Fachbereich Wirtschaftswissenschaft

Improving the Information Flows and Business Process in Global Maritime Logistics Chains considering Digitization and Digitalization Aspects

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Declaration

I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. The work was made without unauthorized aid. No other than the specified sources and aids were used. Except where states otherwise by reference or acknowledgment, the work presented is entirely my own.

Data & Place

Bremen, on April 15th 2021

Signature of author

Acknowledgment

Thanks to my supervisor, Professor. Dr. Hans-Dietrich Haasis. You have always responded to my requests with immediate and practical help. Your guidance helps me to complete this work. Thanks for introducing me to IGS and “via Bremen” project and supporting me to the conference in Opatija. All of these experiences have enriched my study and life here. Thanks to the China Scholarship Council for the financial support. It removes my financial burden so that I only need to concern about my work here. Thanks to my colleagues for sharing research experiences with me and helping me with my work. At last, thanks to my family and friends for being in my life.

Abstract

Maritime transportation especially container shipping has played an important role in global trade. Different actors that related to maritime logistics and business are aimed to improve the safety and security of ocean shipping, enhance the efficiency of ship and port operations, integrate with hinterland transportation network, shorten the time for the regulatory process, and reduce the negative influence on the environment. Digital technologies have been applied to achieve these objectives by logistics services providers, port authorities, governmental organizations, regional economic communities, and international organizations, to make the commercial, regulatory, logistical, and financial procedures in the cross-border trade safe, efficient, and environmentally friendly.

Digital technologies have been used for business and logistics operations for a long time. With continuous improvement and development, they push the maritime industry into an era of digitization and digitalization. For the regulatory process, Single Window System is proposed, which is facilitating with the concept of e-Government. For the logistical process, several concepts and strategies are widespread in the maritime industry, such as IMO's e-Navigation, EU's e-Maritime, Korea's smart-Navigation, and Smart Ports of Hamburg, Shanghai, etc. These ideas are all enabled and inspired by the development of technologies as well as the exploitation of applications in maritime business and logistics.

This paper will first summarize and analyze the influences of digitalization on the maritime logistical process, regulatory processes, and specific data and information. Second, the main digital technologies are identified and categorized into three groups which concern logistical information flow, commercial and regulatory aspects, and the information infrastructure separately. The current and potential usage of each technology is evaluated to provide hints for future maritime digitalization. Third, three developed concepts are identified and analyzed considering the digitalization of regulatory processes, maritime shipping, and port development respectively. The concepts have pointed out the prospects of maritime digitalization. Specific policies, applications, and cases are analyzed in the research of each concept. Finally, the influences of digitalization on the maritime industry's information flow, business, and logistics operations are concluded.

Keywords: maritime digitalization, ICT, IT/IS, Single Window, e-Navigation, e-Maritime, Smart Port.

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List of Abbreviations

AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AIS	Automatic Identification System
BoL	Bill of Lading
BSP	Buy-Ship-Pay
CCL	Core Component Library
CMDS	Common Maritime Data Structure
CPS	Cyber-Physical System
ECDIS	Electronic Chart Display and Information System
EDI	Electronic Data Interchange
EMSA	European Maritime Safety Agency
ETA	Estimated Time of Arrival
EU	European Union
GIS	Geographic Information System
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICT	Information and Communication Technology
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IoT	Internet of Things
ISCRM	International Supply Chain Reference Model
ISO	International Organization for Standardization
ITS	Intelligent Transport System
ITT	Inter-Terminal Transportation
LDC	Least-Developed Country
MSP	Maritime Service Portfolio
NSW	National Single Window
OECD	Organization for Economic Co-operation and Development
OGA	Other Government Agency
PCS	Port Community System
RDM	Reference Data Model

RFID	Radio-Frequency Identification
RS	Remote Sensing
SAD	Single Administrative Document
SOA	Services-Oriented Architecture
STM	Sea Traffic Management
TFA	Trade Facilitation Agreement
UN	United Nations
VGM	Verified Gross Mass
VTS	Vessel Traffic Service
WCO	World Customs Organization
WSN	Wireless Sensor Network
WTO	World Trade Organization

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1 Introduction

1.1 Research Motivation

Ocean shipping is a very traditional transportation mode for international trade. It is relatively cheap but time-consuming compared with air transportation. This mode is commonly used to transport main bulks (iron ore, grain, and coal) and tankers (crude oil, refined petroleum products, gas, and chemicals). Meanwhile, containerized cargo has expanded very fast with volumes rising at an annual average rate of 8.0 percent between 1980 and 2018. An estimated 793.26 million TEUs were handled in container ports worldwide in 2018 (UNCTAD, 2019). According to the International Maritime Organization (IMO), nearly 90% volume of the world's trade travels by sea and the amounts are still increasing gradually. The large volume has brought challenges and opportunities for actors who are involved in ocean shipping, port operation as well as hinterland transportation. They try to save costs, to improve efficiency and benefits thus increasing their competitiveness and market share. For these purposes, Information and Communication Technology (ICT) has been adopted and evolved as indispensable support in this industry.

ICT has largely improved communication among actors and enhanced the security and efficiency of operations. For example, Electronic Data Interchange (EDI) has been introduced to transfer documents electronically. The aim is to replace paper documents with an electronic version. Port Community System (PCS) has been developed by port authorities to manage administrative procedures as well as port operations. It is a very effective way to handle a large amount of information especially refer to container shipping. As maritime transportation involves many different actors, this information system also makes communication among the inter-organizational actors more convenient and faster. For instance, it is applied for customs procedures of exporting and importing containers which usually takes a long time in port. When PCS integrates with the customs system, it saves time to avoid submitting the same documents repeatedly, thus largely facilitating clearance procedures. The Automatic Identification System (AIS) has been used to track vessels and prevent collisions. This enhances the safety and security of ocean shipping. Since ICTs were adopted in the 1960s, they have been widely applied for commercial, regulatory, logistical, and financial processes in maritime transportation. They improve information transfer, exchange, and sharing among different actors. However, in the regulatory process, the majority of actors in the shipping industry still handle documents manually, including the Bill of Lading (BoL), Customs Declarations, and the

Certificate of Origin. The inter-organizational information sharing systems are outdated and manual processes still prevail in large parts of the supply chain (Loklindt et al., 2018). As operating actors often do not have all information readily available, containers standstill almost half of the time of their journey (Jensen et al., 2014). The lack of coordination and information sharing results in little transparency and a general lack of trust between the parties involved. It also poses a security risk and an increased workload. The inaccuracy of information and delays affect operational aspects. The multitude of different actors in the supply chain, their relationships, different regulations, and the cost of information inherently contribute to supply chain barriers, which impede global trade. Therefore, the transportation industry is in dire need to cut costs by improving its inter-organizational processes, such as achieving industry-wide digitization of documentation exchanges (Loklindt et al., 2018). Poor information management leads to increased expenses and can account for up to 20% of an operational budget (Den Norske Veritas, 2017). The cost reduction intentions, the high level of regulation in the maritime industry such as eco-friendly goals, and the large amount of data that maritime companies should process, along with work more effectively, are the main drivers of digital innovation (Gausdal et al., 2018).

Therefore, the industry has a large potential to develop their ICTs and enters into a new era of digitalization. New concepts explode into our view of the maritime industry. In recent years, digitalization has become a buzzword especially under the background of Industry 4.0, e-Maritime, e-Navigation, Smart Port, and Blockchain Bill of Lading are frequently mentioned in business and research areas. This phenomenon attributes to the introduction of new digital technologies such as the Internet of Things (IoT), Big Data, Cloud Computing, Cyber-Physical System (CPS), and Mobile technology, etc. Needless to say, the appliance of new technologies will influence the industry in many aspects such as business model, administrative, and logistics operations. For actors in the maritime industry, they seek to take advantage of new technologies to improve operations and competitiveness to make benefits in the long run. For instance, in a case analysis of 75 port-related innovation initiatives, 40% of the cases are oriented towards the enhancement of the information flow through the maritime supply chain. On the one hand, it shows that the maritime and port sectors have the interest to participate in the trend of digitalization; on the other hand, it also implies the obstacles to take action. Although there is often a benefit-cost balance for every actor, many of them are still in a wait-and-see attitude because they cannot see the benefit. (Sys et al., 2015)

Digital transformation is then defined as the process that is used to restructure economies, institutions, and society on a system level. While digital transformation embraces changes on all societal levels, digitalization employing combining different technologies (e.g. cloud technologies, sensors, big data, 3D printing) opens unforeseen possibilities and offers the potential to create radically new products, services, and business models (Rachinger, 2019). As digitalization has been considered as the developing trend in the maritime industry, it is important to discuss what maritime business and logistics would be like under digitalization and what influences it brings on maritime actors. By analyzing the characters of each generation of digitalization, we can foresee the opportunities in the maritime industry and take action to the changes that happened.

1.2 Research Questions

ICT, which presents the process of digitization, has been used in the maritime industry for more than 60 years, and digitalization is a relatively new concept that has been frequently discussed in the recent 10 years. The digitization and digitalization processes refer to applying the developing and innovative ICTs to the commercial, logistical, regulatory, and financial procedures in the global maritime business and logistics.

In the commercial process, ICTs are applied for e-business. EDI is used to edit and transfer digital documents between trading partners, for example in marketing and purchasing activities. Smooth communication and accurate arrangement supported by ICTs improve the door-to-door transportation service.

In the logistical process, 3S technology (GNSS, RS, and GIS) is used for positioning and navigating vessels in maritime shipping. It can also be applied to identify, track, and monitor containers in ports and hinterland transportation. AIS, a satellite-based navigation system, is used for navigation. The system is demanded to be equipped with specific vessels after 2002 under the SOLAS regulation. RFID is applied to track objects in transportation, terminal management, and container operations. The Real-Time Location Tracking System based on RFID can be used for intelligent pre-shipment inspections, replacing manual-based methods. Big data, Cloud, and IoT are exploited to realize autonomous shipping and automated port. CPS is to improve the intelligent transportation system further to achieve self-configuration. EDI can be used for a stowage plan of container vessels. The concepts of e-Navigation, e-Maritime, smart-Navigation, and Smart Port are proposed and implemented by international, regional, governmental, and port authorities for using digital technologies in maritime shipping.

In the regulatory process, PCS is developed based on EDI technology to replace paper documents for the container's import and export operations and vessel's arriving, berthing, and departing of ports. It is used to improve inter-organizational procedures. Blockchain enables regulatory actors to issue electronic certificates. The blockchain-based tracking system can be used for customs clearance in international trade. The concept of a Single Window is proposed for the integrated or interfaced system. It develops from a Customs/Port Single Window to a Local/National Single Window, and then to a Regional/Global Single Window.

In the financial process, online payment is used within intermediaries between banks, and blockchain is said to improve online transactions without the intermediary banking sector.

Other technologies, such as mobile technology and wireless communication technology, play a role as the information infrastructure. They bring developments and innovations for digital services.

As mentioned above, ICTs contribute to digitize and digitalize the business processes and information flows in global maritime logistics chains. The thesis will address the following main question:

How digitization and digitalization influence the maritime industry's information flows, business, and logistics operations?

To answer this question, further research issues are considered below.

