8-30-2022

Research on the development of port digitalization and SWOT analysis for digital ports

Ling Dong

WORLD MARITIME UNIVERSITY

Dalian, China

RESEARCH ON THE DEVELOPMENT OF PORT DIGITALIZATION AND SWOT ANALYSIS FOR DIGITAL PORTS

By

DONG LING

The People's Republic of China

A dissertation submitted to the World Maritime University in partial

Fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE

In

MARITIME AFFAIRS

(MARITIME SAFETY AND ENVIRONMENTAL MANAGEMENT)

2021

DECLARATION

I certify that all the materials in this dissertation that are not my own work have been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature: …………… Dong Ling………………….

Date: …………………Jun 26th, 2022…….…….

Supervised by: ………………….Zhao Jian…………………….

Supervisor's affiliation: .…………Dalian Maritime University…………

ACKNOWLEDGEMENT

As far as I am concerned, the meaning of life is to travel to different countries, see different scenery, meet different people, and gain different knowledge. Therefore, I was so excited when I learned about the opportunity to participate in the MSEM program and gain maritime expertise that I had never been exposed to before. Although I knew it would be a big challenge for me, who majored in finance before, to finish all the 17 courses and the graduation thesis, I was determined to participate to fulfill my life. Also, I became one of the three overseas students in this class since I stay in Kuwait now.

The professors of all courses in the MSEM program are experts in the maritime industry, and the content they bring to us is the best of their research in the maritime field over the years. I feel very honored to have such professional professors to teach us. Especially Professor Ma Shuo, his course on maritime economics was one of the most fascinating courses for me. The lecture he taught was logical and clear in focus, and he explained every detail to us very clearly. In his class, obscure professional knowledge was explained very thoroughly with plain language and vivid examples. Although I had a basic knowledge of economics before, I never thought that economics could be related to maritime, and President Ma's class opened my gate to a new world.

In addition, I would like to thank Mr. Zhao Jian and Ms. Zhao Lu for thinking of their students and being the first to lend a helping hand whenever they are in trouble. I feel lucky to have such responsible teachers. Mr. Zhao Jian, who was also my thesis advisor, gave me a lot of constructive suggestions for my thesis in particular.

Also, I would like to thank the classmates in Group three, who all worked very hard and were friendly, and showed strong professionalism and team spirit in the group work.

Finally, I would like to thank my parents and my husband, who always support and encourage me no matter what decision I make. I live in love and happiness all because of my family. I love you all.

ABSTRACT

Title of Research Paper: **Research on the Development of Port Digitalization and SWOT Analysis for Digital Ports**

Degree: **MSc**

With the rapid development of global economic integration and digital information technology, the competition among ports gradually evolves into the competition between global networks and the ecosphere in which ports are located. Through business model change and development concept innovation, building a digital port with comprehensive perception, efficient operation, safety and reliability, intelligence and green and reconstructing a multi-border and systematic port ecosystem are important measures for modern ports to win strategic initiatives in the 21st century. In a sense, the digital port is a profound change involving the development concept, organization and management, operation mode and value service of the port, with far-reaching impact.

The first paragraph introduces the background of the development of port digitalization, the purpose and significant of this research, and the research methodology. The second paragraph shows the overview of the development of digital transformation for ports, including the changes in the function of ports, the essence of digital transformation in ports, scenarios supported by the digital business, and the process of digital port transformation. The third paragraph introduces some core technologies applied in port digitalization. The fourth paragraph analyzes whether to develop port digitalization in SWOT analysis and gives the advice on the development measures. The fifth paragraph gives some examples to show the current state of digital development of global ports. The sixth paragraph shows the future prospects of digital port transformation.

Keywords: digitalization, port, SWOT analysis, development.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AI	artificial intelligence
AIoT	The Artificial Intelligence of Things
CIF	Cost Insurance and Freight
CRM	Customer relationship management
CMA CGM	Compagnie maritime d'affrètement - Compagnie générale maritime
EDI	Electronic data interchange
IoT	Internet of Things
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organisation
IP	Internet Protocol
ITF	International Transport Forum
RFID	Radio Frequency Identification
NASA	National Aeronautics and Space Administration
NB-IoT	Narrowband Internet of Things
NIS	Network Information Service
PCS	Port Communication System
VHF	Very High Frequency

CHAPTER 1 INTRODUCTION

1.1 Background

The development of the maritime industry is closely related to the technological revolution in the world economic landscape. Nowadays, maritime industry is facing multiple challenges and opportunities from the reshaping of the global economic and trade landscape, industry chain restructuring and integration, supply chain service transformation, and the application of new technologies, etc.

Since the financial crisis took place in 2008, the world economy has not been completely out of the predicament yet. Political, social, economic and trade black swan events occur frequently. The epidemic of Corona that started to spread at the end of 2019 has produced a double kill of supply and demand in the global economy, leading to the rise of anti-globalization. The global economic landscape is facing huge changes, and the "uncertainty" in the external environment of the maritime industry continues to increase. At the same time, technology-based, digital enterprises are still developing, bringing about great impact on the industry's business model and market trends.

The rapid development of global information technology has driven the continuous advancement of digital change in ports and maritime transportation, and the maritime industry is bound to choose new methods to establish new business models, reduce the degree of dependence of business on people, and promote a more thorough separation of people and the cargo. The dramatic rise in the maritime industry's reliance on processes, data, and platforms will lead to a significant rise in the need for digitization as well. Digital technologies represented by artificial intelligence, big data, cloud computing, blockchain, etc. are maturing and continuously driving changes in business models and business service standards in the maritime industry. Digital products, services and new business models in the maritime industry are emerging.

The digital technology in the process of solving business problems is not through a single point technology to meet business needs, but through the combination of a variety of complex technologies, forming a technology chain to adapt to various forms of business scenarios. Based on EY (Ernst & Young) insight, combined with the research of technology in various business areas and the current maturity of technology, EY initially assessed the data technology relevance of artificial intelligence, blockchain, cloud computing, big data and other technologies in smart shipping, smart ports and other businesses as follows (EY, 2021).

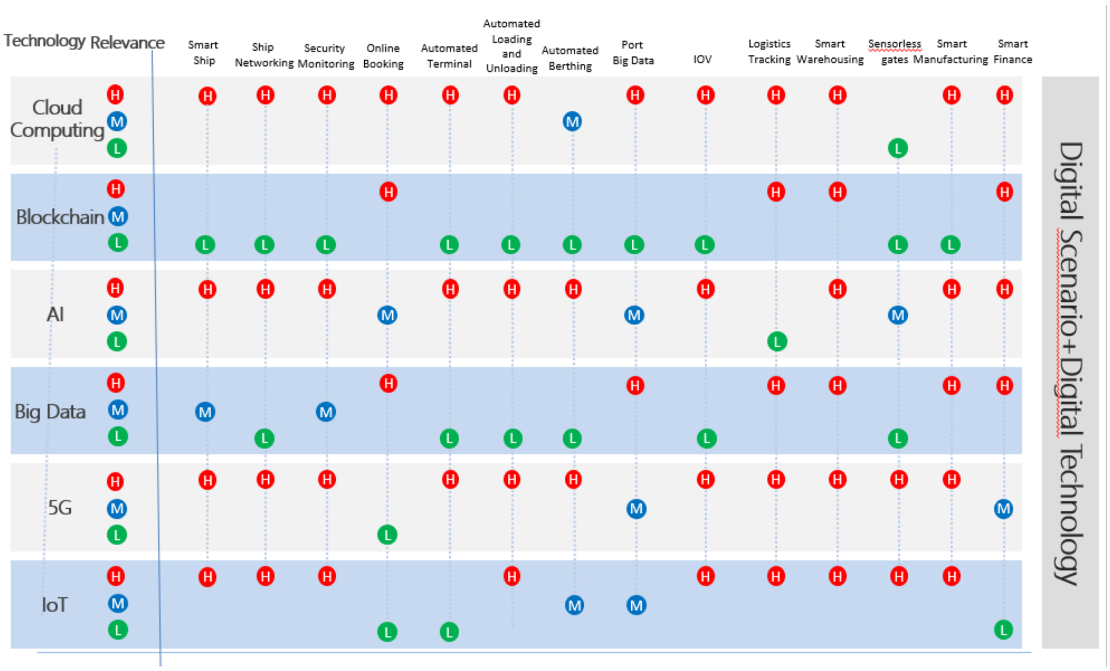

Figure 1.1 Data technology relevance between technologies and maritime business

Ports, as an important part of the maritime industry chain, have also started the digital transformation process. As port informatization, automation, and intelligence continue to deepen, the level of port technology has increased significantly. The strategic focus of ports has shifted from resource control to fine management of resources and from increasing customer value to maximizing the value of the ecosystem. The competition among ports has gradually changed from simple scale competition to all-round competition of logistics chain, service chain, value chain and ecological chain. Ports around the world are paying more attention to the ability of collaborative innovation, comprehensive service and ecological collaboration.

With the goal of creating top-tier smart ports, major ports all over the world have made digital transformation the centerpiece of their plans in recent years. They have revolutionized the idea of port operation and development with the aid of digital technology, worked tirelessly to create complete competitive advantages for ports, and improved port operations in terms of safety, dependability, efficiency, and intelligence.

1.2 Research purpose and significance

Digital transformation of ports has been a hot topic in recent years, and many large international ports have started to develop the digitalization process in full force in recent years. However, the digital transformation of ports is at a preliminary stage, and the ports that have started to develop digital transformation are still figuring it out while developing. This paper will first give a review on what digital transformation of ports means, its supporting technologies, and how digitalization can be applied to port operations. In addition, the process of port digital transformation requires the coordination of many resources and other diverse factors, which can easily lead to blindness and subjectivity in development if strategic decisions are not made scientifically. Therefore, this paper will conduct a SWOT analysis on whether the world's ports should vigorously develop the digital transformation of ports, and proposes future development strategies by understanding the internal potential and the external conditions for digital ports.

1.3 Research Methodology

1.3.1 Literature review method

The university's library and network resources are used to collect a large amount of relevant literature. By collating and summarizing the existing literature, the research results of digital ports are further studied on the basis of understanding the domestic and foreign digital ports. In this way, the basic theoretical knowledge of port digitalization evaluation and construction plan design can be obtained.

1.3.2 Inductive and comprehensive analysis method

Collating and analyzing the information on theoretical research, evaluation models and construction programs of digital ports at home and abroad, so as to derive the current situation and background of research on port digitalization, which determined the research content and research background of this paper and laid the theoretical foundation for this study.

1.3.3 Qualitative analysis

The qualitative analysis method, also known as non-quantitative analysis, is based on people's subjective judgment or practical experience to predict or judge things. It is suitable for analyzing problems with data that do not have complete historical information. SWOT analysis matrix is a qualitative analysis method, which analyzes the subject combining the internal resources and capabilities (strengths and weaknesses) and the external environment (opportunities and threats), and proposes development strategies through the analysis.

CHAPTER 2 OVERVIEW OF THE DEVELOPMENT OF DIGITAL TRANSFORMATION FOR PORTS

2.1 Changes in the function of ports

The traditional port is characterized by the transit of cargo transportation over time.

2.1.1 The first stage

Before the 1960s, the main function of the port was to collect and distribute bulk and liquid cargoes with small variety and large volume, and the function was identified as a "transportation center", which was controlled by manual and mechanical operation. At that time, the maritime industry did not have high requirements for the timeliness of cargo transportation. Besides, the development of ports depended mainly on the production and consumption capacity of the hinterland, while the scale of related services that depended on port cargo transportation was small (Zhuang, 2005).

