiency, and improved overall performance. An additional advantage is that it provides a much-needed tool for handling increasingly complicated challenges in container ports such as container congestion or traffic jam in port.

In 2016, a safety system based on RFID technology was investigated and designed by Bauk et al. [119]. The worker's safety following to necessity of the Port of Bar is solved by the proposed RFID system. The logic level of the presented model is very high. The model consisted of three parts namely the physical part, the active part, and the passive part. The three parts are closely linked through connect layers the RFID system played the main role. Accordingly, the physics department here is the workers at the port, and the active and passive parts here are the workers' equipment such as hats, safety vests, and shoes. These devices are equipped with a piece of PPE (Personal Protective Equipment) and UHF (Ultra High Frequency). In the port area would place the RFID readers, and the results would be simulated by Matlab and OMNeT++. With the PPE protection types of equipment attached to RFID, the worker could avoid occupational risk as well as an alarm when necessary. Based on these findings and conversations, port management may employ this or a similar model for improving port safety and advertising it as a safety one in the maritime industry, as well [119]. The same year, a model of seaport based on RFID technology was built by Ferretti and Schiavone. Mombasa (Kenya), one of the big logistics hubs in the Central and Eastern Africa area, built a smart port that depended on RFID technology [51]. Based on RFID, the authors proposed a smart port model like Mombasa. This model included 5 parts as follows: (1) Centralized Processing and Control Center; (2) Location Movement Control and Management Center; (3) Control of Cargo Handling Center; (4) Cargo Tracking Center; and, last but not least, (5) Center of Verification Control and Release Management.

To minimize pollution and maximize productivity, a Trucking PORTAL web application was built and implemented in the Port of Montreal. As a result, truck routes have been improved, and the congestion at the entrance and exit gates has been significantly decreased at the port. Bluetooth technology and RFID tags help to collect license plates and that data is continuously updated for drivers in real-time. This is a key factor in minimizing wait times and reducing greenhouse gas emissions at the terminal [120].

With its outstanding features, RFID gives international shippers more peace of mind in meeting the requirements of Malaysia's domestic customers. In one of his studies, Masek et al. [121] have shown that the application of RIFD at border gates eliminates most of the unnecessary cross-border transactions, thereby significantly improving the quality of transactions and customer experience by minimizing shipping time as well as constantly updating the status and location of the goods to customers. If applied in all inland ports, RFID can create a data system to secure the reliability and safety of goods as well as simplify all technological operations in cross-border transactions. Fabian [122] announced that RFID technology will improve transaction flexibility, and save operational costs and it will benefit both carriers and their clients. Therefore, it is urgent and practical to equip seaports with RFID to create a centralized data-sharing center between international and domestic members.

Numerical studies show that RFID significantly reduces congestion in port areas. In a study conducted at a container seaport in the south of China, RFID [123][124] collected and stored data from 10 October 2020 to 10 November 2020, which contains 83,582 records. The data includes truck identifiers, the average tractor weight, the average container weight that was loaded, the average container weight empty, and engine working parameters as well as arrival time, in-port time, and off-port time. All truck journey time information will be collected and stored by RFID [125][126] in the port's information management system to analyze and improve lane service speed. With the available metrics, managers can re-plan service lanes for different types of trucks, optimize allocation times, and serve each lane in real-time, thereby minimizing significant operating costs as well as carbon emissions

Another application of RFID technology is to improve basic seals into e-seals. With its outstanding features, RFID allows e-seals to record the locking and unlock the history of seals. If there are any suspicious locking and unlocking attempts, the e-seals will issue a warning signal when the goods pass through the checkpoints. E-seals equipped with RFID technology can record all the other details of goods thanks to large memory and this information can be provided for faster and more reliable customs declaration or also can be used as an electronic database for ports, etc. Not only that but these e-seals also can be reused many times and are extremely environmentally friendly [126].

B. Dedicated Short-Range Communication

Dedicated Short-Range Communication (DSRC) is designed to improve communication by electronic devices over short distances. There will be a fixed central signal station responsible for connecting vehicles equipped with integrated equipment within the permitted range. DSCR not only improves communication by providing better visibility and connection, but also helps to minimize communication latency between road haulers, port operators, and carriers. Fig. 3 demonstrated the relationship between the 3 factors of domestic carriers, shipping lines, and seaports through DSRC.