- The ICTs that bring the maritime industry into an era of digitalization
- The influences of the ICTs on the operations and business
- The developing trends and strategies of the maritime industry under digitalization

For the ICTs, we will study both the old and new ones, as well as the development of previous ICTs that still have a big function in the maritime industry. The ICTs are the infrastructure to realize digitalization. Further, the influences of the ICTs are analyzed from the business and logistics perspective. Finally, the research will focus on strategic concepts in the process of digitalization. These concepts are brought out by global institutions like the IMO, regional committees like the European Union (EU), national governments, and port authorities. They have great influences on maritime logistics and business and represent the next step of this industry to realize digitalization. Therefore, it is important to discuss the deployment of digitalization according to the strategic concepts. The following questions provide a structure to do the research.

1.3 Research Methodology

To address the questions, this work has used several methodologies as below.

1) Literature review

To study the digitalization in the maritime industry, literature is searched in two databases at the beginning which are Scopus and Web of Science. These articles are searched by the keywords of 'digitalization', 'maritime transportation', and 'maritime logistics'. The other research sources are websites of official organizations, maritime companies, port authorities, reports from industry and research institutions, and books. Some articles are found by targeted research. These refer to specific content, for instance, the strategic concepts (e-Maritime, e-Navigation, etc.) and new technologies (IoT, CPS, blockchain, etc.). The literature is analyzed through summarization, categorization, or comparison.

2) Conceptual framework

Digitization and digital transformation are similar concepts to digitalization. The meaning between these concepts is partly overlapped. However, there are differences between these concepts which means they imply different developing trends. Based on the literature review, this work will summarize a clear view of what digitalization is and its relations with digitization and digital transformation. Furthermore, the ICT framework and information flow under digitalization will also be presented.

3) Case study

There are a large number of enterprises that have to use ICTs to improve their business and operations. Also, some changes are compulsory under global and regional agreements and regulations. To understand how digitalization influences this industry, this work will analyze the specific authorities that are in the leading place of this development.

1.4 Research Structure

There are five chapters to study on the research questions. Chapter 1 is an introduction to this work. Chapter 2 studies the knowledge about the maritime industry and its digitization and digitalization from four aspects, which are maritime sectors mainly referring to shipping and port, actors in maritime logistics, business process and information flow of the cross-border trade and logistics, and a literature review of the basic knowledge about maritime digitalization. Chapter 3 works on the digital technologies and information systems that present the digitalization process of the maritime industry. Chapter 4 summarizes the developing trend and policies in this industry and analyzes the influence of digitalization on information flow and business and logistics operations. Chapter 5 is the findings, conclusions, and recommendations of the research. The following picture shows the logical structure of this work.

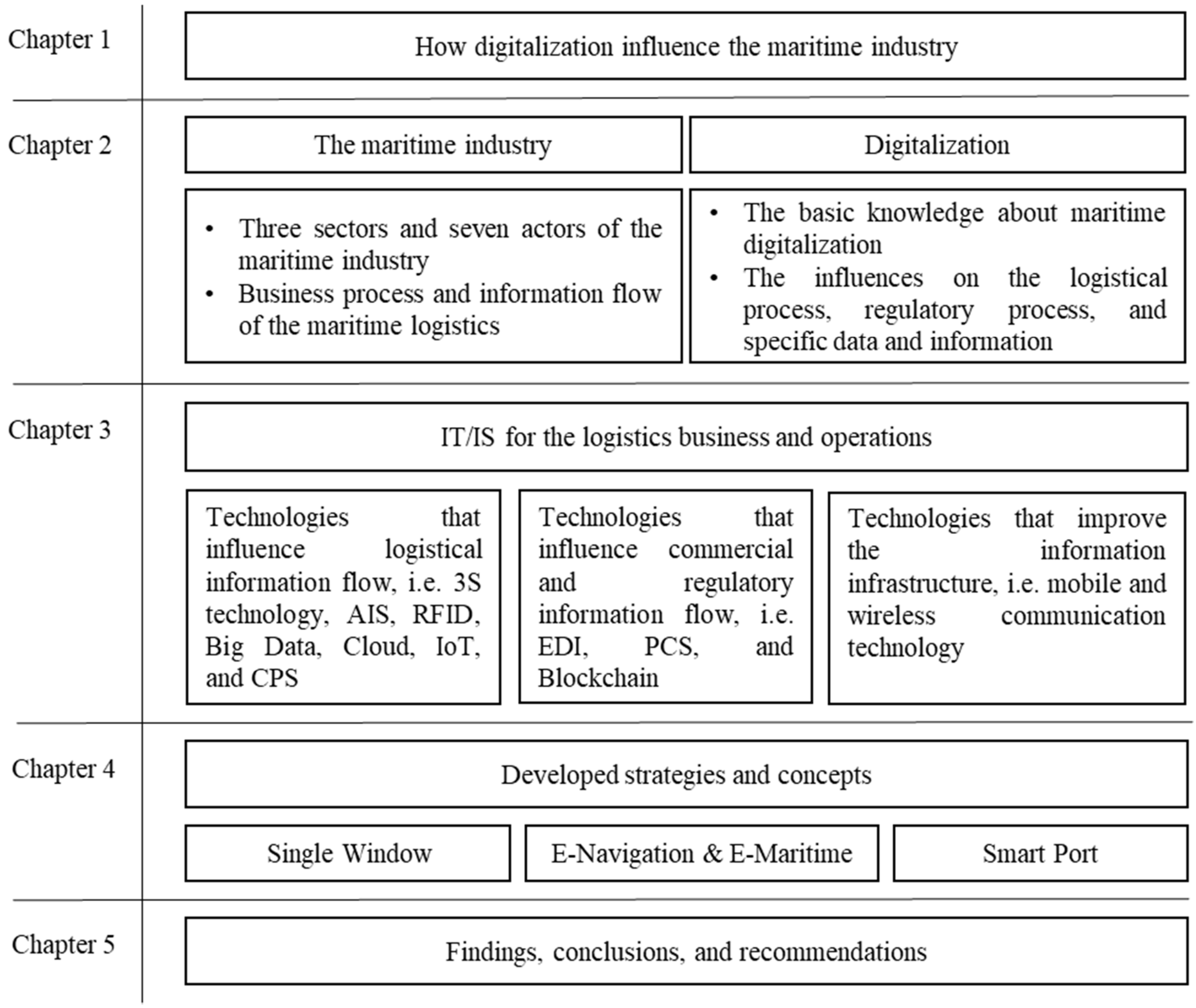

Figure 1-1 Research structure

2 Digitalization in the Maritime Industry

2.1 Sectors in the Maritime Industry

The Federal Ministry for Economic Affairs and Energy in Germany mentioned that the most important sectors of the maritime industry are maritime shipping, ports, shipbuilding, the shipbuilding supply industry, marine engineering, offshore wind energy, and maritime research and development (Federal Ministry for Economic Affairs and Energy, 2021). Merchant shipping accounts for roughly a third of the total maritime activity which divides the maritime business into five groups: vessel operations (i.e. those directly involved with ships); shipbuilding and marine engineering; marine resources, which include offshore oil, gas, renewable energy, and minerals; marine fisheries, including aquaculture and seafood processing; and other marine activities, mainly tourism and services (Stopford, 2008, p48). Here we mainly consider the influence of digital technologies on vessel operations in the maritime business. These operations include ocean shipping, port operations, hinterland transportation, and the related administrative and business processes.

2.1.1 Maritime Shipping

In maritime shipping, ocean shipping and hinterland transportation establish a complete transportation chain of containerized cargo. To achieve the goal of door-to-door transportation in maritime shipping, it is unavoidable to consider improving the transshipment of the two transport models as a holistic and integrated transportation chain.

The maritime transportation process is shown in Figure 2-1. Containerized cargo is collected from consignors and transported and delivered to consignees. They undergo hinterland transportation and ocean shipping. The chain involves operations about intermodal transportation and it happens in ports. In-land terminals, such as rail yard, river yard, distribution center, etc., may also involve in hinterland transportation. The operations are inter-organizational and interregional on the chain. Consequently, it brings about complicates and challenges for the actors to operate as a whole. Digitalization may help with the problems. The shipping industry is cautiously embracing relevant technologies arising from digitalization. Logistics companies are taking measures to digitalize internal processes, provide user-friendly online interfaces for consignors, develop integrated information technology infrastructure, and enhance real-time data and transparency.

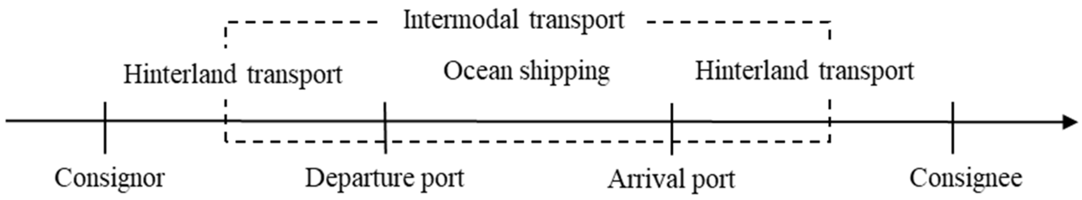

Figure 2-1 A simplified maritime logistics chain

2.1.1.1 Ocean Shipping

Maritime shipping is categorized into deep-sea shipping and short-sea shipping. Deep-sea shipping refers to the maritime transport of goods on intercontinental routes and crossing oceans. It is relatively long-distance transportation compared to short-sea shipping. Short-sea shipping refers to transport within regions, such as maritime transport between ports in EU countries, in the Baltic Sea area, or the Mediterranean Sea area, etc. Some short-sea vessels are small enough to travel on inland waterways.

In maritime shipping, cargo is classified into four groups, which are containers, main bulks (iron ore, grain, and coal), tankers trade (crude oil, refined petroleum products, gas, and chemicals), and other dry cargo. UNCTAD estimates world seaborne trade volumes at 10.7 billion tons in 2017. Containerized trade and other dry cargo represented 24.3 percent and 25.4 percent of the total respectively. Main bulks commodities accounted for 29.9 percent, which was estimated at 7.6 billion tons. The share of tanker trade dropped from around 55 percent in 1970 to 29.4 percent in 2017. The fastest-growing segment was containerized trade, with volumes expanding over nearly four decades at an annual average growth rate of 8.1 percent (UNCTAD 2018, p4). An estimated 793.26 million TEUs were handled in container ports worldwide in 2018 (UNCTAD 2019, p18). The increasing container shipping improves the standardization of maritime shipping. Digitalization influences container shipping largely and the technologies are applied by container companies and terminals.

For the containerized trade, the Trans-Pacific trade lane remained the busiest, with total volumes reaching 27.6 million TEUs, followed by 24.8 million TEUs on the Asia-Europe route and 8.1 million TEUs on the transatlantic route (UNCTAD 2018, p12). The rapid expansion of e-commerce is directly relevant to container shipping. According to UNCTAD, cross-border e-commerce was worth about $189 billion in 2015, accounting for 6.5 percent of total business-to-consumer e-commerce (UNCTAD, 2017). Shipping, like other modes of transport, is also part of the e-commerce supply chain. To tap this trade potential rise, shipping operators need to adapt and leverage technology for greater efficiencies and to design integrated supply chain solutions that are e-commerce friendly. An example is the new global integrator strategy pursued by Maersk to drive down costs, improve reliability, enhance responsiveness, and forge a better link with customers (Maersk, 2018).