2.1.2 The second stage

In the post-1960s, ports volume of major cargoes of global maritime transport, bulk and liquid cargoes has stagnated after rapid growth. At the same time, the demand for global transportation of finished and semi-finished goods increased, and the pattern of "mass production and mass consumption" emerged, which led to an increase in the size of ports and the complexity of the transport chain. During this period, the port was positioned as a "transportation center + service center", with operations including cargo handling and warehousing, commercial and industrial activities, as well as value-added functions. In this period, container transport revolutionized the port transport system and its throughput became the main mark of port competitiveness. Ports also successively carried out the construction of information technology systems and began to focus on solving the management of complex operations at terminals. Global ports gradually entered a period of development in which information systems and port mechanization were combined, information systems gradually determined the scheduling of port machinery, and semi-automatic and fully automatic terminals began to appear (Zhang, 2010).

2.1.3 The third stage

In the 1980s, global integration accelerated and the function of ports changed—ports then were positioned as "international logistics centers". Port services were upgraded to comprehensive services such as transportation, trade information services and distribution of goods, and ports became important hubs and nodes of international logistics corridors between land and sea. Cargo flow, commercial flow, financial flow, technical flow and information flow have converged comprehensively, and the conversion process presented the characteristics of joint transportation, joint operation and container door-to-door multimodal transportation. At that time, due to the development of paperless business, the port business has extended from the traditional freight industry to the modern shipping service industry, and the EDI system has developed and applied in port operation (Zhang, 1997).

2.1.4 The fourth stage

From beginning of the 21st century, the port was repositioned as "more of a link in the supply chain". The role of port has transformed from a logistics hub to that of a part in the supply chain where goods and information pass quickly. Differentiated service demands have emerged in port control, and ports have been required to make agile and rapid responses to market demands. In the operation process, standardized and scaled services have been required to reduce port production costs and increase port convenience. In addition, in terms of quality control, the pursuit of excellent operational quality, process optimization, increased market share, increased efficiency of production services and increased revenue are required for ports at this stage (Zhang, 2009).

Production, delivery and CRM (Customer Relationship Management System) are fundamental to any business and organization, and they are fundamental to Port Terminal. Planning, execution, feedback, and improvement are basic processes in almost any business, while Port is a highly planned and driven operational organization. For a large and rigid organization, this process can be long, while for an agile organization, this process can be short. The process of planning, execution, feedback, and improvement in an ever-shortening chain is the process of continuous agility in the enterprise. A decisive factor in shortening the chain is the continuous improvement of the flow of information, and the basic characteristic of a digital port is the fast flow of information. Therefore, with the change of port function, the importance of digital port is becoming increasingly clear (Liu & Wu, 2019).

2.2 The essence of digital transformation in ports

Compared with traditional informatization, digital transformation is a change from technology application to comprehensive reshaping of industry function, which is not only a systematic innovation in technology, management, operation and service, but also includes vertical and horizontal changes in the humanistic organization, development concept and strategic system of the port, emphasizing on the innovation and reconstruction of all-round, whole-chain and systematic.

Horizontally, digital ports not only reconstruct all product forms and service processes of the port, realizing internal and external integration and linkage, but also promote the integration of port-aviation-material-trade, the integration of port-industry-city. For example, from the perspective of the whole value chain and ecological chain, the Port of Hamburg has improved its port control system, which optimized its business processes, builds an intelligent technology platform, innovats its digital organizational structure, and deepens the integration of port, industry and city. By building a unified big data platform and customer-oriented e-commerce platform PortLog, the Port of Hamburg provides integrated services for cargo owners, warehouse operators, shipping companies, freight forwarders and other customers in the logistics chain, and realizes predictive operations based on data insights (Portnews, 2013). Also, the Port of Hamburg has built automated terminals, modern yards and logistics service bases, and created intelligent transportation systems in terms of land transportation, water transportation and railroad transportation. In addition, the Port of Hamburg is optimizing their logistics value chain services through process re-engineering and business standardization. The digital transformation of the Port of Hamburg has significantly improved the level of port operations and operational efficiency, and has also effectively safeguarded and enhanced its global operation capabilities (Luo, 2021).

Vertically, based on the perspective of port business chain, logistics chain and service chain, the digital ports are able to reconstruct the whole chain of port production, management, operation and services, realize the organic integration and vertical integration of internal resources, comprehensively improve port operation efficiency and service level, and expands and extends the port value chain.

Overall, the essence of port digital transformation is to use modern digital information technology to integrate port business processes through "data + computing power + algorithm" to enhance the port's all-round business innovation capability, and to realize business model innovation and ecosystem reconstruction, making the whole process of port logistics chain, service chain and value chain measurable, predictable and traceable. Its connotation mainly includes three aspects.

First, digital conversion. The digital port uses modern digital information technology to penetrate every corner of port production, operation, management and service in the physical environment in order to realize the digital collection of all elements of the port logistics supply chain. Through the digitalization of the elements, all operations are converted into data that can be stored and calculated, laying the data foundation for digital transformation and empowerment.

Second, digital empowerment. Digital port can promote the integration between data and business through modern information networks and data management technology, and realize real-time data sharing and exchange in all-round, whole process and whole field. This can effectively promote data penetration, resource sharing and business collaboration between the upstream and downstream of the port logistics chain, supply chain and industry chain.

Third, digital reconfiguration. Digital technology is able to be applied to break system boundaries, innovate business services and reconstruct customer experience. Relying on the foundation of digitalization, networking and intelligent construction, especially new infrastructure such as cloud computing, big data, Internet of Things, 5G and artificial intelligence, a new generation of enterprise architecture adapted to the digital economy environment could be built. In addition, the reconstruction of organization, system, design, R&D, production, operation, management and business in the traditional business mode can be realized (Luo, 2021).

Thus, the digital transformation of the port is not simply the application of new digital technology, but a comprehensive and systematic change and reshaping of the port development concept, strategy system, organizational structure, production management, business operation and value service. It is both a business transformation and upgrade, as well as a reconfiguration that integrates technology, business, technology and organizational system, with far-reaching impact.

It should be noted that in this era of great change, there is no experience or model that can be copied, and ports should combine their own resource endowments and environmental conditions, highlight innovation-driven and demand-oriented, and find a digital transformation path that suits their own characteristics, which is the right solution.

From technology mastery to business innovation, from capacity building to talent training, from organizational change to cultural reshaping, port digital transformation cannot be achieved overnight, but will be a long-term, continuous and gradual systemic project.

2.3 Scenarios supported by the digital business

Digital transformation must be considered together with digital business to be effectively promoted. Combining the past practices of consumer Internet and industrial Internet, the main scenarios supported by digital business are the following: information, sharing, connection, visibility, and intelligence.

2.3.1 Information

Access to information is the fundamental requirement of human beings and all living beings. People are constantly dealing with other people in society, constantly checking whether what people say is true, whether what they do is right, where they care about the target, and so on, which is the most fundamental information. Many participants in port logistics operations are also constantly confirming this information: whether my cargo (ship) is still there, where my cargo is, and whether the cargo is consistent with the stated value.

2.3.2. Sharing

Sharing can be considered as a sub-application category of information, which can be understood more as the sharing of large amounts of data, including actions such as searching, publishing, exchanging, and subscribing. Sharing is based on the simple knowledge that the value of data is different in the hands of different people, and only those who use and consume the data truly understand the value of data. Therefore, in order to maximize the value of data, it is necessary to continuously promote the flow of data, so that the data can reach the people who really need it.

2.3.3. Connection

The purpose of connection is to eliminate information asymmetry. The development of mobile Internet is a process of eliminating information asymmetry, and it is the connection that creates the trillion-dollar industry chain of mobile Internet. E-commerce connects buyers, goods and sellers, social connects people and people, payment connects people and money, sharing connects people and resources, and accurate marketing connects people and information flow. When there are multiple participating bodies in a business, there is bound to be information asymmetry, and connectivity can certainly play a huge role in this scenario. Port logistics is the most complex part of social and economic operation, involving many participants and resources, and the interlocking of these participants and resources is a good place for connectivity to play a role.

2.3.4. Visualization

Visibility may not be very important in the consumer Internet, but it will be in the core of the industrial Internet. The spatial and temporal characteristics of the weakened resources in digital transformation need to be presented in the visual scene. Visibility in the digital port is mainly presented in three aspects: portable port terminal, cognitive assistance, and visual empowerment.

Portable port terminal. It allows port terminal personnel at all levels to see what is happening at the port at any time and from anywhere.

Cognitive assistance. Digital ports interweave massive amounts of data. Most people have cognitive barriers to recognizing high-dimensional data, and visualization can effectively achieve dimensionality reduction and give users better cognition.

Visual empowerment. Visible is always easier to be cognized than digital. Empowering information, sharing, connection and intelligence makes these scenario-based applications more penetrating and expressive.

2.3.5. Intelligence

The exploration of intelligent applications in port terminals has been at the forefront of the industry, from intelligent gates and remote control to automated terminals, all of which are the continuous promotion of intelligence in port terminals. Now intelligence is in its infancy, but the broad application prospect of intelligence may be as important as connectivity in the future. The core value of connectivity is to eliminate information asymmetry, while the strength of intelligence lies in learning, recognition and judgment, and the core value also lies in empowering the human brain and replacing it. Intelligence can be considered from the following perspectives in terms of application scenarios.

Firstly, whole human brain intelligence. There are many talented people who can handle high-dimensional data. The main role of intelligence at this time is to help them handle and process data, so that the chaotic data can be sorted into categories to form a knowledge map.

Secondly, Human brain intelligence assists. Most ordinary people are weak for processing high-dimensional data, so that too much data could be overwhelming. At the same time, ordinary people are also weak at handling weak scenario data, where too limited information cannot provide help. Intelligence needs to do two things here: reducing the dimensionality of high-dimensional data so that ordinary people can deal with it efficiently; supplementing the context of weak scene data, and increasing the dimensionality of weak-dimensional data so that ordinary people can deal with it efficiently.

Thirdly, simple automatic intelligence. For simple decisions and efficiency-first scenarios, machines often do better than humans. Smart gates are typical simple automatic intelligence applications, with various identity verification and simple risk control functions, such as face recognition, risk identification, and compliance control. Most operations at port terminals are reflected in simple decision-making, efficiency-first, and are scenarios where automation or semi-automation is inherently useful.

Finally, complex automated intelligence. Fully automated terminals are a typical application of complex automatic intelligence. Complex automatic intelligence learns, processes, adjusts and judges autonomously in complex environments, completely or partially replacing human work (Liu & Wu, 2019).

2.4 The process of digital port transformation

Digital ports is different from traditional information construction, even from smart port construction, and has its own different logic to follow. The foundation and goal of digital transformation does not only depend on business data, but requires a broader data space. Based on the scenarios supported by the digital business, the process of digital port transformation can be divided in five steps.

2.4.1 Digitization

Digitalization is the basis of digital transformation. The goal of digitization is that all production factors, processes and environments involved in port terminal operations need to be transformed into digital expressions. The current information construction has only partially completed the digitalization of business data. Obviously, digitalization is not an overnight process, but a continuous iterative process to complete.