Fig. 3 DSRC is the platform that can be used to support data exchange among different users of the port [127]

In the DSRC system, the devices are divided into two types: Onboard Unit (OBU) and Roadside Unit (RSU). Communication methods are also divided into two categories: communication between vehicles and vehicles (V2V), and communication between vehicles and roadside infrastructures (V2I). In vehicles often equipped with an OBU, a DSRC transceiver can, in many cases, act as a mobile device. OBU records the vehicle's movements even in a moving or stationary state. The OBU receives and transmits signals over one or more channels by approaching competing channels [128]. With its outstanding advantages, DSRC has laid the foundation for the success of combined projects such as Connected Vehicles, Cooperative Vehicle Infrastructure Systems, Cooperative Systems for Road Safety, Strategic Platforms for Intelligent Traffic Systems, Car-2-Car [71,129–132], and many great projects have been and will be implemented. The above projects meet IEEE 802.11p standards in 5.850 GHz to 5.925 GHz, which allows the devices to transmit up to 1 km with 32 dBm power contributing to improved smoothness of transportation [133].

The applications of DRSC in road transport are not difficult to find, but the most popular is the electronic free collection (EFC), known as a decision of the European Parliament. , Directive 2004/52/E [134]. Besides EFC, DSCR is also used in intelligent traffic systems, such as transactions through cars, collision warning, rollover warning, vehicle, and cargo tracking, vehicle identification at parking areas, etc [134][135]. The synchronous implementation of DRSC can minimize congestion at ports. Not only that, but this system also ensures the safety of traffic participants. In addition to improving the operational management of the seaport, this system is also considered a promising supporting technology for future vehicles. There have been many independent studies on the application of this technology to transportation systems, especially road traffic. Sai et al. invented a dedicated antenna system based on DSRC wireless communication technology to ensure the safety of the car traffic system [136]. In another study, Bey and Tewolde improved safety as well as provided other convenient services when participating in traffic based on DSRC technology combined with other mobile communication methods such as 4G/LTE or 5G. Experimental results show that combining DSRC with 4G/LTE or 5G mobile networks can create a much more stable and comprehensive vehicle communication system [137]. The DSRC system is considered a step towards bringing autonomous vehicles to work in seaport areas safely. In addition to research related to autonomous vehicles, DSRC technology can also be applied to multimodal transport management at a seaport. A study by Komol et al. [138] built a smart water vehicle monitoring system for mobile bridges based on vehicle traffic responses conceptual framework and modeling. In this study, DSRC was utilized to locate the ship, control traffic on the bridge, and move the bridge. However, service provisioning features for extremely maneuverable environments, like those discovered in seaport container terminals, could only be used successfully if they were built with strong architectures that can keep working well even in hostile environments [139]. Also, the fact that logistics operations in seaports were so complicated showed how important it is to have an infrastructure that makes communication reliable and easy [140][141]. Satyavathi et al. [142] proposed a wireless communication model to ensure data security and save energy. LoRa, a kind of wireless technology, was employed to meet this need. LoRa, Sigfox, and Narrowband Internet of Things (NB-IoT) are just a few of the long-range, low-power wireless communications technology that has emerged in recent years. These devices may help with low-power smart applications both inside and out, device-to-device interaction didn't rely on a network connection or a subscriber identity module (SIM) card.

C. Discussion

With the rapid development of new technologies, old technologies will quickly be eliminated, but it creates new opportunities for business transformation. It is not difficult to list the seaports that have deployed blockchain technologies, Big Data technologies, and IoT, however, the number of ports that have not yet been applied is not small. Although this is an inevitable trend shortly, there are still difficulties in applying these new technologies such as large investment costs, insufficient ability to integrate all stakeholders, issues related to network security, legal barriers to the privacy of personal data, and the lack of uniformity in the infrastructure of seaports [143]. Jović et al. [144] claim that the entire port operations can be fully automated if the Internet of Things (IoT) is drastically deployed. The Internet of Things (IoT) provides sensor signals on trackers that can automatically record data on the blockchain without any human intervention. Several other sensors can be installed in containers that can provide insurers with real-time information on the status of their cargo.

A few seaports have applied an information system based on the enterprise resource planning (ERP) system. However, the reality shows that the data is not optimized, but is run traditionally and lacks planning. Fig. 4 shows the current global flow of information systems.