2.1.1.2 Hinterland Transportation

Hinterland transportation is an essential and important part of the whole maritime logistics chain. As containers arrive at ports, they are transported and delivered by other modes to consignors. The hinterland transport system consists of an extensive network of roads, railways, and waterways using trucks, trains, and barges. It interfaces with the shipping system through ports and specialist terminals (Stopford, 2008, p51). Consequently, the intermodal infrastructure is a competitive factor for ports to enable moving containers to an extensive market.

From ocean shipping to hinterland transport and vice versa, efficient operations are based on smooth communication and accurate arrangement. Digital technologies provide the possibility to take into account all types of interaction and coordination of activities of different transportation modes when choosing routes for freight flows (Bubnova et al., 2018). Beyond usability and ecological benefits, service integration offers economic potentials as well. From the transportation providers' perspective, it offers the potentials to increase the provider's market share by adding complementary services and synergistic effects (Beutel et al., 2018).

The improvement of intermodality in maritime shipping contributes to sustainable development under competitiveness conditions, providing door-to-door transport services, by efficiently integrating at least two different transport modes for moving goods. The next step is to manage, monitor, and optimize the information sharing and integration of each actor in the logistics chain to improve transportation.

2.1.2 Port

Containers are loaded and discharged at ports. The ancient ports are simple harbors where vessels stop by. They act as a sea-land interface and a point of convergence between different transportation modes, providing access to the overseas market. Modern ports tend to be hubs in logistics chains and networks. It involves inter-organizational communication and activities in ports. ICTs play an important role as they can promote the development of inter-organizational relationships among different actors. Both physical infrastructure and ICTs in ports are critical assets in the process of fulfilling customers' satisfaction. When a port authority becomes aware of the strategic role of inter-organizational relationships as new sources of value creation and competitiveness, it can set a systematic evaluation of their nature and contribute to improve and sustain the port's innovation. The recognition of the interactive nature of relationships among port actors in the port service supply chains represents a critical and fundamental issue for spreading innovation in the port, especially from a cultural perspective, as it allows interpretation and consideration of collaboration as a means of value creation (De Martino et al., 2013).

In the global maritime logistics chain, seaports and inland ports are two types of ports that deal with different business and logistics services. Seaports handle large container ships and other cargo ships from ocean shipping. Modern seaports are equipped with specialized containerized cargo-handling machines, such as gantry cranes, reach stackers, and forklift trucks. They also have inland transport infrastructures, such as rail, road, and river or canal selectively. Inland ports are situated along the river or canal with access to a sea or ocean. Generally, they also refer to dry ports that are directly connected by rail or road to a seaport. Inland ports act as the transshipment center of containers to an inland destination (FDT, 2007).

The sea-side area encompasses the quays where ships berth and the quay cranes that provide the loading and unloading of containers into and from ships. The land-side area provides the interface with the hinterland transportation system and encompasses the truck and train gates. Trucks are generally loaded and unloaded directly in the yard area (Crainic et al., 2007). The logistics operations at a seaport can be classified as seaside operations, terminal operations, and landside operations summarized in Figure 2-2.

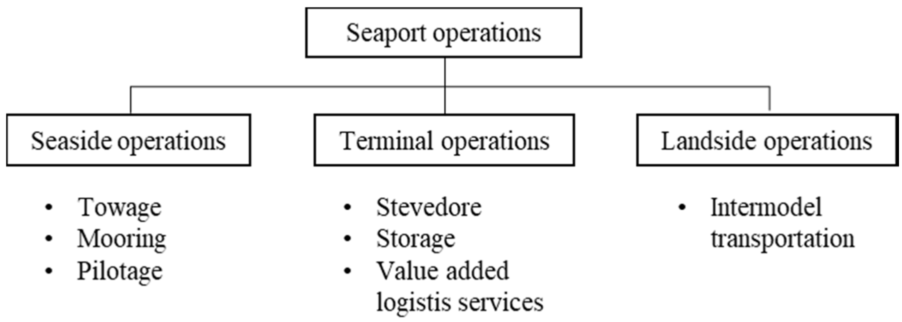

Figure 2-2 The common operations in a seaport

The seaside operations mainly contain three operations that are pilotage towage and mooring. Firstly, pilotage is navigating vessels to a desired course or location. Secondly, towage means to use tugboats to maneuver large vessels' berthing in queys Thirdly, mooring refers to the act of attaching a vessel to a permanent structure on a berth to prevent the free movement of vessels on the water. Among the three operations, pilotage is a mandatory technical-nautical service organized on a monopoly basis in most European ports; whereas towing and mooring services can be provided by either the public or private sector on a voluntary or mandatory basis, exclusively or in competition with other operators.

The terminal businesses include loading and unloading containers, warehousing, and other value-added logistics services. Three main types of handling operations are performed in a container terminal: (1) ship operations associated with berthing, loading, and unloading container ships, (2) receiving/delivery operations for outside trucks and trains, and (3) container handling and storage operations in the yard (Crainic et al., 2007). The first type involves berth scheduling, quay crane allocation, and stowage sequencing. Berth scheduling determines the berthing time and position of a ship at a given quay. Quay crane allocation is to determine the specific servicing vessel and the associate service time of cranes. Stowage sequencing is to determine the sequence of unloading and loading containers.

The landside operations are to manage and arrange the intermodal transportation activities. Containers are moved to either trains or trucks or barges for further transportation and delivery by arrangement after the customs process and security check. The transportation network to the hinterland is a competitive factor for ports. Digital technologies also help to improve landside operations. For example, Geographic Information Systems (GIS) is invaluable in the cost-effective construction and maintenance of the intermodal network and the subsequent validation of mode sequences and route selections (Southworth, 2000).

The future port is the Smart Port. Smart Port uses technologies, including the IoT, artificial intelligence (AI), and blockchain to realize process automation for terminals and container handling (Port Technology International Team, 2019b). Smart Port usually deploys cloud-based software as part of the process of greater automation to help generate the operating flow that helps the port work smoothly (Port Technology International Team, 2019a). Due to global government initiatives and exponential growth in maritime trade, the amount of intelligent ports has gradually increased and the market will grow continuously (Visiongain, 2019).

The contemporary maritime logistics supply chain management decision areas should focus on the maritime container terminals, i.e. berth allocation problem, quay crane scheduling, container storage and handling in the yard, truck appointment systems, horizontal transport of containers within yards, and Inter-Terminal Transportation; hinterland logistics and transport corridors, knowledge lads for maritime logistics clusters, and digital innovation and emerging technologies (Buer, 2019).

2.2 Actors in Maritime Logistics

Shipping is ultimately a group of people – shippers, ship owners, brokers, shipbuilders, bankers, and regulators – working together on the constantly changing task of transporting cargo by sea. (Stopford, 2008). The main actors will be categorized and introduced by their functions in the maritime business and logistics in the maritime shipping business. They are consignees and consignors, freight forwarders, shipping companies, shipping agents, port terminal operators, port authorities, customs, hinterland transport companies, and banks.

1) Consignor and Consignee

The consignor (the shipper) and consignee (receiver) are the customers of the maritime shipping market. The global business creates different logistics service demands. Transportation is the basic demand for customers. Other logistics and value-added services are also developed according to consignors' and consignees' demands. There are also cases that maritime logistics companies take part in managing the customers' global supply chain. E-commerce is developed in the industry that consignors check information and book orders online. Logistics service providers have advocated the door-to-door transportation service which integrates different transport modes.

2) Freight Forwarder

Freight forwarders are the ones who collect the orders from consignors and integrate the orders to book with the shipping company. Normally, consignors who own the cargo are not available to book the space with the shipping company. Cargo that is not enough for a container is called Less-Than-Container-Load (LCL). Shipping companies don't offer LCL consolidation services themselves. Meanwhile, it involves other transportation modes and logistics services, and a large number of documents for customs clearance. Therefore, freight forwarders function to provide these services. If the consignors have adequate, stable, and continuous demands for overseas transportation, they may build their own logistics companies to act as freight forwarders. Normally the foreign trade companies and consignors with a small volume of cargo will find a freight forwarder to transport the freight. A well established and experienced freight forwarder is expected to have the capabilities below (either owned or outsourced):

- To provide cost-saving and efficient shipping solutions for consignors
- To negotiate the freight contract and rate with a carrier
- To arrange trade finance, customs clearance, and port inspection
- To arrange the warehousing and distribution of containers

- To book ship with the shipping company and issue House Bill of Lading (not all freight forwarders are allowed to do these based on business and shipping companies' regulations)
- To arrange hinterland transportation that moves containers from the origin to the port by rail, road, river, or canal
- To monitor and track the movement of containers along with the transportation

3) Shipping Agent

Shipping agents represent carriers (shipping companies) within a certain geographic area. If shipping companies do not have their own business offices or shipping agents overseas, they cannot do business in that country which means ships may even not stop by the port there. Shipping agents manage activities that are related to ships' and cargo's import and export procedures.

- To book berths at ports
- To arrange towage, mooring, pilotage, and other port services
- To arrange ship supplements and crew affairs
- To collect orders from freight forwarders or consignors and to keep contact with them
- To issue Master Bill of Lading
- To prepare the documents for the customs and harbor services

The application for shipping agents' licenses is very strict. For example in China, shipping agents are operated by national or local port bureaus. Some global shipping lines may prefer to build their own offices overseas to run the business. However, it is also determined by the business policies in foreign countries.

4) Non-vessel Operating Common Carriers (NVOCCs)

There is one actor whose functions overlap with freight forwarders and shipping agents. They are Non-vessel Operating Common Carriers (NVOCCs) that appear when freight forwarders' business develops to a more extensive range. They have similar functions as normal freight forwarders and equivalent rights as a real carrier by law. NVOCCs make contracts with consignors and issue House Bill of Lading. Meanwhile, they have business with shipping companies or their agents to book ships and get Master Bill of Lading.

5) Shipping Company

Shipping companies are the real carriers. They own or charter ships to run the shipping business. By principle, vessel fleets are categorized as oil tankers, bulk carriers, general cargo ships, container ships, and other types which include gas carriers, chemical tankers, offshore vessels, ferries, and passenger ships, etc.

The container shipping market share has increased stably over forty years. Ports are ranked by their container throughputs worldwide. There are increasing consolidation and concentration in the container shipping market. The top 10 container shipping lines have already shared 90 percent of the market in 2019 (UNCTAD, 2019). Three alliances, 2M alliance, Ocean, and the Alliance, are formed mainly by the top 10 container shipping companies. This further phases out or inhibits the development of other players in this market. Table 2-1 shows the alliances and their members.

Table 2-1 The alliances and members

Alliance	Members
2M Alliance	Maersk and Mediterranean Shipping Company
Ocean Alliance	COSCO, CMA CGM and Evergreen
The Alliance	ONE, Yang Ming and Hapag-Lloyd

These alliances have taken most of the market share in major East-West trade routes. 8 of the 10 top container shipping lines belong to these different alliances separately. Pacific International Lines and Hyundai which ranked 9th and 10th are out of these alliances. From 2014 to 2019 services offered by all operators that are members of an alliance change as following:

- The numbers of services increase by 90%
- Numbers of ships per service increase by 8.5%
- Average ship size (TEUs) increase by 31.8%
- Average round trip (days) decrease by 2.5%

On the contrary, services offered by all operators that are not members of an alliance changes in a reverse direction (UNCTAD, 2019). This represents a determining influence on the container shipping market of the top 10 global shipping lines. Figure 2-3 shows the market share of the three container shipping alliances on major East-West trade routes in February 2019, it exemplifies the large market share of the top 10 companies (review of maritime transport 2019). Consequently, the actions and attitudes of the companies in the alliances to digital technologies will have a large influence on maritime digitalization.