2.4.2 Integration

Integration is the process of data quality integration and governance. First, it integrates the data that is scattered all over the world and organizes the data in a better way to make it easier to understand. After that, data cleaning and governance are performed to make the data less ambiguous, easy to understand, and of high quality. The integrated data forms the basis of the digital port, which can be considered as a digital representation of the realistic analog port terminal.

2.4.3 Connection

Connection is not necessary for production operations. However, connection becomes a fundamental requirement when we want the data to be used for more than just production operations. Connection requires us to look at data from an investment and financial point of view, and requires a set of financial management practices to be applied to the data.

2.4.4 Visualization

Unlike information technology and smart port construction, visualization can be considered as the basic engineering of digital port. Make data visible and measurable is the beginning of all the work of the digital port.

2.4.5 Intelligence and automation

Unlike digitalization, integration, connection and visualization which are the basic engineering of digital port, intelligence and automation can be considered as the upper layer application of digital port. A manipulable digital twin or digital port is a prerequisite for automation.

CHAPTER 3 TECHNOLOGIES APPLIED IN DIGITAL PORTS

3.1 Blockchain

3.1.1 Introduction to Blockchain

Blockchain technology is a distributed ledger system built on open and transparent cryptographic principles that enables everyone to contribute to the database records. Distributed here refers to the distributed storage of data, or the distributed recording of data (Shen & Zhong, 2018). All nodes participate in the storage process, while the system collectively records and maintains together, and will generate a set of time-stamped, decentralized, trustworthy and tamper-evident database, which can effectively ensure data security. The peer-2-peer networks use consistency mechanisms to ensure that transactions are valid before they are recorded in the ledger (Hou, Zhuang, Shi &Wan, 2022).

The same hash that the other parties in the network have to be provided by one party in order to validate a transaction. This hash is a precise and distinctive code that describes the information-containing message. The block contains a record of the verified message. You may think of a block as a container; while anybody can see it from the outside, only those with access and a private key can open it and access its contents. Each subsequent block is then chronologically connected to the one before it. It is possible to create a public or private blockchain, which affects who has access to the network and may access data. Permissions are issued according to a permission-setting rule in a private network. A public network, on the other hand, is open and is governed by consensus. Everyone who has access to the data is the owner in a blockchain system. (Wattenhofer, 2016).

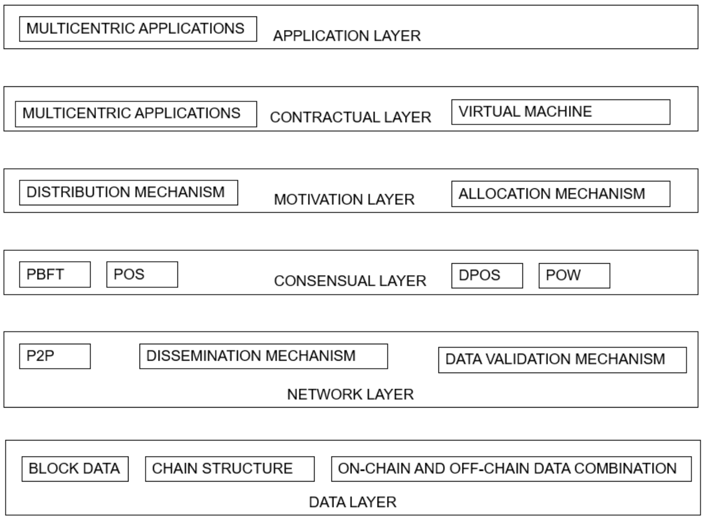

Figure 3.1 Data Layering of Blocks

The core technologies of blockchain also include distributed ledger, asymmetric encryption, consensus algorithm, and smart contract technologies in addition to peer-to-peer networks. The following six fundamental characteristics of these major technologies, which together provide a new method of recording, storing, and expressing data, are: Digital transaction, smart contract, federated chain, distributed ledger, and tamper-evident traceability (Chang, 2018).

3.1.2 Application of blockchain in digital ports

The "trust" and "security" core of blockchain can enable port digitization and port logistics in a variety of ways.

The use of blockchain technology will make the whole port supply chain more visible. This implies that containers or other cargo may be traced throughout for port logistics. Additionally, improved visibility might make it easier for companies to share information with one another. Data sharing may dramatically enhance port logistics. For instance, typically a charge must be paid and a payment confirmation must be given before a container may be released. However, if the blockchain solution is used, both sides of the transaction can immediately execute the payment, confirmation and release of the container when it is unloaded through data sharing, shortening the whole process from days to minutes and significantly improving efficiency.

Blockchain can contribute to the expansion and interconnection of logistics mutual trust networks. The Port of Rotterdam in the Netherlands is currently interconnected through Portbase, but with blockchain, a new growth pole has emerged (Luo, 2019). With a blockchain solution, the network of mutual trust will become more decentralized and each party will be able to connect individually, without the need for a "hub". Additionally, many blockchain networks may communicate with one another globally, enabling various ports to collaborate in various ways.

3.2 5G

3.2.1 Introduction to 5G

Communications technology at ports have made it simpler for people to connect with one another, from cable broadband to 4G, from WiFi to VHF radio. The only difference of 5G is that for the first time, it will make communication between items exponentially simpler. The bandwidth, latency, and number of devices are the three main characteristics that distinguish 5G from earlier technologies.

Bandwidth is the amount of data that can be transmitted over a network in a given time. Bandwidth is often thought of as a pipe; the wider the pipe, the more data can be transmitted. With each generation of mobile networks, bandwidth increases exponentially. While 4G networks have an average speed of 10mbps, 5G networks will bring the average speed to 50mbps, which represents a significant change in the ability of mobile networks to serve users who need to transfer large amounts of data quickly (e.g. ports).

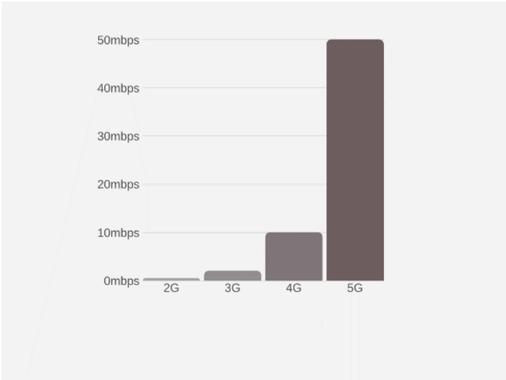

Figure 3.2 The comparison of different networks

Latency is the time it takes for a signal to travel from a device to the network and back, sometimes referred to as ping time. It is a critical component for those who use real-time communication services such as video calls or remote operation of devices.

The latency of 4G networks is about 50 milliseconds or one-twentieth of a second (Levanen, Pirskanen, Koskela, Talvitie & Valkama, 2014). This is fast enough that most users will not recognize the delay, but not fast enough to operate high-speed devices remotely. A light signal registered in the human eye takes about 10 milliseconds to reach the brain.

The average latency of a 5G network is about 10 milliseconds (Ford, Zhang, Mezzavilla, Dutta, Rangan & Zorzi, 2017). In terms of data transmission, this puts it roughly on par with the speed of the human eye. Autonomous and remote operation of machines such as trucks, cranes and straddle trucks is limited by the latency of existing networks. 5G removes these limitations, allowing signals to travel as fast as with human-operated devices.

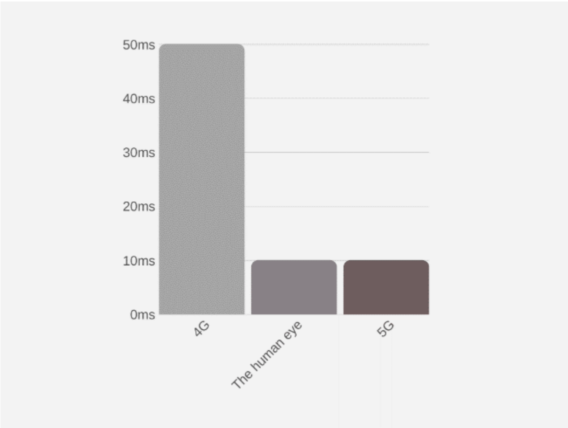

Figure 3.3 The latency of 5G networks, the human eye and 4G

4G supports about 4,000 devices per square kilometer. In comparison, 5G supports up to 1,000,000 devices per square kilometer. This makes it possible to connect not only cell phones to the network, but also hundreds of thousands of sensors to the network.

While this is not related to the development of 5G, it is important to also note that the cost of connected sensors is rapidly declining. According to General Electric, the cost of an IoT sensor has dropped from an average cost of $1.30 in 2004 to $0.38 in 2020. The affordability of sensor technology, combined with the growing amount of network support, makes a large-scale IoT a possibility that did not exist before (Chubb, 2020).

3.2.2 Application of 5G in digital ports

5G is a technology enabler, and many of the technologies available to ports will only work when 5G networks are in place. Perhaps most importantly, it makes it possible to expand many of the technology trials conducted in recent years from a proof-of-concept level to a viable port-wide solution.

Computer vision, for example, is an area of artificial intelligence that trains computers to recognize patterns and objects in video material. At the Port of Antwerp, 600 cameras have been installed to automatically monitor berths, people and traffic flow around the port area.

Networking HD video signals over a large area can be very expensive. However, 5G makes it possible to connect thousands of cameras and other sensors to the network without the need for additional communication infrastructure.

In addition to monitoring vessels, 5G makes remote control a more viable possibility. In Copenhagen, Svitzer has been testing remotely operated tugboats for the past two years. While there are some questions about the business case for remote operation, the benefits to the safety and welfare of tug captains are clear.

Compared to 4G networks, 5G offers low latency, large links and high bandwidth technologies. Unmanned trucks, automated yards, and cranes remote control all have high network latency requirements in port production operations. Take crane remote control as an example, the signal transmission delay requirement for bridge crane/gantry crane remote control operation is within 30ms, which is difficult to be met by 4G and WIFI networks, while 5G network with low delay characteristics can guarantee reliable communication in the remote control process, which can significantly improve the reliability and stability of the application while reducing the cost of port wisdom transformation (Tan &Chen, 2022).

3.3 Big Data

3.3.1 Introduction to Big Data

NASA researchers Michael Cox and David Ellsworth first used the phrase "big data" in 1997 at the IEEE Eighth International Conference on Visualization (Logica & Magdalena, 2015). In 2011, McKinsey & Company, a renowned global consulting firm, stated in "Big Data. The Next Frontier for Innovation, Competition, and Productivity" (Fairhurst, 2014), stated that "data have permeated every area of industry and business today and is becoming as important a factor of production as labor and capital." This marks the beginning of the big data age. Meanwhile, McKinsey defines Big Data in its report as a large amount of data (Xu & Wang, 2021). In addition, the National Institute of Standards and Technology defines Big Data as consisting of "large sets of data - characterized primarily by volume, velocity, and/or variability - that require a scalable architecture for efficient storage, manipulation, and analysis."

Another definition of Big Data is the exponential growth and availability of data. This comes from a wide range of sources: smartphones, sensors, point-of-sale terminals, consumer wearables, electronic health records, and more.
This data may seem disorganized, but behind this vast amount of data lies a huge advantage over rivals.

Healthcare systems can detect people at danger and take quicker action by utilizing the power of big data. Police forces are able to anticipate crime and prevent it before it occurs. Retailers can enhance the effectiveness of their supply networks and estimate inventories more accurately. The options are limitless (UW, 2019).