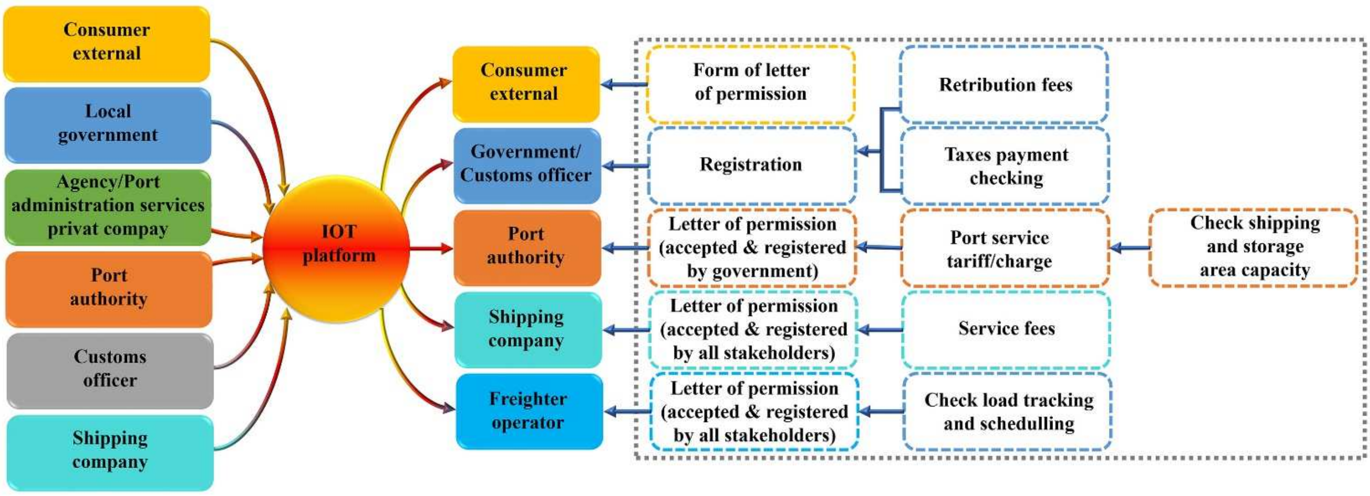

Fig. 4 The architecture of the IoT technology platform [145]

With the help of technology, two main development trends are being directed by seaports: smart ports and environmentally friendly ports [146]. With the rapid development of IoT technology, the transportation and logistics industry is also one of the most strongly applied aspects. Seaports are one of the key factors affecting the world's entire supply chain, and the performance of seaports is significantly influenced by their IT infrastructure [147][148]. Therefore, it is not surprising that more and more studies are focusing on the implementation and assessment of the impact as well as the decisive factor for the application of IoT in seaports, a key factor for the design of smart seaports bright. An ideal model for the smart port concept is the wide-scale deployment of IoT and synchronization of all its logistics management activities [149][150]. Nguyen et al. [151][152] presented the shared ideas of smart ports and the advancement of their growth in the direction of the construction of a long-term maritime environment, this research focused on applied systems for port energy management. Therefore, it can be seen that these two trends have a necessary relationship with each other. Nevertheless, to achieve the development goals of the above two trends, managers will also face many obstacles depending on each situation. Bayoumi et al. [153] collected and analyzed the difficulties in IoT adoption in Egypt and classified them into 3 main barriers. First, although in the long term, the application of IoT will optimize operating costs and generate huge revenue, however, in the short term, applying and deploying IoT still needs an abundant source of investment costs. The second barrier to mention is the lack of knowledge of the operators and the training and equipping them with the necessary knowledge is not simple and will take a lot of time, not to mention the inertia when it comes to accepting changes. Last but not least, the last barrier concerns customs procedures in Egypt as they cannot yet be fully automated. Interviewees believe that IoT applications when not synchronized will not be unified and standardized, which will lead to conflicts. In fact, the above barriers do not only occur in Egypt but are also common barriers in most countries that are trying to apply IoT as well as other modern technologies for the purpose of creating smart seaports. As mentioned, the application of modern technologies requires a great deal of personnel and investment costs in a very short time. In addition, some objective factors such as the volume of goods or the number of ships in circulation at the port. If the flow through the port is not high, the cost of IoT adoption will be much higher than the revenue of that port, leading to a breakeven point that will occur for a very long time in the future. Similarly, there are also many green port models researched and developed. Alzahrani et al. [154] designed a model of a decarbonized seaport. This model requires a seaport to converge 9 components to become a green port. 9 components include a Smart grid, Microgrid, Distributed generation, Energy management system, Virtual power plant, Artificial intelligence, Information and communication technology, Internet of Things, and Smart port. Annunziata et al. [155] emphasize three key points that government agencies should develop to minimize CO2 emissions, including the efficient use of energy and renewable energy, the development of energy-saving technologies as well as zero-energy buildings. In another study, Moya et al. [156] emphasize the importance of government in facilitating the development of energy efficiency programs to reduce GHG emissions as well as energy consumption. Hoang et al. [157] studied solutions to follow the International Maritime Organization's (IMO) policy guidelines, the authors found effective ways of changing port and ship energy consumption patterns to secure long-term operation and minimize CO_2 emissions. An important target adopted by the EU in 1997 was to reduce GHG emissions to ensure supply chain security and improve EU competitiveness [158]. In addition, the EU also sets strict requirements to reduce CO2 emissions and make the most of renewable energy sources [159].