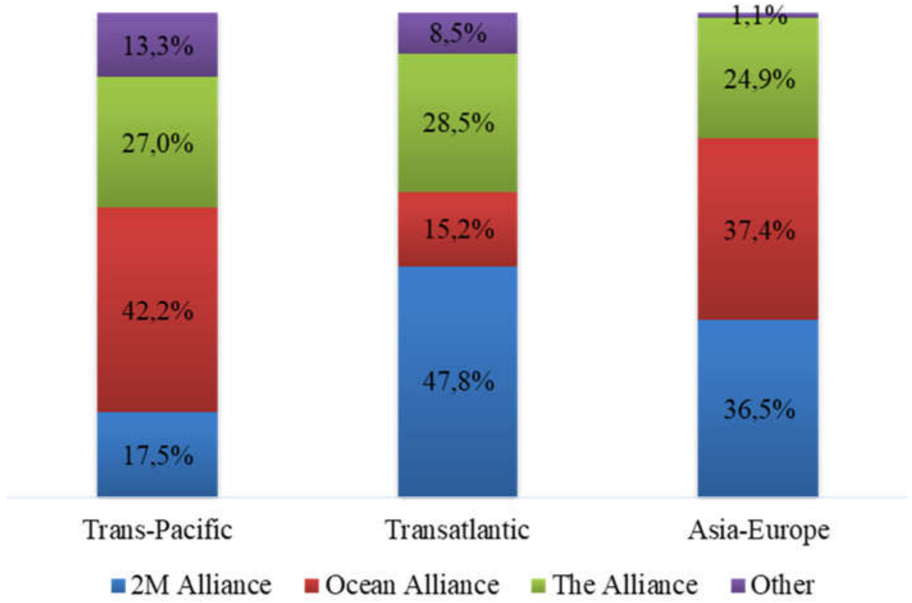

Figure 2-3 Market share of the alliances

The parent company groups of the global shipping lines also invest in port terminals, hinterland transportation, and IT/IS applications. For example, Maersk and IBM have cooperated to develop the blockchain Bill of Lading. With the steps to enlarge the business ranges, shipping lines will have the ability to provide door-to-door transportation services to customers.

6) Port Terminal Operator

Port terminal operators manage both maritime access and land access. They mainly have three tasks: firstly, to arrange and facilitate berthing of ocean ships; secondly, providing intensive cranes to stevedore containers and ample storage space to stack them; thirdly, connecting with hinterland transport modes. The main types of port terminals include break-bulk, dry bulk, liquid bulk, container, Ro-Ro, and passenger terminals. (Notteboom et al., 2020)

According to Lloyd's List, the top ten port terminal operators are Cosco Shipping, Hutchison Port, Port of Singapore Authority (PSA) International, Dubai Ports World (DPW), China Merchant Port Holdings, APM Terminals, Yilport Holding, Shanghai International Port Group, International Container Terminal Services, and Terminal Investment Ltd. They are grouped into three categories: deriving from a stevedore background and expanding into new markets like PSA International, maritime shipping companies like APM Terminals, and financial holdings like DPW. In 2018 the top seven global terminal operators accounted for 34.5% of global container port activity in terms of equity-based throughput. The trend is that they now dominate at the most important container ports in the world and wield monopoly power in many smaller ports. (Notteboom et al., 2020)

Automation is the present developing trend of port terminals. There are already automated port terminals in practice, and many are still in construction. The automated terminals reduce labor costs, enhance productivity, and maximize efficiency. The increased ship size forces the port infrastructure to improve efficiency. Automation will help avoid port congestion, decrease port storage charges, and reduce demurrage and detention. It also reduces carbon emissions. The situation of existing and planned automated container terminals in 2018 is presented by Drewry Maritime Research shown in Figure 2-4. The competitiveness of container terminals is determined not only by terminals' facilities but also by the external infrastructure. The hinterland transport connection is an important factor for the success of terminals.

Figure 2-4 Existing and planned automated container terminals (Port Technology International, 2019)

7) Port Authority

Port authorities take charge of ports. They should be responsible for the port management and take three types of functions as the landlord, regulator, and operator (Verhoeven et al., 2010). Port authorities are to develop, manage and exploit ports in a sustainable way and to render speedy and safe services for shipping (Port of Rotterdam, 2020). Infrastructure and ICTs construction are both important elements for a modern port. The infrastructure represents the productivity of ports to handle containers. ICTs assist physical operations and speed administrative processes.

Port authorities have developed their PCSs to manage the shipping services. PCSs are neutral and open platforms that enable the exchange of electronic information between public and private actors. These systems have largely improved the efficiency of port operations and customs processes. Previously, companies had to organize matters such as pre-reporting vessels, the status of shipments, export documentation, loading and unloading papers, or communication separately by e-mail, fax, or telephone. By using PCS, tasks are merged into a single system. This results in increased efficiency, lower planning costs, better and transparent planning, faster handling, and fewer errors. (Port of Rotterdam, 2020)

According to meet the increased demands of shipping companies, ports are forced to respond with new terminals and new cranes, and to ally them with the shipping companies, either land-based or water-based or both. The increased competition not only takes place in ports but also spills over into the service area of ports (McCalla et al., 1999). The competitive position of a container port is also dependent on the capacity and efficiency of the land transportation system (Crainic et al., 2007).

To make developing plans, port authorities should consider the economy and city development plan. They need to improve cooperation with hinterland transportation and with other ports. In summary, port authorities are required to construct ports from the perspectives of the whole transportation system and economic development. The central role of the port as a collaborative link in the global supply chain is emphasized, especially concerning the availability and variety of information in port. Consequently, the allocation of power on port strategy development, especially on digitalization strategies should be considered. The collaborative approach provides the port supply chain with balanced power, leading to the necessity to reduce barriers of equal power and support the supply chain collaboration. (Brinker et al., 2020)

8) Customs

Customs take responsibility for scrutinizing cargo and personnel to prevent smuggling and other crimes, as well as collecting taxes and duties. As a government role, each country will have its own national Customs agency. They are based on local, national, and international legislation and regulations. Customs officers play an enforcement role in the maritime industry. Customs processes are necessary and time-consuming in international maritime transport.

The regulations about customs are quite different. There are also agreements among countries or policies from one state to stimulate the economy and international trade. For example, there are Free-Trade Area (FTA) and the Free-Trade Zone (FTZ). The countries in FTA have little or no barriers to trade in the form of tariffs or quotas between each other. FTA is a region in one country that provides customs-related and economic advantages such as reducing taxes, customs duties, and regulatory requirements for registration of business. These unions and policies limit or eliminate trade barriers, but are quite subject to politics and international relations (Investopedia, 2020). FTZ is a geographic area where goods may be landed, stored, handled, manufactured, or reconfigured and re-exported under specific customs regulation and generally not subject to customs duty. Free trade zones are generally organized around major seaports, international airports, and national frontiers—areas with many geographic advantages for trade. (The Editors of Encyclopaedia Britannica, 2006)

Customs clearance has been sped up and simplified by EDI. When customs systems integrate with PCS, it largely shortens the time of document transfer and handling. The information on import and export containers is shared among the systems. Many countries have developed their e-Customs systems to increase the level of security in international trade and to facilitate the completion of customs formalities. E-Customs systems accelerate the movement of goods and reduce administrative costs.

9) Inland transport company

Inland transport companies are responsible for transportation from origins to ports and from ports to destinations. The well-developed hinterland networks enhance the port's competitiveness. Hinterland transportation has become a very important part of the development of global supply chains. The inland accessibility and other logistics functions have gained prominence in the achievement of higher port performance and competitiveness.

The transport modes of inland transport are by rail, truck, or inland waterways. These transport modes are competitors as well as cooperators. Road transport is flexible and fast. Rail and barge transport have the economics of scale, extend the area of the hinterland, and reduce port congestion. It can be road transport only or a combined transport mode for inland transportation.

For road container transport shown in Figure 2-5, there are four patterns which are Round Trip (RT), One Way (OW), Cargo rotation, and Round Trip double 20-foot container. RT means the truck transports a 20' container back and forth between the port and destination. Starting with the provision of RT services, truck companies developed other services to streamline transport and reduce costs. In the OW pattern, containers are sent to an inland depot and then back to the port again after refilling with new cargo. The complexity is that the inland depot needs to attract new container loads. It takes time and cost. Therefore, the transport price per kilometer of OW is higher than that of RT though the transport distance for the container is decreased. Cargo rotation is to bring the empty container from the import client to an export client to be filled with cargo. The detour cost should be considered in this pattern. RT double 20' is only possible for 20’ containers that do not exceed the maximum permissible laden weight. (Frémont et al., 2010)

For the combined transport mode shown in Figure 2-6, containers are first transported by barge or train to the inland terminals and then by truck to the consignee. Each trip by barge and train takes more containers than trucks. The mode improves efficiency, reduces cost, and extends the hinterland area of ports. The different factors and conditions have resulted in a variety of forms for combined transport development in hinterland transportation.

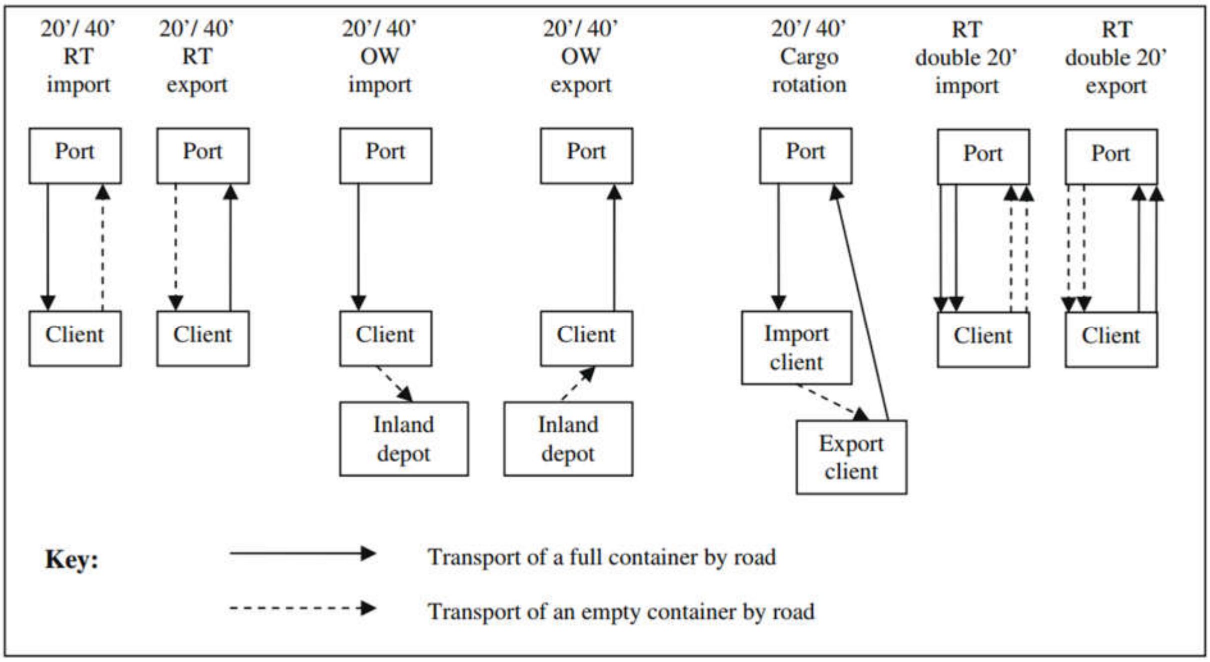

Figure 2-5 Different organizational strategies for road container transport (Frémont, 2010)