3.3.2 Application of big data in digital ports

The volume of data created during port operations is continually expanding given the increasing size of ships and the increasing throughput of ports. As an important node in the logistics chain, the data of the port's management operation can, in turn, play a guiding role in its business after big data processing and analysis, and the scheduling, management and business connection of the port can also benefit.

Some ports plan to build a big data platform integrating data access, data processing, data storage, query retrieval, analysis and decision making and information sharing based on big data technology. This kind of development and application mode with massive data as the core provides the necessary technical support for the construction of digital port (Yuan & Sui, 2022).

Currently, the use of big data technology in ports is primarily concentrated on a small amount of data collection and index calculation after the completion of the ship, but the functions of data collection, operation prediction, plan optimization, and intelligent decision-making prior to the operation are not perfect. However at this point, the big data analysis system is capable of gathering enormous amounts of data on the entirety of the automated container terminal's operation and building a big data knowledge base for wise decision-making.

Data warehouse is the core component of port big data management system. As the main collection and distribution center of port production data, the data warehouse is responsible for storing, cleaning, analyzing and exchanging relevant data, providing basic data support for the subordinate units of port enterprises, and reprocessing the data according to the needs of the subordinate units of port enterprises. The process of port big data management is shown in Figure 1.

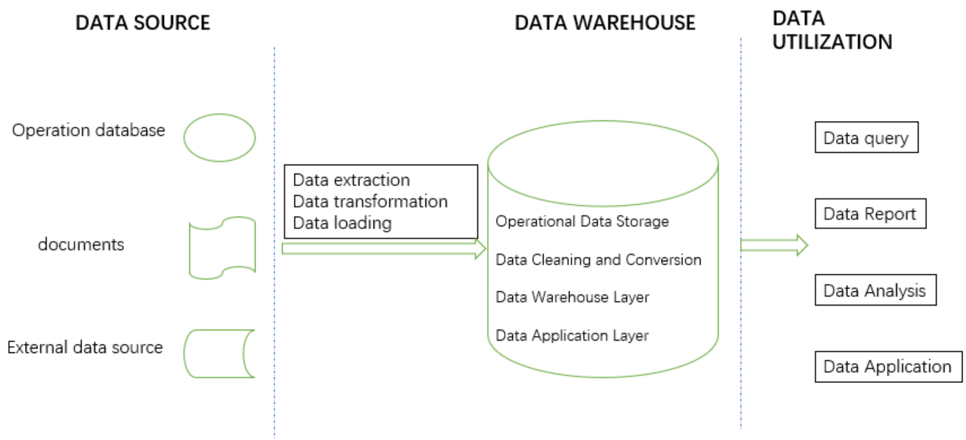

Figure 3.4 The management process of big data in ports

According to the actual needs of the business end, the initially cleaned data are processed and the specific functions at the application level such as analysis report, visualization chart, production planning and intelligent warning are formed through regression analysis, classification and clustering, visualization and other multivariate analysis (see Fig. 2).

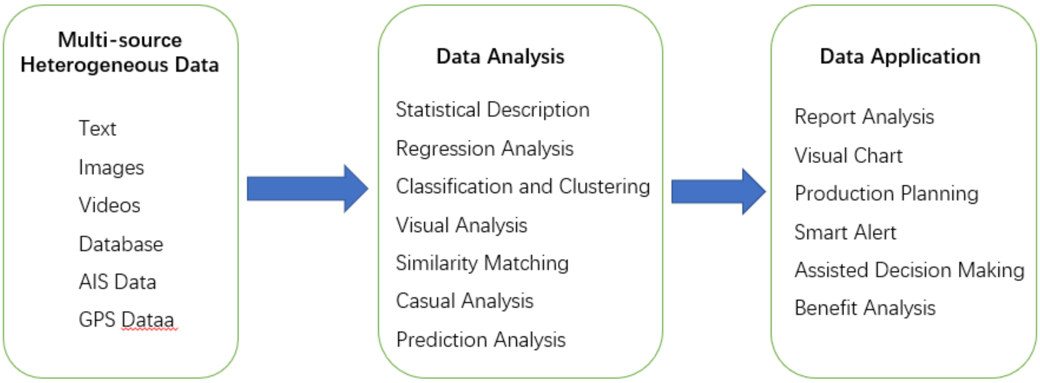

Figure 3.5 The application of big data in ports

3.4 IoT

3.4.1 Introduction to IoT

loT is an important development in the interconnection of personal computing apparatus. These apparatus are capable of "communicating" to one another online. The idea of linking actual physical items to the Internet is how loT is frequently defined. in 2017, Atzori defined IoT as "a conceptual framework that leverages the availability of heterogeneous devices and interconnected solutions, as well as enhanced physical objects that provide a shared information base on a global scale to support, at the same virtual level application design involving human and object representation" (Atzori et al., 2017). Thus, the IoT "enables things to speak" (Bassi et al., 2013), which means all kinds of data related to things are collected by sensors and subsequently connected via the Internet, which can be sent to a cloud system for storage or computation (Vaggelas& George, 2020). Then the analyzed data can be transmitted to users or other connected devices for collaboration and decision making (ADB, 2020).

3.4.2 Application of IoT in digital ports

In recent years, with the gradual development of IoT technologies such as NB-IoT and AIoT, their advantages of massive connectivity, deep coverage, low power consumption, low cost and intelligent analysis provide a solution path for port sensing network construction. By deploying sensing instruments and networks in key areas and core facilities of ports to collect and analyze information such as cargo, vehicles and personnel in ports, intelligent and linked port sensing can be realized (Sun, 2019).

1) RFID Technology

Radio Frequency Identification (RFID) sensors can be placed on all facilities at seaports, including sites such as terminals, shipping center buildings, storage centers and yards, but also specific objects such as ships, berths, trucks, loading and unloading cranes, cargo, containers and hazardous materials.

The use of IoT applications, such as RFID, at several U.S. ports ensures transparency in logistics and helps in the fight against terrorism. This technology also provides secure transportation of cargo to its destination. With RFID tags, cargo managers can determine the exact location of cargo at the port, allowing for quick access (Joanne, 2020). The processing of containers, trucks, and ships in many ports is made possible by the IoT's ability to link components in various locations.

2) Information Technology

IoT or other data-based technologies can be used by ports in applications like tracking cargo and monitoring warehouse storage. The utilization of cranes, carriers, storage facilities, parking lots, vehicles, and other forms of infrastructure may also be monitored using these technology. This assists in locating unused assets and creating strategies for improved optimization. IoT-based alarm sensors may be used to track theft and increase the security of port goods. Additionally, sensors may be used to monitor environmental factors like humidity and temperature, enabling port operators to offer the ideal storage conditions for a variety of cargoes (Huang, 2020).

Additionally, ports may interact with navy vessels using this technology to direct them to specific docking spots. The technology may also be used to send trucks to open parking areas, reducing congestion and enhancing port productivity.

3.5 AI

3.5.1 Introduction to AI

The study of artificial intelligence is interdisciplinary and draws on cutting-edge fields including computer science, psychology, linguistics, and philosophy. The goal is to develop artificial systems or technologies that can mimic human intellect in order to further the study of human intelligence. The "Logic Expert," created by Newell and Simon in 1955, was the first truly intelligent program (Anyanwu, 2011). An major turning point in artificial intelligence history was reached with this system. Later, in 1956, at the Democratic Convention, the term "artificial intelligence" was first used. AI has advanced and is now a necessary source of energy for society advancement after more than sixty years of development. Heuristic search, fuzzy theory, expert systems, and artificial neural networks are the four categories that may be easily distinguished from artificial intelligence applications.

Currently, artificial intelligence has the following five characteristics: First, it has changed from the previous artificial knowledge expression to the knowledge learning technology based on big data driven. Second, from multimedia data processing to cross-media cognition, learning, reasoning, where the "media" is the interface or environment, rather than the news media. Third, the pursuit of the goal has changed: from the previous pursuit of intelligent machines to the synergy and integration of high-end brain-machine and human-machine. Third, the pursuit of the goal has changed: from the previous pursuit of intelligent machines to a high level of brain-machine, human-machine synergy and integration. Fourth, a shift from the aggregation of individual intelligence to the intelligence of many people can be gathered and integrated into a group intelligence based on the Internet and big data. Fifth, the shift from anthropomorphic robots to intelligent factories, intelligent unmanned aircraft systems and other more extensive intelligent autonomous systems.

3.5.2 Application of AI in digital ports

Artificial intelligence is a new technical science that contains many fields, such as computer vision, machine learning, and intelligent decision making. In the construction of digital ports, there are two main applications.

With the rapid expansion of port business scale, the amount of data to be processed increases exponentially, which is difficult to be supported by the traditional information system. Therefore, it is urgent to rely on machine learning, audio and video recognition and other artificial intelligence technologies to optimize the transformation of all operational aspects of the port in order to meet the business development requirements of loading and unloading, stacking and storage, etc. (Chinaport, 2021). In terms of production, artificial intelligence can be used for autonomous planning and decision-making in the yard to reduce container shifting operations and improve yard efficiency.

In addition, it can also be used to establish a port intelligent transportation system based on artificial intelligence, which is a synergy between horizontal transportation and vertical transportation, to realize intelligent route planning and automatic loading and unloading operations. In operation, AI can be used for intelligent analysis and decision making of production data to achieve autonomous operation and management within the port (Tan &Chen, 2022).

CHAPTER 4 SWOT ANALYSIS ON PORT DIGITALIZATION DEVELOPMENT

4.1 SWOT Analysis Concept

SWOT analysis is proposed by Professor H. Weihrich of the University of San Francisco, also known as the situational analysis method (Tian & Hu, 2021). At the beginning, it was mainly used for the analysis of the internal and external environment of enterprises, and can effectively help enterprises to make strategic decisions. Later, after the theory was continuously improved, the scope of application was gradually extended from enterprises to other fields, and good practical results were achieved. In this paper, we use SWOT analysis to analyze the digital port.

S, W, O and T refer to: Strength, the advantages and strengths of the digital port in the internal and external environment; Weakness, the shortcomings of the digital port in the internal and external environment; Opportunity, the policies and opportunities in the development environment of the digital port; Threat, the risk, challenges and competition in the development environment of the digital port.

SWOT analysis is an important tool for investigating the influencing factors of the development environment through effective analysis of these four aspects.

4.2 Three steps of SWOT analysis method

The first step of SWOT analysis is information collection, that is, detailed data collection on the object of analysis. Internally, the researcher needs to master the various elements of the object of analysis and have a clear understanding of the industrial environment of the object of analysis and its own strengths and weaknesses; externally, the opportunities faced by the industrial environment of the object of analysis are collected and analyzed, and the potential risks and threats that the object of analysis may encounter are statistically analyzed. The more detailed the information collected, the more objective the face of the object will be, and the more accurate the decision conclusion of the final analysis will be.

The second step is to construct a matrix, where the collected strengths and weaknesses, opportunities and risks and challenges of the analyzed object should all be listed and combined into a SWOT analysis matrix. After all the factors are reflected in the matrix, the factors are arranged by the importance of the development of the object of analysis, the timeliness and the contact surface, and then matched with each other to draw conclusions. The matrix is illustrated in the following figure.