Bui et al. [160] pointed out an optimized system of energy management at seaports to achieve the requirements of green and sustainable development in seaports. Besides, a model was built to measure and quantify green development by Wan et al. [161] based on Drivers, Pressures, States, Impacts, and Responses (DPSIR) factors. The weight of each indicator in the model is calculated based on the hierarchical process analysis method, and the evaluation results of the gates are aggregated using the obvious methodology. The assessment model is validated after undergoing a comparative analysis of the five main ports in China and becomes a potential tool to conduct a green development assessment of any port. In another study, Hua et al. [162] proposed another system of criteria to control environmental pollution and evaluate the effectiveness of green development in ports. The study was carried out at Zhuhai port, China. This study indicates that Zhuhai Port needs to focus on monitoring the quality of energy consumption as well as polluting emissions, updating the most advanced technologies, and putting them into application. In addition, green port development plans must be built close to reality for easy implementation, thereby improving the port's energy-saving and environmental friendliness [163–165]. Another significant source of emissions at seaports is the shipbuilding, repair, maintenance, and demolition of ships. This is an occasional source of emissions, but a big problem if not addressed. This can pollute both the air and the water environment of the seaport. To solve this problem, Vakili et al. [166] developed an energy management framework to reduce air emissions in shipbuilding. In addition, optimizing the ship design [167–169], using advanced techniques and applying post-treatment methods for SOx and NOx reduction [170–177], using low or free-carbon fuels (hydrogen, ammonia) [178–185], and/or developing methods for recovering the waste heat from large marine diesel engines [186–189], using renewable energy and energy storage technologies in ships, port, and vehicles in port [85,190–192] could also be potential solutions to reduce pollutant emission from maritime and port actions. Although the above studies propose to solve this pollution by different methods, they are all towards sustainability for the environment, especially a specific environment such as seaports.

The common point of all the above studies is the high consensus in focusing on energy management factors. This is an important factor to evaluate the green development capacity of any port in the world. To achieve that, the application of smart technologies is imperative for effective green port management. There are certain connections between smart ports and green ports, so the combined development trend is both feasible and very promising. However, there are also problems associated with this combination, especially the problem of energy consumption that will increase significantly when using IoT technology in seaports. Therefore, more studies are needed to calculate and evaluate the energy consumption of high technologies such as RFID or DSRC to help managers properly assess the general picture and make rational decisions because these technologies compete with each other in terms of energy efficiency, investment costs, and deployment capabilities, and it is difficult to say which one dominates the rest. After having the standard assessment and choosing the method, managers should drastically implement and increase awareness and knowledge for employees about the efficient use of energy.

IV. Conclusion

IoT has become an important foundation for modern port management technologies, helping to optimize seaport operations around the world. The RFID technology based on the IoT system has proven to be preeminent in ensuring safety on seaport systems and, at the same time, helping to reduce the time of delivery of goods through ports. Another technology is the DRSC, which helps solve problems in port management, such as tracking vehicles and goods, resolving congestion at seaports, ensuring traffic safety, and operating seaports effectively. Modern management technologies based on IoT platforms have high energy consumption, which makes environmental pollution more serious. Therefore, comprehensive studies are needed in the development of smart seaports and environmentally friendly seaports.

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