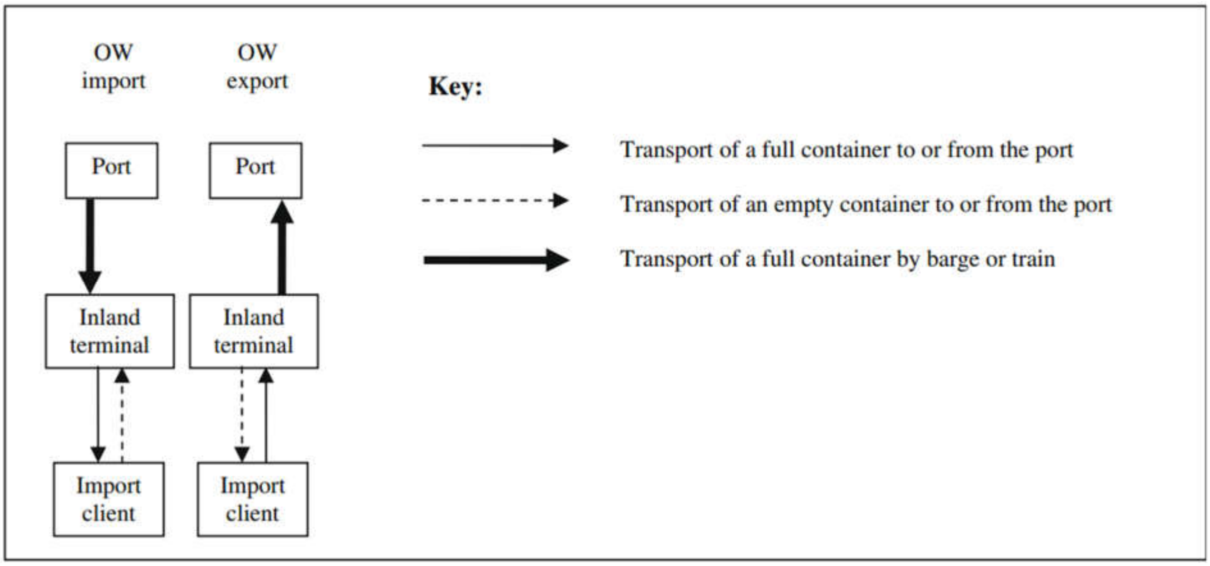

Figure 2-6 Different organizational patterns for combined transport (Frémont, 2010)

The above are the main actors in maritime transportation. The intermediate actors, like freight forwards, shipping agents, Non-Vessel Owning Common Carriers (NVOCCs), result from the market demand and development. The interregional and inter-organizational characters of maritime logistics bring about complicated administrative procedures and a large number of business and logistics documents. It is necessary to improve information sharing and integration among actors to support the business and logistics activities. ICTs are effective methods used to support business processes, customs clearance, and logistics operations. In recent years new digital technologies, such as mobile, cloud, blockchain, etc., have been applied to further simplify the business processes and improve information sharing.

Nowadays maritime transport is considered as an integrated demand to minimize costs, improve reliability, and provide services from the point of production to the point of consumption. The convergence of maritime transport and logistics may be largely attributed to the physical integration of transport modes facilitated by containerization and the evolving demands of end customers. The integration in maritime logistics is on physical, economic/strategic, and organizational levels. Physical integration is represented by intermodal transportation. Vertical integration and governance structure influence on economic/strategic level. The organizational level shows in the relational, people, and process integration across organizations. Maritime logistics largely focus on the transportation of containers about the integration of all the actors and on the achievement of logistics goals such as timeliness, reliability, low cost, etc. (Panayides, 2006)

2.3 Business Process and Information Flow

2.3.1 Business Process

International Supply Chain Reference Model (ISCRM) maps business processes in four main areas which are commercial, logistical (transport), regulatory, and financial. Figure 2-7 illustrates the key roles and actors related to each different business area, considering the specific procedures on the supply chain. Furthermore, Figure 2-8 elaborates on the main activities in each procedure. The commercial and transport procedures both have contract establishments, one is the sales contract and the other is the transport contract. The commercial procedures produce shipments, and the transport procedures produce consignments. The sales contract is signed between suppliers (sellers) and customers (buyers). The transport contract is with intermediaries or carriers.

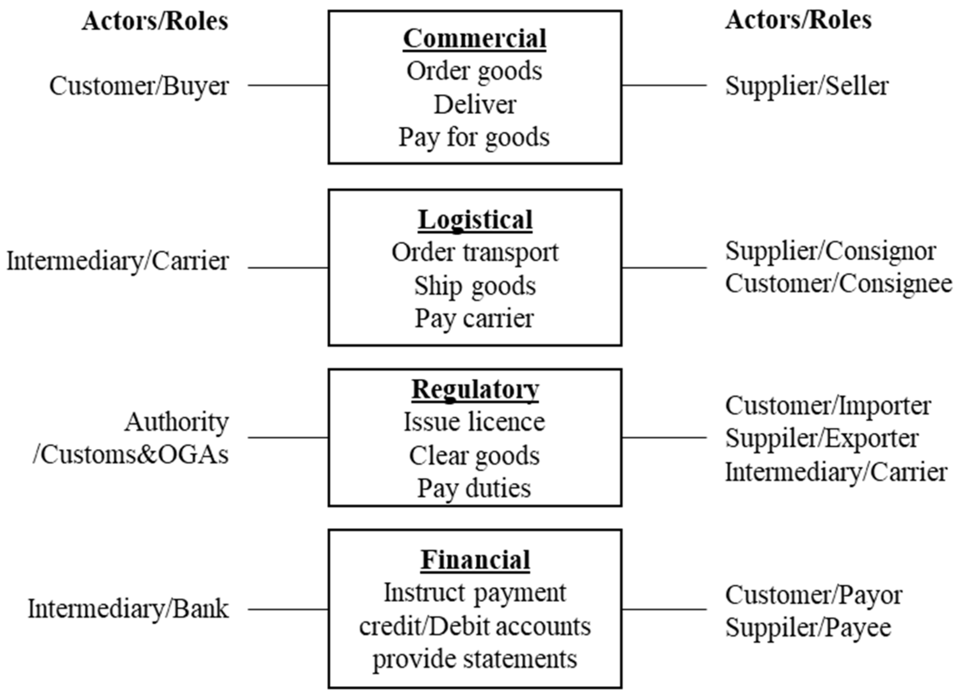

Figure 2-7 Key actors/Roles associated with the four main business areas (UN/CEFACT, 2017)

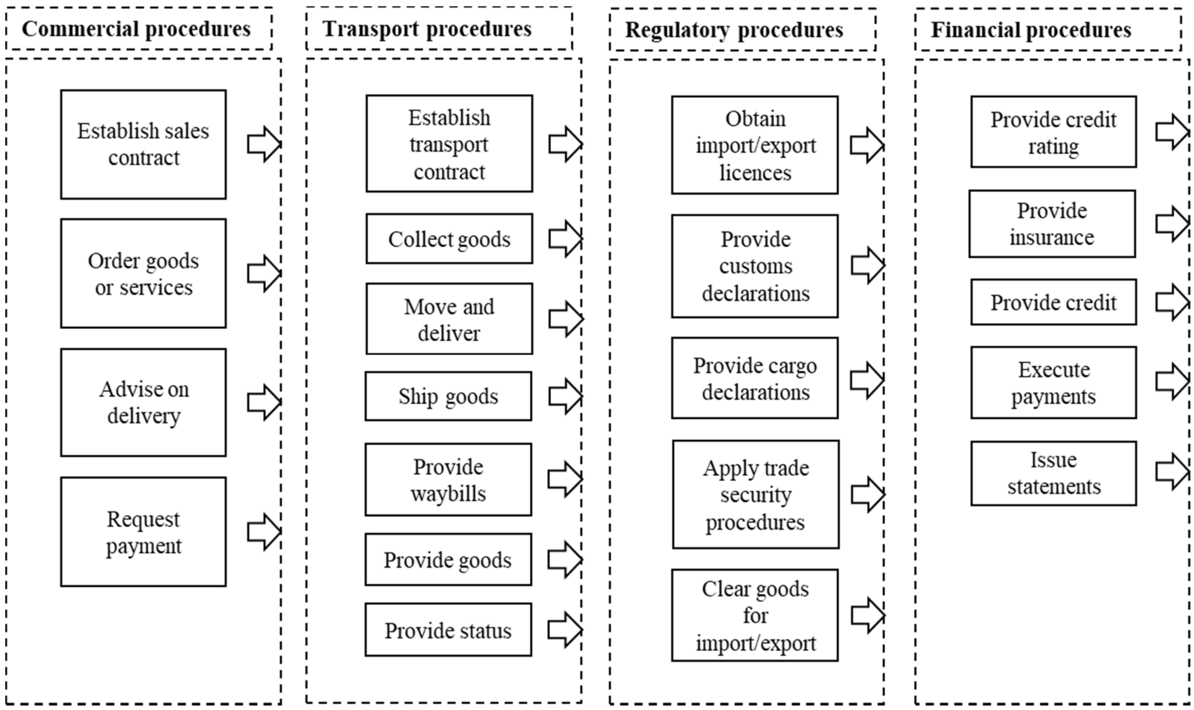

Figure 2-8 Business processes within the four business areas as defined in ISCRM (UN/CEFACT, 2019)

UN/CEFACT has been working on two Reference Data Models (RDMs) for International Supply Chain and Multi-Modal Transport separately. These two RDMs share the same base of components from the United Nations Core Component Library (UN CCL) but are used differently due to the differences in context and semantics between the international sales and transport contracts, information exchanges, and business practices. If the two RDMs are developed separately, any changes in one will require changes to the other. A higher level of RDM is needed to facilitate the use and maintenance covering the Buy-Ship-Pay (BSP) shown in Figure 2-9. The BSP-RDM has the intention to provide a unifying framework, consolidating the constituent data models by addressing any overlaps between the concepts used in their different contexts. The BSP-RDM current project aims to create an intermediate subset of the UN CCL. (UN/CEFACT, 2019)

The BSP-RDM below describes a generic reference data model and provides a framework to accommodate the requirements of:

- cross-border supply chain trade-related transactions, including government domain needs for their specific information exchanges;
- supporting the transport-related processes involved in the cross-border supply chain and covering the involved business areas at a high level, the main parties, and the information involved. (UN/CEFACT, 2019)