Table 4.1 The Matrix of SWOT

	Strength	**Weakness**
Opportunity	Growth Strategy (SO)	Turnaround Strategy (WO)
Threat	Resistance-based strategy (ST)	Defensive Strategy (WT)

The third step is to analyze alternative strategies. By matching the analysis of factors, four different strategic options can be obtained: "defensive strategy" refers to the strategic option of eliminating one's own disadvantages by avoiding the unfavorable factors and corporate weaknesses in the development of the object of analysis. The "resistance strategy" refers to the strategy of avoiding or reducing the blow of external threats and finding new development opportunities by diversifying the business by taking advantage of the subject's own strengths and facing severe external challenges despite the subject's large internal advantages;

"Turnaround strategy" means facing external opportunities but lacking conditions, the subject should actively take measures to turn around and change the unfavorable conditions within the subject.

"Growth strategy" means that the target has strong internal advantages and many external opportunities, and should actively increase investment, expand production and increase production share.

The general principles of the four strategies are to bring into play the strengths, overcome the weaknesses, exploit the opportunities, and resolve the threats, which provide good strategic reference ideas for the subject.

4.3 SWOT analysis

4.3.1 Strengths

(1) Automated port operations

One of the main advantages of digitalization is the ability to automate operations through monitoring. Sensors, automation and simulation, for example, are technologies that can be used for terminal productivity. In addition to this, (semi-)automation and robotics also further improve the efficiency of port documentation management and ship berthing, which reduced operating time and thus increased productivity (Carpenter & Lozano, 2020).

The utilize of digital technology for infrastructure management in intricate systems is an illustration of an application. For example, the Port of Hamburg, whose rail network is managed by the Port Authority, has more than 300 kilometers of rail and more than 850 interchanges, with more than 200 trains departing daily, two-thirds of which are dedicated to containers. In addition to its efforts in rail, the Port of Hamburg has enhanced the application of robotics and automation in terminals and ships.

On the other hand, port staff is susceptible to fatigue or distraction, while automated systems always operate with the same performance, regardless of unforeseen events. This makes the port more reliable in terms of delays and unexpected events, which are often caused by avoidable human errors. It also prevents uncertainty due to situations such as strikes.

(2) Improvement of the quality of port services

A second advantage of digitalization is that it can improve the quality of port services by increasing the traceability and transparency of the logistics chain. To this end, blockchain technology is seen as a key solution for ensuring full visibility of cargo handling, although its use has so far been limited to pilot projects and it is not clear how this technology will be used on a large scale. The blockchain issue also raises important questions about the management of information and technology and the antitrust implications of these developments.

In addition, increasing transparency in port management through an open platform for public data (also known as Open Data) allows information held by the public sector to be made available to all in a digital format, in a standardized and open manner. This allows all citizens and entities to have access to data about the management being implemented in the port complex, ensuring transparency, efficiency and equal opportunities in the creation of value.

Security is a key use of the new technology, both for port operations and to stop criminal activity like smuggling or terrorism. Digital technologies play a crucial role in maintaining the effectiveness of port operations (such as customs operations, security, and cargo inspection), and they can also result in the creation of new services with added value. Examples include the use of drones to inspect port areas and identification processes (face recognition) or data authorization.

(3) Environmental protection

Digital technology also has a third benefit related to environmental preservation. The most recent advancements and numerous modifications to port rules are motivated by the desire to lessen the environmental effect of port operations and ships in port. Increased regulations frequently result in increased operational expenses, complicated administrative processes, and extended loading and unloading times. An illustration would be the monitoring of emissions and fuel limits, the decrease of energy consumption through electrification and automation, the certification of waste treatment, or the use of renewable energy sources that are prohibited from being utilized in ports without digitalization (e.g. in the implementation of virtual power plants).

(4) Connection and financialization

In addition, another obvious benefit of a digital port is connection and financialization, which can be done only after the digitalization is done. When we consider data as an asset, we think in terms of continuously improving the return on assets. More importantly, data connection can lay the foundation for data financialization. In complex international trade, finance is always the core infrastructure that drives international trade. Here is an example of supply chain finance: once the goods enter the controlled area, they become a collateral. The owner can get the payment for the goods earlier than after loading the ship to when the goods arrive in the controlled area, and the bank gets a quality collateral loan. At the same time, once the cargo enters the controlled area, its risk is reduced, the cargo owner can deliver lower premiums, and the insurance company gets a safer business.

(5) Improved efficiency

Last but not least, digital technologies improve transparency in the transportation chain, provide more centralized management and have a positive impact on transit times (efficiency). For example, the advent of blockchain technology has improved the transmission, reliability and security of electronic protocols and documents. This in turn speeds up the flow of money and materials, reduces the number of intermediaries in the chain, and thus reduces costs. For ports, the ensuing benefits manifest themselves in (most likely) more efficient flows (e.g., terminal time per ton), easing the pressure to build capacity. Even in larger ports, cargo volumes must be related to the size of investments in automation and robotics in order to be financially justifiable, even if resources are available for larger technological adaptation projects. A fundamental goal of digitization is to improve cost-effectiveness, which means that it should lead to more efficient workflows and productivity, which in turn would result in cost reductions (Zhu &He, 2021).

4.3.2 Weakness

(1) Incompatible systems

Many of the large infrastructures and machines in ports have an applicable lifetime of decades, but technologies associated with digital ports, such as IoT and other digital technologies, are only just being introduced, leading to a need for incremental development in the integration of digital technologies and port infrastructure. The main advantage of IoT technologies is interconnectivity (Jovic, Tijan, Aksentijevic & Cišic

2019), and machine-to-machine interaction and automated operation of machines and automated processes are the main factors that makes digital ports more efficient.

Digitization enables the creation of digital platforms on which ports and logistics companies can connect, which is the first step in a global network. However, incompatible systems can pose challenges to this.

In practice, different operators in the port logistics chain will operate digitally at different stages and at different time intervals. Problems arise when systems are designed for integrated technology domains: non-operability leads to serious challenges and high costs for redesign and re-installation.

For example, the development of loT is directly related to sensor technology and 5G networks (Ahokangas, Matinmikko-Blue, Yrjölä, & Hämmäinen 2021). Technically, all devices interact through loT and are equipped with a specific Internet Protocol (IP). This allows them to be tracked and identified, enabling remote management of individual devices and applications. Gartner predicts that the number of devices connected to the loT domain will grow almost exponentially until 2025 (estimated 25 billion devices worldwide) (Gartner, 2019). However, interoperability issues can lead to serious implementation problems if procurement cannot be executed without interruption.

A typical example is the Port Communication System (PCS) implemented by DAKOSY (Datenkommunikationssystem AG) at the Port of Hamburg. At the end of 2018, DAKOSY launched its first blockchain project. PCS connects customs, authorities, front lines, importers and exporters, terminals and all modes of transport (Kapkaeva, Gurzhiy, Maydanova & Levina 2021). However, incompatible systems can pose challenges to this.

In order to digitize ports, the entire transport process should be globalized, which means all countries, ships and cargo must use a common system in order to achieve full system coordination. To achieve this goal, all logistics operators should have a common language. The first step will be digitization through data conversion, which means changing from analog to digital formats, converting paper documents, photos, microfiche, etc.

In addition, ports and port-related companies use different equipment and they often require different technological solutions. Therefore, an ecosystem needs to be created to enable better interoperability between production manufacturers and logistics companies. In addition, a more obvious problem is that the same information is collected multiple times by different parties. The collected information is processed in different information silos, which leads to duplication of efforts. The lack of information sharing can lead to inefficiencies (Carlan, Sys, & Vanelslander, 2016).

(2) Significant increase in labor costs

As port terminals become more digital and automated, there is an increasing need for personnel who are adequately trained in the use of the new technologies, especially when it comes to special cargo or container terminals. Therefore, for a considerable period of time after the digital transformation begins, many of the personnel working in the port will be unqualified, so existing staff will have to be retrained or new professionals will have to be recruited who are qualified by providing the required skills and competencies in line with the new technologies being implemented (González-Cancelas, Serrano, Soler-Flores & Camarero-Orive, 2020).

In addition, as described above, IP device connectivity is essential to the development of digital ports and will be a fundamental driver of change in machine-to-machine communications in ports. In the future, integrated solutions for collecting and distributing data are expected to be an important area of development. According to Inkinen et al, it was found that the cost of equipment is decreasing and the physical equipment size is getting smaller. Self-monitoring of equipment allows for automatic maintenance reporting, thus reducing the role of human factors in operational management. In ports, the highest expectations are placed on automated loading and unloading. That is, by implementing digital systems, there will be relatively labor-intensive operations that will no longer be performed by humans. This will mean the loss of jobs and may have more or less social and economic impact. At the same time, a fully automated or remotely controlled loading process may cause opposition from trade unions. This would take a lot of effort to solve such problems and the labor costs of the port would rise as a result (Brunila, Kunnaala-Hyrkki & Inkinen, 2021).

4.3.3 Opportunities

(1) Rapid progress in smart port support technology

In 2006, Geoffrey Hinton clarified the deep learning model by publishing his paper "A Fast Learning Algorithm for Deep Confidence Networks", and the field of neural networks in artificial intelligence once again gained a breakthrough (there was a rise and fall in the 80s). After more than 10 years of algorithmic practice and thanks to the strong support of machine performance, deep learning has become the most successful area of AI and leads the third wave of development to date. For the first time, artificial intelligence has demonstrated the technical possibility of passing the "Turing test" (an intelligence assessment method in which an AI has to successfully mislead a certain number of assessors to consider it as a real person in a given time) and has surpassed the limits of human intelligence in several areas (Gao, 2020). Driven by this technological development, the digital port has a firm cornerstone in terms of technical support, with the possibility of further development of intelligent supervision, intelligent decision-making, and autonomous loading and unloading working models. Whether from the point of view of the present digital port self-awareness of the primary stage, or the future port self-application of the advanced stage, artificial intelligence technology has already been the core technology to complete the realization of self-function.

(2) Huge digital port profit value prospects

According to the conservative estimate of the Accenture Consulting and Shanghai Port Group, digital port construction can bring huge practical value to the society. Taking the Yangtze River Delta region of China as an example, the amount of international trade through maritime transport is about 8.1 trillion yuan, and the proportion of China's social logistics cost to GDP is about 18%, among which, transportation cost accounts for more than half, storage and stacking and other costs account for about one-third, and management cost accounts for about one-eighth. The initiative to build a digital port can reduce logistics costs by about 3.6% and is expected to create a value of RMB 33.8 billion per year for hinterland maritime logistics.

Through bottom-up analysis of the impact of digital port construction on terminal efficiency, shipping company efficiency, and hinterland logistics efficiency, the construction of automated intelligent terminals and port information platforms greatly improves the efficiency of transportation, bringing about 22.7 billion yuan of value added per year; because of the intelligent information platform and the optimization of inland transportation network, the annual capital cost can be reduced by about 2.2 billion yuan, and generate about 8.9 billion yuan of trade financing benefits.

At the same time, with the help of automated processes, energy structure optimization, management innovation and information technology level improvement, the reliability of the port will be greatly enhanced in the future, and the emission of sulfur oxide will be reduced by about 60,000 tons and nitrogen oxide by about 70,000 tons per year. Thus, the profitability of digital ports is huge.