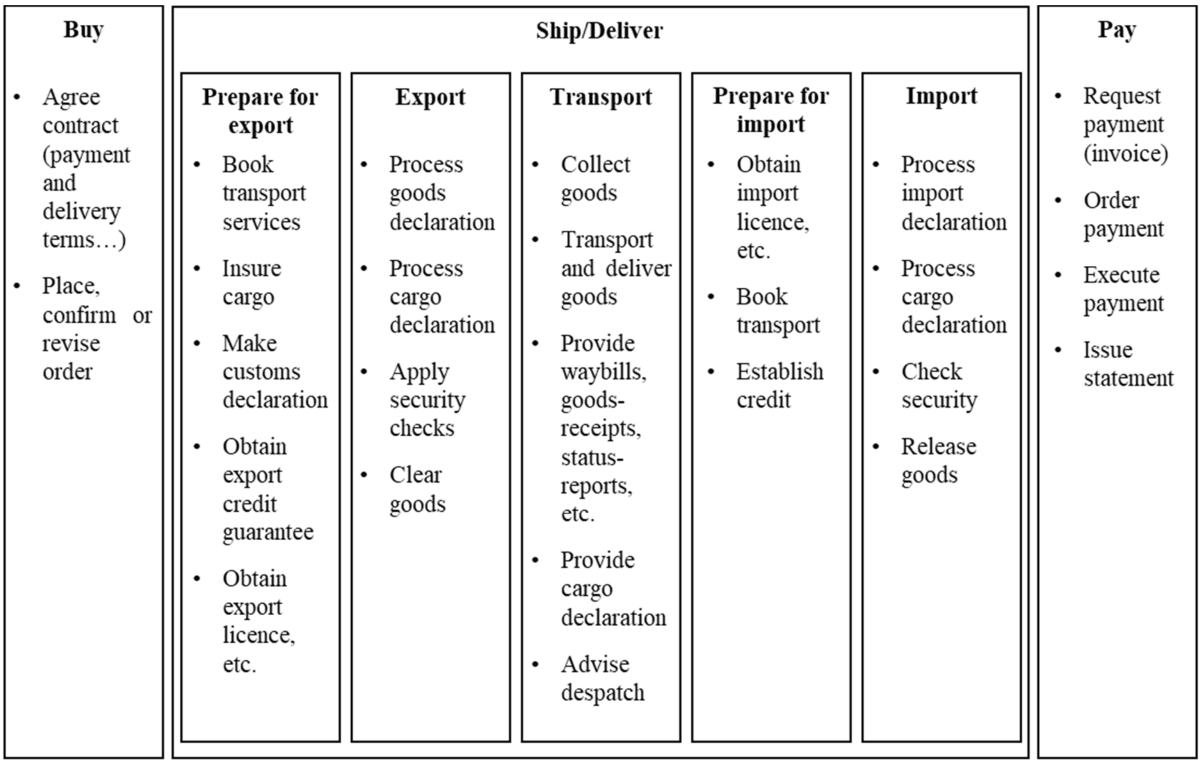

Figure 2-9 Buy-Ship-Pay model, Business processes and transactions (UN/CEFACT, 2019)

As described above, the BSP model represents commercial transport contracts, operational transport and logistics, regulatory and border clearance processes, and the corresponding information within each business area. The current project scope includes and addresses all entities related to the first three ISCRM business areas, i.e. the commercial, the logistical, and the regulatory.

The BSP-RDM project adopts a holistic approach to develop a reference data model to satisfy the data exchange requirements of international transport processes including related trade, insurance, customs, and other regulatory documentary based on trade facilitation and e-business.

2.3.2 Information Flow

Considering the four business areas in the international supply chain, the data and information that may be processed and exchanged are shown in Figure 2-10.

Commercial Processes	Logistical Processes	Regulatory Processes	Financial Processes
• Issuing of catalogues, • Issuing of quotation, • Confirmation of sales order, • Delivery scheduling, • Issuing of despatch advice and packing list, • Sales invoicing, • Remittance advice	• Booking of cargo space, • Issuing of shipping instructions, • Issuing of transport contract document (i.e. Air Waybill), • Transportation of goods, • Requesting and issuing of transport status reports, • Freight invoicing	• Import/export declarations, • Cargo and transit reports, • Cross-border regulatory data pipeline data, • Certificates of origin, • Phytosanitary certificates, • Dangerous goods declarations including Organization of Economic Cooperation and Development (OECD) hazardous waste notifications,	• Instruct payment, • Credit/debit accounting, • Statements and reporting, • Cargo insurance.

Figure 2-10 Data and information in the four processes

We mainly consider the information flow in the logistical and regulatory processes of the four business areas in the ISCRM. The interrelated business areas in maritime logistics may include commercial transport contracts, operational transport and logistics, regulatory and border clearance processes. The corresponding information is transferred and used within each business area. Figure 2-11 shows the key process area with an indication of the documentary requirements.

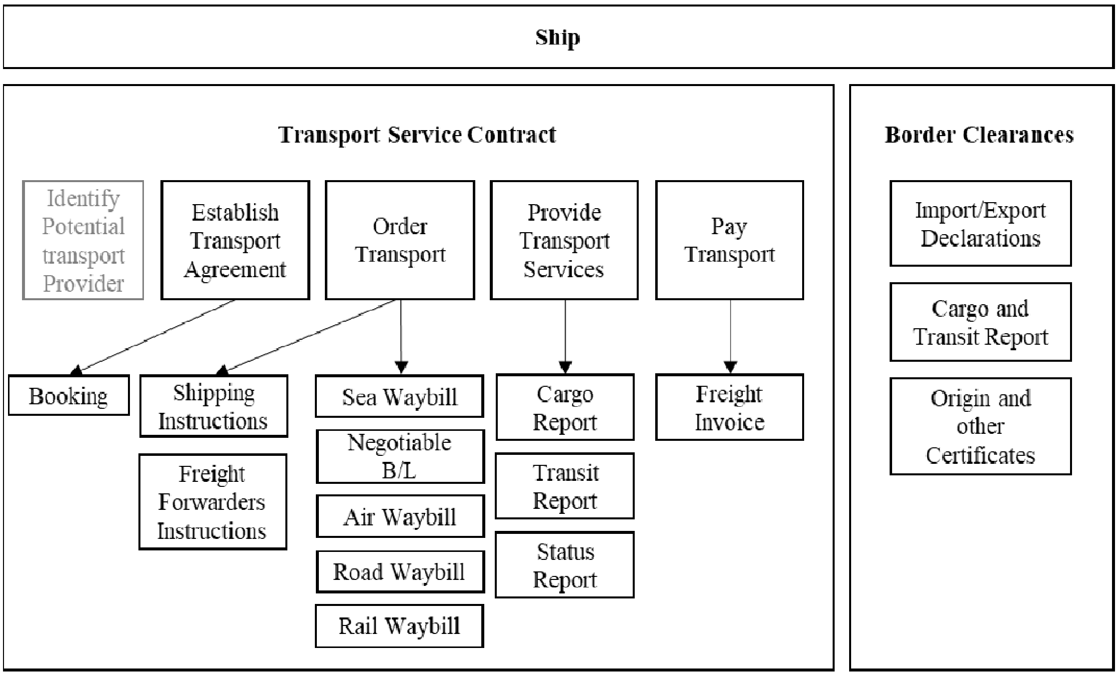

Figure 2-11 Information flow in the logistical and regulatory processes (UN/CEFACT 2018)

There should have a negotiation process among exporters and logistics service providers during the processes of establishing the transport agreement and ordering transport. Figure 2-12 presents a Business Process Execution Language (BPEL) negotiation process of maritime transportation. BPEL is an XML-based language that allows web services to operate business processes. In the figure, the last shipping agency refers to the hinterland transportation company. The process does not happen every time for a shipping request. The freight forwarder or shipping company may already have the service package as a mature transport service product. Once the necessary preliminary permits are acquired, the delivery of goods is enacted. (Bisogno et al., 2015)

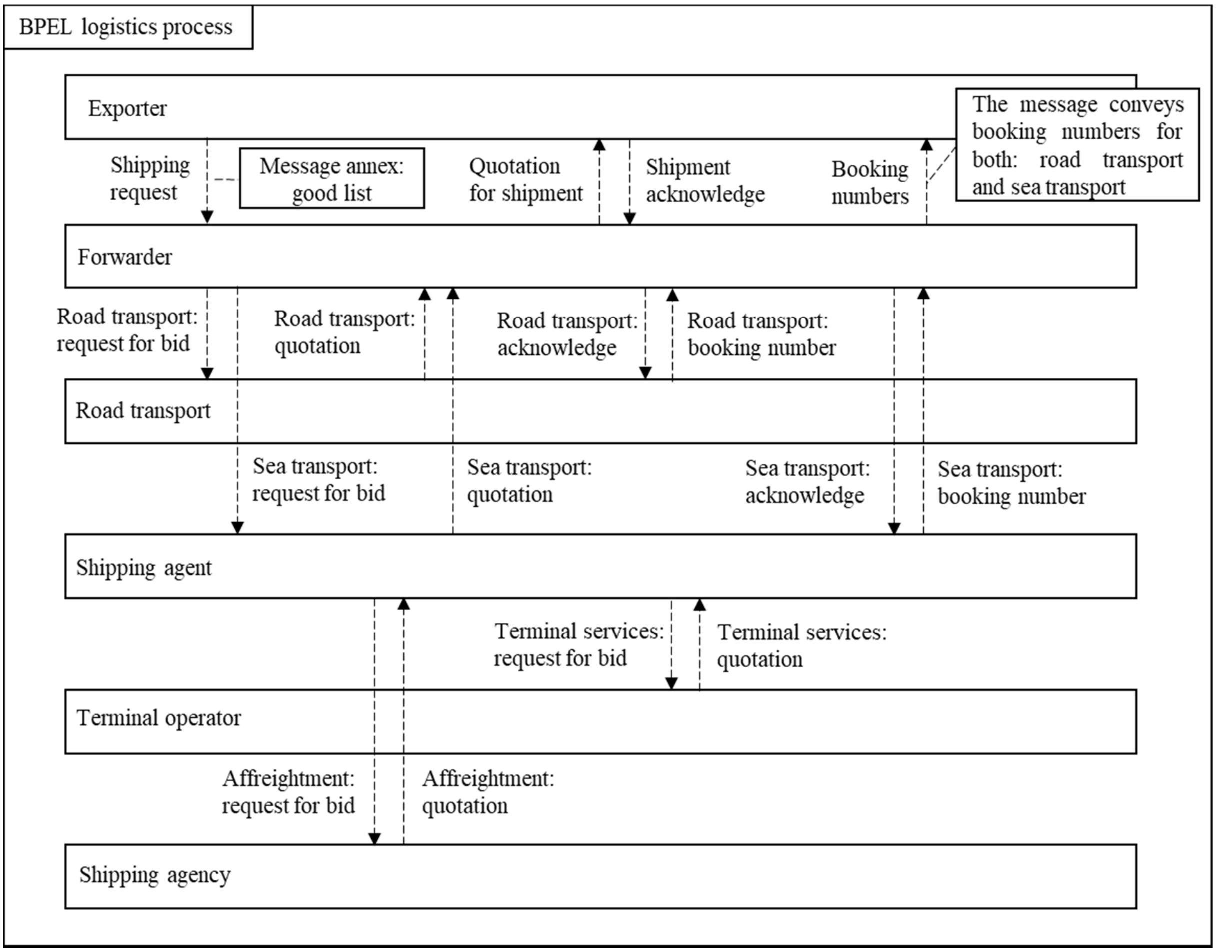

Figure 2-12 The negotiation process for the transport of goods (Bisogno et al., 2015)

The following Figure 2-13 provides the entities and the relationships between the highest-level Business Information Entities (BIEs) of the BSP-RDM considering the logistical and regulatory procedures. The diagram highlights an issue appearing in customs reporting, where data arriving by both the supply chain and the transport-related sources are not consolidated, making it difficult to cross-relate descriptions related to the same trade item. (UN/CEFACT, 2019)

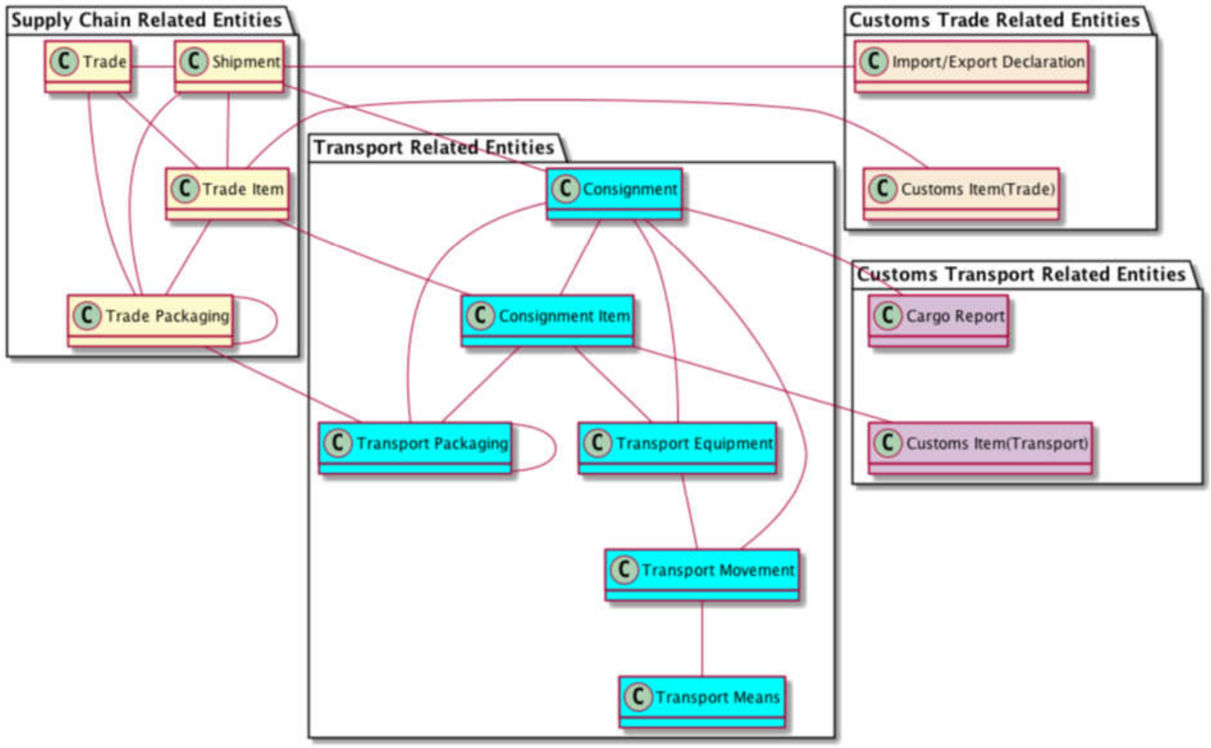

Figure 2-13 High-Level BSP-RDM (UN/CEFACT, 2019)

Since the 1960s, the Electronic Data Interchange (EDI) has been used to edit and transfer documents in the digital version. The maritime industry's specific UN/EDI-FACT standards were built in the late 1980s. Subsequently, important paper documents, like BoL, etc., were transformed into electronic documents. This change largely improves the efficiency and accuracy of handling documents. It paves the way for the first digital transformation in this industry.

Digitalization enables online markets in the maritime industry. The international shipping liners like COSCO, Maersk, MSC all build their e-business sectors on the homepages. Through the online portal, customers can check the shipping routes, schedules, and prices, and book the ships. There are also light capacity companies that have an online maritime business. INTTRA, developed in 2000, is the first e-commerce platform that is still in the leading place in this industry. This kind of company focuses on building a collaborative relationship with ports, carriers, and information technology companies. The online platforms collect container orders and provide integrated logistics schedules. Meanwhile, the positioning and tracking technologies and information systems enable the customers to search for their container transportation status.

The previous digitalization has improved the appearance and popularity of online markets and the quality of maritime logistics services. Online business reduces supplier response times to the needs and simplifies the planning stage for the offers. The suppliers can easily summary all the orders and get a scale of the freight, this then can largely use the vessel capacity. The new digitalization technologies such as cloud technology can facilitate logistics integrations and service qualities. New applications on mobile phones make customers more easily to get information. Big data and mobile applications may create new logistics services and attract customers.

The information created along international maritime transportation is mainly categorized into regulatory and logistical information. The international committee FAL deals with matters related to the facilitation of international maritime traffic, including the arrival, stay and departure of ships, persons, and cargo from ports. Since April 2019, the FAL Convention makes it mandatory for ships and ports to exchange FAL data electronically and encourages the use of the so-called ‘Single Window’ concept, in which all the many agencies and authorities involved exchange data via a single point of contact.

The FAL documents include seven documents which are IMO general declaration, cargo declaration, ship’s stores’ declaration, crew’s effects declaration, crew list, passenger list, and dangerous goods. Three additional declarations that entered into force on 1 January 2018 are security-related information, advance electronic cargo information for customs risk assessment purposes, and advanced notification form for waste delivery to port reception facilities. These documents are the recommendation for public authorities about the maximum information and the number of copies that should be required.

According to the business process, Figure 2-14 mainly presents the transfer of the BoL and other documents among different maritime actors. It is a developing area to use web-based technologies or Intelligent Transport Systems (ITSs) to reduce repetition and mistakes of information and to integrate and share information.

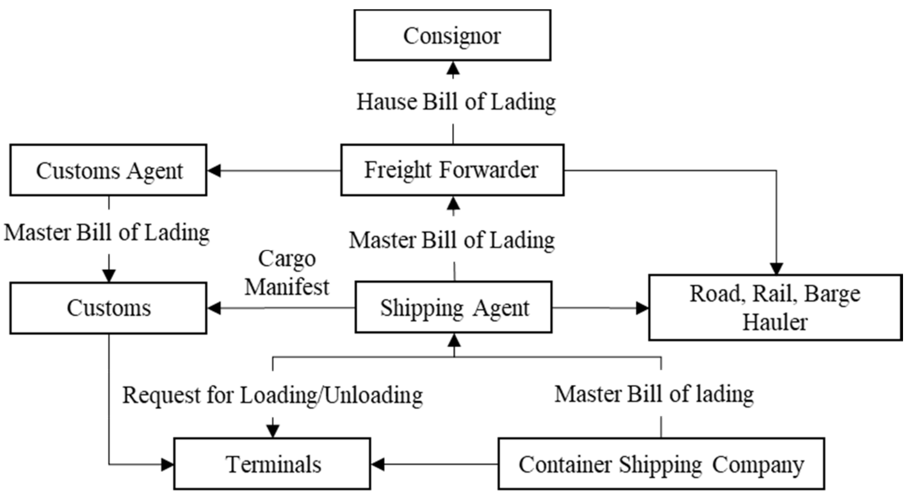

Figure 2-14 Information of port users considering logistics

From above, we can see that documents are transferred in a bilateral way to support the business, customs, and logistics processes in international trade and transportation. Here is only an example mainly for the transfer of BoL. A large number of other documents are also needed in cross-border trade based on international and different countries' regulatory regulations. The information is repeatedly required by different authorities such as container information. The use of ICTs is an effective way to transfer documents and share information.

PCSs operated by port authorities play an important role to improve information flow. The Hamburg port cooperates with Dakosy to develop its Port Community System. The system is used by forwarders, shipping companies, inland transport companies, customs, etc. Dakosy also provides an Import Message Platform (IMP) which consisted of a central data pool collecting and providing information about flows of goods into the port and forwarding information of these containers from the port. Transatlantic carriers file their customs declarations on the IMP which can then be retrieved by customs and where the appropriate assessments and information on their statuses can be filed. In this way, the port container terminals are informed of the containers' customs status, the arrival time, and the information about inland transport. Trucks, trains, and feeder shipping which are loaded or unloaded at the container terminals receive their transportation orders based on this data.

Ports play an important role as a network hub for the Single Window concept in cross-border trade with maritime shipping. Traffic centers may be built by ports to control river-, rail-, and road-bound traffic. They can plan traffic capacities by integrating and sharing information about containers. Ports need to handle incoming and outgoing traffic, as well as the length of time vessels park and the number of parking spaces. Some ports build the inland port as container transfer points outside the port to extend the capacity of ports and facilitate hinterland transportation.

A general model of the Smart Tunnel project is shown in Figure 2-15, which aims to sustain the chain of port logistics and road transport of goods through the integration of IT technologies and innovative communication systems. The platform enables the actors, i.e. freight forwarders, road transport companies, shipping agents, terminal operators, shipping companies, to share data and information, thus improving the performance of administrative processes, process coordination, and role collaboration (Bisogno et al., 2015).

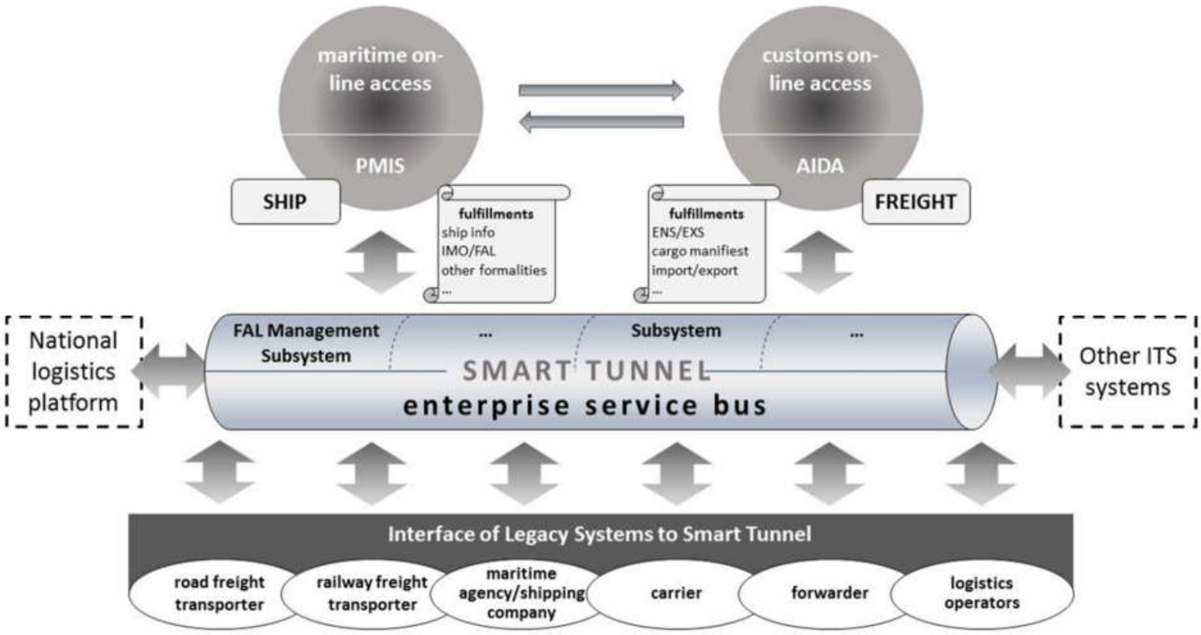

Figure 2-15 The architecture of the Smart Tunnel project (Bisogno et al., 2015).