(3) Policy Support

In 2020, the importance of digitization of shipping was highlighted several times during the "Maritime Perspectives, The Future of Shipping" webinar series, jointly organized by the International Maritime Organization (IMO) and the Maritime and Port Authority of Singapore (MPA). It was suggested that digitization is key to enabling post-COVID recovery, strengthening the resilience of the global supply chain and bringing shipping into a new era. Shipping-dependent supply chains need to further digitize trade and customs procedures to ensure the rapid and secure exchange of data and information. The IMO is also working to ensure that the shipping industry can embrace the digital revolution - while ensuring security, promoting environmental protection and managing cybersecurity risks. IMO has embraced EDI, which has been mandatory under the facilitation convention since April 2019. Just one week before this meeting, the IMO Facilitation Committee approved a revised version of the IMO Facilitation and Electronic Commerce Compendium at a virtual meeting. These are key steps towards harmonization and standardization of digitalization. The meeting called for the drive to digitize the shipping industry to be more important than ever. Improvements in data collection, processing and interconnectivity allow automated systems to be controlled remotely or through artificial intelligence. Increased automation in shipping has the potential to increase safety, improve environmental performance and ensure more efficient and sustainable shipping (IMO, 2020).

As can be seen, from IMO's perspective, the drive to digitize shipping is fully supported, and IMO is calling on all member countries to join the digital voyage and focus on strengthening cooperation between shipping, ports and logistics. Digital ports will develop faster and better with the premise of policy support.

4) Port-city synergy

The digitization of ports associated with the development of smart cities creates synergistic interactions between the two institutions, their governments and citizens. Digital ports are made of and for people, and are therefore a key part of facilitating their future development. Digital ports need to build a better relationship with cities and include citizens: digital platforms allow citizens to understand the opportunities offered by the port and the wealth it creates for the entire population. Likewise, citizens can make suggestions or proposals to the port management, which can be translated into improvements in their daily work and promote a better coexistence between the port and the city (González-Cancelas, Serrano, Soler-Flores & Camarero-Orive, 2020).

4.3.4 Threat

(1) Security threats

The digitization of ports has also given rise to new security threats. For example, the quantity, quality and sensitivity of data transferred to digital formats pose threats as they are related to information security and other cybersecurity-related threats (Heilig & Voß, 2017). Cybersecurity may be considered as the most important underlying factor that hinders the rapid phase of digitization.

Earlier studies have identified cyber security as the most important area of development in port digitization, as it lays the (trust) foundation for the development of all systems (Senarak, 2021). Therefore, preparedness plans to deal with cyber threats need to be updated regularly with predefined time intervals and a relatively short time span (up to 2 years).

The European Network and Information Security Directive (NIS) applies to European ports belongling to the TEN-T core network. However, this leaves many ports outside the reporting obligation and therefore, the role of the NIS in providing guidance and managing the process becomes more important (BLED, 2019).

Cybersecurity has also attracted the attention of regulators and the public sector. in 2018, an EU decree established a framework for port data security in the Union's TEN-T core network. Security will face the classic challenge of technological convergence or divergence, which also requires the principle of open and closed digitization. Sensitivity-based classification of information requires appropriate precautions, and careful advance planning is the key to success. For example, data on types of goods and their movement require "careful handling" and clear identity management (access rights to data).

Data and systems, whether in a private, public, or hybrid cloud, can result in new methods of labor organization and boost productivity and port efficiency. If appropriate measures are not adopted to restrict access, they may also pose a danger of external access. Infrastructure-related tasks and activities are especially sensitive to cyber threats and have a higher risk of being used for illegal purposes. Port managers should get special attention since they are frequently less prepared for such aggressive cyberattacks than the ports themselves (Barreto, Amaral & Pereira, 2017).

In practice, cybersecurity threats at ports can include, for example, the harmful manipulation of operational data. A meticulously planned cyber assault can access restricted data, seize a ship, take over port operations, or just disrupt systems by altering cargo manifests or container numbers (Alcaide & Llave, 2020). Even a "small" cyberattack can cause significant damage. Identified vulnerabilities within ports include: inadequate preparedness for cyber attacks, lack of logging and monitoring to quickly detect vulnerabilities; older versions of software with known security vulnerabilities; and network interdependencies.

(2) Low return on investment in the early stage for small ports

According to previous studies, smaller port companies do not have resources similar to those of larger companies when it comes to investing in digitalization (Qin, Liu & Grosvenor, 2016). It is clear that the relatively small cargo volumes of small ports make investments in digitalization (in a short period of time) unjustified. An IT transformation project requires comprehensive planning and resourcing to achieve long-term strategic goals. The initial scope of a digitalization project should start with the allocation of resources needed for the planning, implementation and operational phases. For any digitalization project, "going live" requires the expertise of the users and the human resources responsible for staffing.

Currently, some smaller ports, such as those in the Baltic Sea region, are still developing their digital capabilities, which will benefit their efficiency and productivity and be cost effective. The correct implementation of digitalization is also a key tool to reduce environmental emissions and associated costs (Giuliano & O'Brien, 2007). To ensure a smooth logistics chain, some shipping companies are likely to choose their destination ports based on their ability to handle digital interactions and operations. Therefore, the level of digitalization is also an important factor in the competitiveness of ports. Although for small ports the return on investment for developing digitalization is relatively low in the short term and may not even be able to make ends meet, in the long term, it is still necessary to develop digitalization in order to improve the competitiveness of ports and to be in line with international standards.

(3) Benefit distribution issues

With the in-depth development of globalization and digitalization, the pursuing of profit will inevitably lead to the aggregation of resources to the value chain integration with more monopoly advantages. A problem at any node in the port supply chain will affect the normal operation of the supply chain. Due to the dynamic market competition changes and increased uncertainties brought by customer demand, the supply chain is required to have the ability of risk prediction and control, and continuously accumulate and form the management mechanism of supply chain collaboration. With many parties involved in port capital and complex business relationships, the issue of dealing with the distribution of interests among related parties would be the most prominent part of the conflict, which requires ports to continuously explore the fundamental issues of the conflict and continuously promote the evolution of the supply chain into a system that responds to market demand.

4.3.5 Summary on SWOT analysis

After making the SWOT analysis of the development of the port digitization above, the strength, weakness, opportunity and challenge of the digital port have been analyzed from several aspects. The following table is a brief summary of the elements of the SWOT analysis above and a deformation of the SWOT matrix.

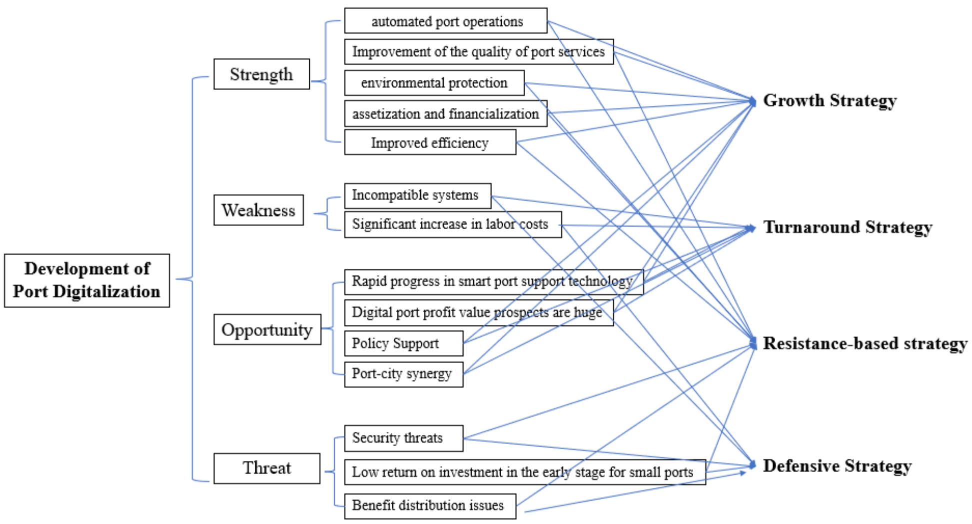

Figure 4.1 The deformation of SWOT matrix on development of port digitalization

Which strategy is applicable to the development of digital ports? Where will the development of digital ports go in the future? The most important thing is to analyze all the factors in the SWOT analysis from different aspects on the development of the port.

In the above analysis, it is easy to find that whether from the analysis of the advantages of the digital port itself or the external environment for the digital port technical support, policy support, social support and future prospects, the development of the port digital is very favorable, and in the long run, its competitiveness is higher compared to traditional ports.

However, currently, the weakness of digital ports is also very obvious, including the system mismatch among the relevant parties, and labor issues, etc. But these problems will not exist in the long-run. With the development of technology and the international and inter-industry cooperation, it is only a matter of time before the systems are adapted to each other.

Although it may take a lot of effort at the beginning for trial and teething, the prospect of a better future for digital ports will not be extinguished by the mismatch between systems.

In terms of labor's issue, this is common to almost all new technology introductions, for example, the rapid development of communications technology that has made the "telephone operator" disappear forever. Another example is the once bustling NYSE, which has become much quieter with the advent of electronic trading and a massive reduction in the number of floor traders (Levine, 2013). The development of technology will eventually eliminate a group of people, but also will make another group of people. The development of digital ports, for example, eliminates people who can only work mechanically, but allows people who are proficient in new technologies and digitalization to have more opportunities to work and develop themselves. Although the change of labors will be obstructed and costly at the beginning, these costs are undoubtedly not recurrent costs and cannot have a sustainable impact on the long-term development of the digital port.

As for the threats encountered by digital ports, including security threats, small ports with low return on investment, and uneven distribution of benefits, are indeed barriers to the development of digital ports, especially cyber security, which has been a concern in recent years. We have to admit that if cyber security cannot be guaranteed, the potential threat to ports, and even the entire maritime industry, is enormous, but it also gives us the incentive to address such issues. If we don't move forward, we will never be able to identify problems and we will never be able to solve these problems.

In summary, after considering the above, this paper concludes that the strategy for developing port digitalisation should be a "growth strategy", with strong internal advantages and many external opportunities. If we don't move forward, we will never be able to identify problems and we will never be able to solve them.

CHAPTER 5 THE CURRENT STATE OF DIGITAL DEVELOPMENT OF GLOBAL PORTS

5.1 "Single window" provides one-stop service

In terms of digital port transformation, Chinese ports are at the forefront of the world. The standard version of the international "single window" has been promoted nationwide, and its functions have been continuously improved. At present, it has completed cargo declaration, manifest declaration It has completed the construction of many functions such as cargo declaration, manifest declaration, transportation declaration, license application, certificate of origin application, enterprise qualification and inquiry statistics. In addition, with the rapid development of paperless customs clearance, and the data interoperability between international trade "single window" platform and the bank back office , data inter-embedding between the enterprise declaration information and trade settlement information is available now, thereby greatly enhancing the efficiency of payment. In addition, in February 2019, the European Council, the European Commission and the European Parliament adopted the European Maritime Single Window Bill, which aims to rectify the onerous and uncoordinated reporting requirements currently faced by ships calling at EU ports, enabling the same data to be submitted in the same way and applying to the same operations and procedures in all EU ports, in order to reduce the administrative burden and increase the competitiveness of European ports (Feng, 2019).

Although the "single window" is continuously promoted and its functions are constantly improved, it still faces the problem of "data silos", where data are stored and maintained independently in the information systems of different departments, forming physical silos. Moreover, different departments understand and define data from their own perspectives, so that some originally identical data are given different meanings, which invariably increases the cost of cross-departmental data cooperation. In the future, new technologies such as blockchain can be used to break through data silos, for example, a consensus database can be created through distributed bookkeeping and free notarization of the whole network, so as to break data silos and make data information more useful in a short time.

5.2 Digital transformation of the terminal operating system

The container terminal operating system has been developed for more than 30 years, through continuous upgrading, digitalization has basically completed the transformation of the terminal operating system. Take the world's most advanced U.S. Navis supplier as an example, in 1998 the U.S. Navis was established; in 1990 in the United States Seattle (SSA) terminal launched the first generation of SPARCS container terminal operating system, only to provide container handling services; to 2014, Navis announced the launch of XVELA, which is a cloud-based technology to connect terminal operators and maritime companies business network. From a single loading and unloading service to a series of digital services such as ship loading optimization, yard utilization optimization, crane scheduling and monitoring, from serving terminal operators to connecting maritime companies and logistics companies throughout the supply chain, the digital transformation of container terminal operating system has been continuously improved, with more comprehensive functions and gradually improved efficiency (Ylian, 2019).

Compared with the traditional operating system, the world's advanced container operating system integrates more advanced digital technology, integrated with advanced logistics technology equipment, such as the seamless integrationlarge among equipment vehicle terminals, handheld terminals, video surveillance system. In addition, the integrated application of electronic gate equipment, such as OCR container number recognition, OCR license plate number recognition, RFID and other technologies in the system have a fairly mature application, effectively improved the efficiency of terminal operations, reduced the number of on-site operators, improved the safety of operations and management and operation level. Most of the global mainstream container terminal operating system products have the following three major functions: planning system, management system, and operation system.

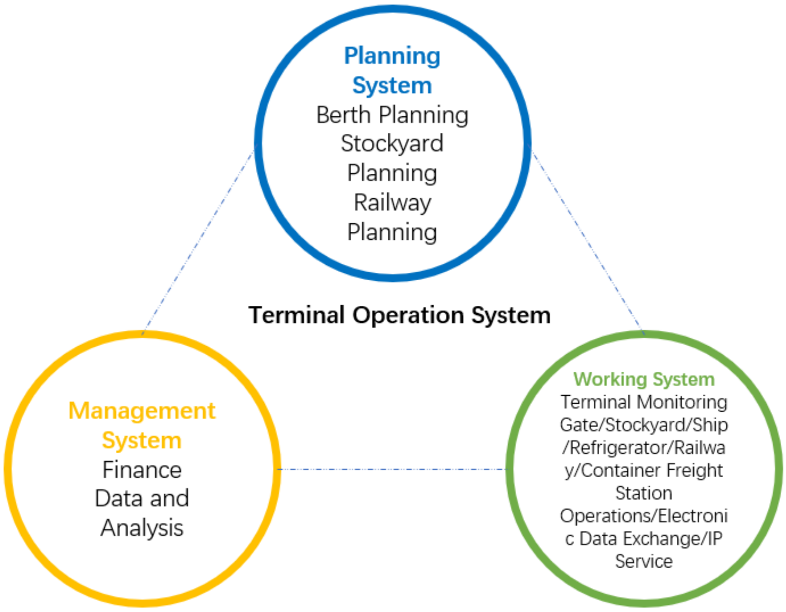

Figure 5.1 Container Terminal Operating System

5.3 Multidimensional development of digital ports

As a significant advocate for international commerce, DP World Dubai concentrates on technology-enabled growth and actively encourages the development of a new breed of digital ports. It offers integrated trade solutions ranging from marine and inland terminals, maritime services, logistics, and auxiliary services to technology-driven solutions, all from the perspective of the entire spectrum of port value chain services. Dubai Trade, the country's national trade platform, links customs, port and industrial park owners, as well as other parties involved in trade and logistics, and it offers value-added services all along the value chain. Additionally, it actively researches new technology to boost productivity. In the global logistics supply chain, its industry-first three-dimensional automated container terminal technology delivers a three-dimensional automated container yard system, cutting the time needed to load and unload mega-ships by 30% and enhancing operational effectiveness and service standards.

Jebel Ali Port in Dubai has also been investigating how to utilize digitization to enhance berth management. A Smart Fender monitoring system has been installed on a 400-meter-long bed. This enables the port to gather precise information on the state of the boats, which is wirelessly uploaded to the cloud where it can be processed to produce insightful results. By using these insights, the port may identify vessels operating outside of the norm and identify major berthing situations, averting accidents (Yang & Zhao, 2020).

Nowadays, e-commerce activity has been accelerating, with U.S. sales, for example, increasing by 32% to $792 billion in 2020, a goal achieved two years ahead of Covid's previous estimates, and trends seen in 2021 suggest that e-commerce growth will accelerate. Many consumers have now permanently changed the way they transact business, and it is expected this trend will accelerate in emerging markets. DP World's early investments in digital technologies, such as Dubai Trade and terminal automation, have enabled them to deliver the solutions that today's shippers are demanding. This focus on innovation continues as DP World invests in building an intelligent platform that enables shippers to transact directly (DPW, 2021).

5.4 Port and maritime companies adopt digital business management

French liner giant Duffy Group has launched CMA CGM eSolutions, which is a 100% digital ecosystem. This system has developed a range of new features to provide Duffy Group's customers with a new sales channel, in addition to the customer centricity and digitalization that Duffy Group has put at the heart of its strategy. The majority of Duffy

Group's bookings are done through its e-commerce solution, half of them through the Group's web platform (Tinarak, 2019). With the CMA CGM eSolutions platform, it will be possible for customers to experience a 100% digital journey when they choose Duffy Group to transport their cargo.

In addition, Maersk is also working on using digitalization to enable remote management of containers. Maersk Line already has 270,000 reefer containers on board more than 600 ships (Oyku, 2017), and has equipped digital equipment capable of transmitting real-time data on the status of reefer containers via satellite to management offices, ports and suppliers. Maersk is taking a systematic approach to digitalizing its own port operations at 3 different aspects: First, in terms of the asset, Maersk is attempting to digitalize data on all facets of each asset's performance, efficiency, maintenance, etc. by connecting all of its cranes, yard bridges, straddle carriers, and terminal vehicles to the Internet of Things. To boost operational effectiveness, asset deployment, and decision support, Maersk is trying to digitally optimize all assets across system processes for each specific terminal. Third, Maersk has a global network of 78 terminals that will leverage digital data to enable operational efficiency management, benchmarking, and KPI reporting.

5.5 New digital platforms continue to emerge

The Port of Los Angeles and GE Transportation have teamed together to create a $13 million platform that integrates port data for terminal owners, shipping lines, truckers, chassis suppliers, railways, and shippers to increase operational efficiency and transparency (GE, 2017). The objective is to give shippers a single window through which to access tailored cargo status updates and schedules for ocean-going vessels. They can now pay freight rates, schedule pickup times for incoming goods, increase visibility, improve real-time decision-making, and optimize cargo flow through the San Pedro Bay terminal thanks to this. The Port of Hamburg has merged all of the region's disparate systems into a single, unified platform (Lengenfelder, 2018). The platform combines information from many sources, including sensors, mobile devices, and partner databases. These technologies not only assist port authorities and their partners in streamlining internal processes but also gather real-time data on port traffic, reducing congestion at yards and terminal gates. The port can more effectively arrange the flow of container truck traffic if the platform includes geolocation features that allow it to precisely locate trucks as they arrive at the port.

CHAPTER SIX FUTURE PROSPECTS OF DIGITAL PORT TRANSFORMATION

6.1 Information Services

The focus of this service is to access data streams through the port production value chain. Data in the 21st century is like oil in the 18th century, which is an extremely valuable and untapped asset. Port production value chain can obtain a large amount of valuable raw data, and deep mining of these data can provide reference for port enterprises' decision making. In practice, logistics elements such as loading and unloading equipment and transport assets, infrastructure, workers and customer requirements can be continuously and automatically monitored with the support of IoT technology, and these efforts can be controlled by means of communication technology. In this context, the problem facing port companies is how to make the most of the vast amount of data generated by this technology to improve monitoring and control intelligence. Generally speaking, this process consists of three aspects.

Process execution: including functions such as transportation planning, tracking and tracing, auditing and payment.

Data analysis: including assessment and value targeting, route optimization, compliance management and performance analysis only.

Visibility and data integration: including functions such as control and generation of alerts using monitoring panels.

6.2 Logistics services

Currently, global logistics and transportation platforms are broadly divided into two types: one is the consolidation of a small number of shipments, as a single customer, to large logistics service providers; the other is the logistics and transportation platform, or comparison platform for logistics and transportation service providers.

However, these two models do not have the ability to precisely match shipping needs with logistics capabilities. A digital global shipping platform not only connects a single seller with millions of potential buyers, but also clearly displays CIF costs, CIF times, and provides segmentation of shipping services, etc. Besides, there is also the option to issue a pickup request. The service partners supporting the platform can solve the issues on customs declarations, international parcels and import payments, and provide end-to-end tracking of products sent to international buyers. The digital platform can also integrate the needs of different carriers, optimize the end-to-end logistics planning process, and suggest appropriate shipping methods based on warehouse locations and designated delivery locations.

6.3 Distribution capabilities

As science and technology continue to advance as well as the global transportation demand grows, distribution methods are beginning to change Innovations in manufacturing methods (3D printing) and technologies such as drones and self-driving vans are providing more possibilities for the development of the port logistics industry.

Taking driverless vans as an example, data from the International Transport Forum (ITF) shows that between 2010 and 2050, the volume of road freight will grow to four times its original size, and self-driving vans will optimize the final link of consumer-oriented distribution services, but the biggest changes will occur in the B2B logistics sector. The way cargo is picked up upon arrival at port may change with the use of driverless vans. Driverless freight fleets bring many benefits to the logistics industry. Not only are they able to save 12% on fuel consumption compared to traditional vans, they can also save on labor costs, with just one driver able to control a fleet of three or four vans. At the same time, autonomous trucks can also reduce maintenance costs by 14%. It is expected that the automatic driving truck will save a total of $30 billion in operating costs. In addition, the application of autonomous vans can also benefit society - reducing carbon emissions by 25 million tons, while preventing 400 road traffic fatalities. The above estimates are based on the assumption that driverless cars will be sold in developed markets from 2020 and that market penetration will reach 5% of new car sales in developed markets by 2025.

6.4 Circular Economy

A circular economy is different from a traditional linear economy. In a traditional linear economy, resources are made, used, and then disposed. A circular economy, on the other hand, is one in which resources are used in such a way as to capture the maximum value, and in which their constituent products and materials can be recovered and recycled near the end of their useful life. As the circular economy develops and becomes more widespread, companies will use as few "new" materials as possible, which will reduce potential logistics orders but increase the need for complex return (recycling) processes. For example, computer technology giant DELL will work to create a closed-loop plastic recycling system, not only to recycle customers' old systems, but also to become the industry's first computer company to provide third-party certified, closed-loop recycled plastic manufacturing, which can help companies save costs (He, 2017). In the context of the development of circular economy, port logistics services should be able to adapt to the complex demand for returned goods, and can develop a derivative service industry based on the demand of circular economy.

6.5 Employment

The port environment has undergone many changes due to technological, operational and organizational developments, and ports must redefine the critical skills required of port labor . Besides, as technology continues to advance, specialized training courses must be developed to keep pace with groundbreaking innovations. The digitization and automation of the contemporary shipping and port industry require fewer workers but are able to perform a variety of tasks more flexibly; for this reason, multitasking workers and multi-skilled operations are becoming more common in ports. As a result of these developments, new career opportunities are emerging in the port sector; for example, software and hardware engineers will become core occupations in ports in the near future, along with programmers, designers, etc (Vaggelas & George, 2020).

The development of technological, operational, and organizational have led to increasing levels of demand for new jobs and roles, with a focus on new hard and soft skills for the port workforce. In addition, technological developments have created better health and safety conditions in the port workplace and increased labor productivity, thanks to regular monitoring of port operations and security systems to comply with the most stringent safety and security regulations. Another impact is the creation of strategic jobs that have a direct impact on the workflow, characterized by interdependence and irreplaceability. On the other hand, the evolution of the port workforce has created disadvantages such as job losses, especially in low-skilled jobs, and changes in job descriptions due to different skills brought about by trends such as digitilization and automation, triggering the need for a highly skilled workforce. In addition, port jobs are becoming more mentally demanding (Vaggelas, 2020).

CHAPTER SEVEN CONCLUSION

Starting from the four stages of port development, this paper summarizes the essence and connotation of digital transformation of ports and the process of developing digital ports. In addition, the digital transformation of ports is based on various advanced technologies, including big data, 5G, AI, blockchain, etc. What are the principles of these technologies and how they are applied in digital ports are also explained clearly in this paper. After understanding the theoretical knowledge and application examples of application related to digital port transformation, this paper then makes a SWOT analysis on the development of port digitalization from a practical perspective and finally concludes that port digitalization should be vigorously developed, which is beneficial to the future development of ports and even the shipping industry. Finally, the paper summarizes the current global applications of digital ports and the future prospects of port digitization.

Digital transformation of ports is a big topic, and this paper is only the tip of the iceberg. Especially in the process of making the SWOT analysis, only qualitative analysis is conducted, while in recent years SWOT analysis is often combined with AHP analysis, making the results of the analysis supported by data, which is what this paper lacks. However, in the process of the analysis, especially when analyzing the weakness and threat, this paper proposes a solution to each problem, which is not found in most SWOT analyses, and is also an innovative point of this paper.

REFERENCE

A.D.B. (2020). Smart Ports In The Pacific.

Ahokangas, P., Matinmikko-Blue, M., Yrjölä, S., & Hämmäinen, H. (2021). Platform configurations for local and private 5G networks in complex industrial multi-stakeholder ecosystems. *Telecommunications Policy*, *45*(5), 102128.

Alcaide, J. I., & Llave, R. C. (2020). Critical infrastructures cybersecurity and the maritime sector. Transport Research Procedia, 45, 547–554.

Anyanwu, K. (2011). Overview and Applications of Artificial Intelligence. *Bachelor of Engineering (B. Eng), Electrical and Electronic Engineering, University of Technology Owerri*.

Atzori, L., Iera, A., & Morabito, G. (2017). Understanding the Internet of Things: definition, potentials, and societal role of a fast evolving paradigm. *Ad Hoc Networks*, *56*, 122-140.

Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 implications in logistics: An overview. Procedia Manufacturing, 13, 1245–1252.

Bassi, A., and Lange, S., (2013), "The need for a common ground for the IoT: the history and reasoning behind the IoT – a Project." In Enabling Things to Talk, pp. 13-16. Springer, Berlin, Heidelberg.

Brunila, O. P., Kunnaala-Hyrkki, V., & Inkinen, T. (2021). Hindrances in port digitalization? Identifying problems in adoption and implementation. *European Transport Research Review*, *13*(1), 1-10.

Carpenter, A., & Lozano, R. (2020). *European Port Cities in Transition*. Springer International Publishing.

Carlan, V., Sys, C., & Vanelslander, T. (2016). How port community systems can contribute to port competitiveness: Developing a cost–benefit framework. *Research in transportation business & management*, *19*, 51-64.

Chang, Z. W. (2018). Optimization of the "last mile" distribution mode of e-commerce logistics based on the background of "Internet+". *Times Agricultural Machinery (07)*, 132.

China Ports. (2019). *Blue Book on AI-Enabled Globalized Smart Ports Released.*

Chuub Nick. (2020). How will 5G enable smart ports? https://thetius.com/how-will-5g-enable-smart-ports

DP World. (2021). *DP world reports strong 1h2021 financial results.*

EY. (2021). Smart shipping breaks the wave, the digital trend of maritime industry geometry? https://www.sohu.com/a/455411623_676545

Fairhurst, P. (2014). Big data and HR analytics. *IES Perspectives on HR*, *2014*, 7-13.

Ford, R., Zhang, M., Mezzavilla, M., Dutta, S., Rangan, S., & Zorzi, M. (2017). Achieving ultra-low latency in 5G millimeter wave cellular networks. *IEEE Communications Magazine*, *55*(3), 196-203.

Future of Shipping: Digitalization. Maritime Perspectives Series - jointly organised by the International Maritime Organization (IMO) and the Maritime and Port Authority of Singapore (MPA)

Gartner. (2019). Gartner Identifies Top 10 Strategic IoT Technologies and Trends. *https:// www. gartn er. com/ en/ newsr oom/ press-relea ses/ 2018-11-07-gartn er-ident ifies-top-10-strat egic-iotte chnol ogies-and-trends. Accessed 25 Dec 2021.*

GE. (2016). Port of Los Angeles and GE transportation partner to digitize maritime shipping and help goods reach consumers faster. https://www.ge.com/news/press-releases/port-los-angeles-and-ge-transportation-partner-digitize-maritime-shipping-and-help

Giuliano, G., & O'Brien, T. (2007). Reducing port-related truck emissions: The terminal gate appointment system at the Ports of Los Angeles and Long Beach. Transport Research Part D: Transport and Environment, 12(7), 460–473.

González-Cancelas, N., Molina Serrano, B., Soler-Flores, F., & Camarero-Orive, A. (2020). Using the SWOT Methodology to Know the Scope of the Digitalization of the Spanish Ports. *Logistics*, *4*(3), 20.

He, Y. (2017). Supply risk sharing in a closed-loop supply chain. *International Journal of Production Economics*, *183*, 39-52.

Heilig, L.; Voß, S. Status quo and innovative approaches for maritime logistics in the age of digitalization: A guest editors' introduction. Inf. Technol. Manag. 2017, 18, 175–177.

Hou, J. K., Zhuang, Y. B., Shi, Z. K. Wan, C.X. (2020). Blockchain-enabled smart port construction. *China Management Information Technology(21),* 72-75.

Joanna. (2020). RFID in logistics: implementation practices & benefits. https://e-tagrfid.com/rfid-in-logistics-implementation-practices-benefits/

Jović, M., Tijan, E., Aksentijević, S., & Čišić, D. (2019, May). An overview of security challenges of seaport IoT systems. In *2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* (pp. 1349-1354). IEEE.

Kapkaeva, N., Gurzhiy, A., Maydanova, S., & Levina, A. (2021). Digital Platform for Maritime Port Ecosystem: Port of Hamburg Case. TransSiberia 2020 conference. *Transportation Research Procedia*, *54*, 909–917.

Lengenfelder, K. (2018). Port of Hamburg as digital networking pioneer. https://www.hafen-hamburg.de/en/press/news/port-of-hamburg-as-digital-networking-pioneer--36029/

Levanen, T., Pirskanen, J., Koskela, T., Talvitie, J., & Valkama, M. (2014, June). Low latency radio interface for 5G flexible TDD local area communications. In *2014 IEEE International Conference on Communications Workshops (ICC)* (pp. 7-13). IEEE.

Levine, D. M. (2013). A day in the quiet life of a NYSE floor trader. https://fortune.com/2013/05/29/a-day-in-the-quiet-life-of-a-nyse-floor-trader

Liu, Z.L, & Wu, X.F. (2019). Some thoughts on "digital transformation" of port groups. *China Ports (08),* 33-36.

Logica, B., & Magdalena, R. (2015). Using big data in the academic environment. *Procedia Economics and Finance*, *33*, 277-286.

Luo, B. C, (2021). The essence of digital transformation of ports and the path of realization. *China Ocean Shipping (09),* 48-53.

Portnews. (2013). Port of Hamburg launches PORTLog online service. https://portnews.ru/news/161938/

Qin, J., Liu, Y., & Grosvenor, R. (2016). A categorical framework of manufacturing for industry 4.0 and beyond. *Procedia CIRP*, *52*, 173–178.

Oyku. (2017). Maersk and digital revolution in shipping industry. https://digital.hbs.edu/platform-digit/submission/maersk-and-digital-revolution-in-shipping-industry/

Senarak, C. (2021). Port cybersecurity and threat: A structural model for prevention and policy development. *Asian Journal of Shipping and Logistics, 37*(1), 20–36.

Shen, Q. Q., & Zhong, X. Y. (2018). Application of blockchain technology in the field of port shipping. *Logistics Technology (12),* 63-66.

Sun, H. (2019). Research on the application of Internet of Things technology in smart ports. *Electronic World (09),* 150-151.

Tan, Y. & Chen, K. F. (2022). Exploring the path of smart port construction from a technology-driven perspective. *Communication and Information Technology (01),* 62-65+42.

Tian, Y., & Hu, X. (2021). SWOT Analysis of China's Ceramic Industry and the Use of Computers for Scientific and Technological Innovation Research. *Scientific Programming*, *2021*.

Tinarak, S. (2019). CMA CGM Launches Digital Shipping 'eSolutions' Experience. https://logistics-manager.com/cma-cgm-esolutions/

Transportation management systems in seaport digitalization. In 32nd Bled eConference humanizing technology for a sustainable society, BLED 2019—Conference proceedings

University of Wisconsin. (2019). What Is Big Data? *https://datasciencedegree.wisconsin.edu/data-science/what-is-big-data/*

Vaggelas, G. K. (2020). PORT LABOUR CHALLENGES AND OPPORTUNITIES IN THE ERA OF PORT AUTOMATION AND DIGITALIZATION. *labour*, *10*, 12.

Wattenhofer, R. (2016). *The science of the blockchain*. Inverted Forest Publishing.

Weinstein, R. (2005). RFID: a technical overview and its application to the enterprise. *IT professional*, *7*(3), 27-33.

Xu, X.C. & Wang, Y. (2021). The application of big data in enterprise production and operation. *Reform (01),* 18-35.

Yang, Y.B.L., & Zhao, Z.Q., (2020). A new future for digital smart ports. *http://scitech.people.com.cn/n1/2020/1022/c1007-31901328.html*

Zeng, L. L., & Wu, H. (2021). The main problems and countermeasures faced by big data application in the construction of smart ports. *Containerization (10),* 1-5.

Zhang, Z. (2021). An analysis of the Internet of Things in shipping logistics and ports. *Software(06),*168-170+176.

Zhuang, Q. W. (2005). Analysis of typical port logistics model. *Waterway Transport Digest (12),* 33-34.

Zhang Y. Y. (2010). Intelligent development measures of China's ports. *Port Economics (02),* 53-55.

Zhang, Y. Z. (1997). The impact of global economic integration and new dynamics of world shipping on the development of modern ports. *China Ports (03),* 38-39.

Zhang, J. S., Zhen, H, L, J. L. & Gao, J. (2009). Research on the characteristics of the fourth generation port concept and development strategy based on the supply chain idea. *China Harbor Construction (05),* 70-73.

Zhu, L. & He, L. (2021). An analysis of the trend of digital transformation of port business. *New Industrialization (11),* 83-84+87.