2.4 Basic Knowledge about Maritime Digitalization

2.4.1 Definition

Digitization, digital transformation, and digitalization are becoming common terms in the research as well as the business area and social life. They are closely related but also have slight differences. Digitization is the process of changing from an analog to a digital format, whereas digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities, that is, the process of entering a digital business (Sanchez et al., 2019). It often means converting diverse forms of information, such as an object, text, sound, image, or voice to a single binary code. Digitization is the framework for digitalization, which is defined as the exploitation of digital opportunities. Digitalization is the process of applying ICTs to operations and business. Digitalization means to employ combining different digital technologies (e.g. cloud technologies, sensors, big data, 3D printing) to open unforeseen possibilities and to offer the potential to create radically new products, services, and business models. Digital transformation is defined as the process that is used to restructure economies and institutions, and society on a system and level (Rachinger et al., 2019).

2.4.2 Motivation

The motivations of digitalization within the maritime industry are concluded as: (1) to save costs and improve process efficiency; (2) to enhance customer satisfaction and company competitiveness; (3) to help following the strict regulations and improve safety; (4) to improve information flow; (5) to improve integration in the transport chain and supply chain performances; and (6) to protect the environment.

Take an example of the air transport industry, the role of cost-saving is a key driver behind the digitalization of airport ground operations. The ground handling agents are deploying new technologies mainly to boost process efficiency and to cut costs. New technologies, such as cloud, mobile, big data, smart sensors, and IoT, directly affect the core business processes and supporting processes of airport ground operations (Kovynyov et al., 2019). It parallels port operators that use digital technologies to improve efficiency and save costs for operations in terminals and port areas. Ports are developed with semi-automated or fully-automated container terminals. The realization of automation attributes to the technologies. For other actors, such as freight forwarders, shipping agents and companies, port authority, etc., the ICTs save time and costs for handling documentary processes. As container shipping networks are important components in global supply chains, route design should consider both maritime and inland factors to work out an optimal shipping route. For this demand, ICT can be used to minimize the total costs concerning ship costs, port costs, inland transport costs, inventory costs, and CO_2 costs (Tran et al., 2017).

Customer satisfaction is an important aspect to evaluate companies' management and operation. High satisfaction increases the loyalty of customers and attracts more potential markets. According to a survey in the container shipping industry, the top three service characteristics that influencing customer satisfaction are the quality of customer service representative, quality of digitalization, and quality of sales representative in decreasing order. However, among the three aspects, digitalization tops the liner shipping managers' agenda. The previous advantage, the ability to offer long-term rates, is not as effective in enhancing customer satisfaction as it is usually perceived (Hirata et al., 2019). A sample of 938 companies and multivariate statistical analysis show that entrepreneurs' and managers' profiles and these leaders' adoption of new digital processes contribute to these companies' greater competitiveness (Ferreira et al., 2019).

ICT itself has advantages to apply in business. It helps regulators to increase knowledge and exercise their authority in a more directed manner. For instance, ships in the international passage have for centuries been operating outside the reach of national regulations. Regulators have challenges and dilemmas to improve safety in this situation. Digitalization and international collaboration improve the management of this problem (Almklov et al., 2018). Information technology provides solutions to follow the regulations. For example, the regulation Verified Gross Mass (VGM) is facilitated by ICT to take into action. VGM was introduced in 2014 and came into effect on 1 July 2016 by the IMO to guarantee maritime safety. VGM is the shipping container's total weight, including its contents measured using the equipment that meets the applicable accuracy standards and requirements of the State. It has to be declared in the BoL and submitted to the terminal operator. The structuration of port communities through a strong digitalization of data exchange, such as the PCS, made easier the transition and compliance towards this regulation. It illustrates that PCS has a positive influence on the adoption of mandatory regulation (Fedi et al., 2019). In maritime supply chains, measures are taken to mitigate different security risks. Future managers for security in supply chains need to be trained to select appropriate measures on different security-related risks, as well as use ICTs to improve security (Müller et al., 2018).

Another motivation is to improve information flow in logistical and regulatory procedures. In the maritime industry, the low interconnection of information technologies was evident. Basic local navigational information was dispersed, sometimes conflicting or inaccessible. These increased uncertainties and complicates for ship-based and shore-based actors to make decisions. The projects like EfficienSea2, under the e-Navigation strategy approved by IMO, have focused on improving information exchange, safety, and efficiency of navigation. New e-Navigation solutions may not only alter work processes but also the organization of the maritime network. (Costa et al., 2018).

Digital technology is also beneficial to improve an integrated transport chain and supply chain performances. Sea transport needs to be integrated into a larger transport chain to reach its full effects. Digitalization could enable door-to-door processes, seamless integration, and multi-modal integration. The concept of Sea Traffic Management (STM) is introduced as a way to enable integration by an increased degree of digitalization (Haraldson et al., 2015). It can enhance supply chain performance for shipping companies (Feibert et al., 2018). A project named ECORADAR is achieved by ICTs to provide an innovative Internet portal to over 80 German enterprises and institutions as instruments for sustainable business management. The ecoradar-community can develop, share and use the available knowledge by using the tools of knowledge management and concentrate on the field of energy management and climate protection instruments (Kreeb et al., 2017).

Despite the benefits to apply ICT in their business and administration management, there are also barriers to digital innovation: (1) the low-cost orientation in this industry; (2) the current limited and slow internet speed; (3) the current low level of digital diffusion within the supply chain; (4) the current reluctance to invest and a certain disinclination to risk-taking; (5) the reluctance to innovation leadership; (6) the old-fashioned, non-pioneering culture and conservative senior decision-makers; and (7) the engineering and installation technology-oriented culture with a low focus on efficient business processes. These all appear to be barriers to digital innovation within the maritime offshore industry. (Gausdal et al., 2018)

2.4.3 Digitalization on Logistical Process

2.4.3.1 Ship-related

Digitalization has influences on design and shipbuilding, vessel operations, onboard systems, people onboard, voyage planning and navigation, and autonomous shipping.

Digital technologies improve shipbuilding. For example, the hull-plate forming process can be better finished by the multi-point digital method instead of handwork in shipbuilding. The method can be been used in the bending process of the hull plate, which improves the digitalization of hull construction (Zhang et al., 2018). Another example is the ship power system design. With digitalization, the onboard systems of marine vessels are available for data analysis. To extract valuable information from the analysis, it can reveal the real power demand and learn about the rarely occurring high power demand situation. This is critical for power system design and optimization. It can facilitate the selection of the optimal size, number, and configuration of generators or batteries when designing a new power system on vessels (Swider et al., 2018). Robotics, AI, Virtual Reality (VR), IoT and Cloud, and 3D printing and Additive Engineering have also been used to build autonomous unmanned vessels (Sanchez-Gonzalez et al., 2019).

Digitalization works on onboard operations, systems, and people. In today’s shipping industry, issues like energy efficiency, condition-based maintenance, and asset management are increasingly gaining the attention of ship owners and operators. Monitoring and benchmarking are two methods for handling these issues. On the monitoring side, the evolution of smart sensors and data acquisition systems, along with advanced telecommunications for transferring data provides a solid basis for the primary source of information needed. For the benchmarking side, detailed mathematical simulation models, Big Data, and machine learning techniques allow the production of all needed benchmarking sets of data. From above, digitalization brings real value to onboard operations and management (Theodossopoulos et al., 2018). Efficient data collection and analysis can be used to improve operations. Digitalization enables onboard monitoring systems of marine vessels available for data analysis. Data-driven techniques can be utilized for establishing finer resolution vessel tasks. It helps to find vessel operational modes based on available signals involving machine learning techniques (Swider et al., 2018). IoT is applied to render marine environmental monitoring in the politically contested Arctic. Sensors capture an expanding richness of physical objects, qualities, and processes and can feed real-time streams that make IoT rendered digital representations 'real' (Monteiro et al., 2019). This technology can also be applied in vessel operations.

Digitalization of ship operation will affect the people and the organized work onboard. Command of vessels has been as a human domain. Digitalization realizes the automated vessels thus influence the leadership. Human-automation coordination and human-human coordination are the keys to support future ship operations. A master is a leader and there will be other shore-based human operators and/or high-tech machines. A kind of co-management of ship and container operation between ship and shore may be a way forward. (Kitada et al., 2019)

The future ship may be autonomous vehicles. Future vessels will be facilitated by the modern technology, IoT, to collect various ship performance and navigation information. Such information is collected as large-scale data sets and formed as the so-called Big Data. Data-driven models, the so-called digital models are proposed, which can be derived from ship performance and navigation data sets by considering the high-dimensional parameter (Fedi et al., 2019).

Finland is set to take the lead in developing maritime digitalization and autonomous shipping. The government started maritime digitalization programs in two ways: by increasing the Finnish Transport Agency (FTA) services' operational efficiency or by creating new software applications, digital services, and value-added services for customers. The maritime affairs managed by FTA are Vessel Traffic Service (VTS) and waterway infrastructure service. The VTS centers inform ships of the traffic situation, the conditions of waterways and safety devices, severe weather and ice conditions, and other issues concerning the safety of navigation and following situations in the area in real-time. Waterway infrastructure services concern cartography, the safety of waterborne traffic, aids to maritime navigation, and waterway markings and maintenance. The digital transformation rests on transparency efforts by the Finnish government, characterized by participatory democracy and co-creation of services in the public sector. Two forms of transparency-driven innovation took place during 2016–2018 as part of the waterway digitalization initiative by the FTA: 'Open Data Innovation' as opening up government processes and data and 'Open Door Innovation' approach as transforming service delivery. The innovations aim to improve information disclosure, clarity, and accuracy, thus contribute to maritime safety, transport and service efficiency, environmentally sustainable development, and reduction in traffic emissions. The maritime affairs consist of VTS and waterway infrastructure service. However, unintended consequences occurred in the later stages of the digitalization phase due to the lack of interest from businesses and the greater public. Consequently, researchers conclude with lessons learned and share recommendations for government to succeed in digitalizing one of the most conservative industries. The results are not as good as expected. It brought up also the low quality of user ideas (excessive use of similar datasets leading to numerous similar apps). They pointed out the problems that innovating through open data required at least a basic skill set of maritime-specific knowledge and familiarity with definitions, something that was traditionally present among software developers. Other types of skills such as advanced software knowledge in geographical information systems, machine learning, and computer vision became obvious shortages in the open door innovation community. Another obstacle is the traditional maritime culture placed safety first into the equation of potential benefits. (Meskauskiene et al., 2019)

The digitalization on seafarer's book, embedded with a Radio-Frequency Identification (RFID) chip containing the personal and biometric information of a holder and a communication antenna, helps maritime police to manage the crews and is useful for e-Navigation. A system can be constructed to track seafarer's books based on Bluetooth 4.2 or 5 and BLE beacon-based positioning technology. It is the possibility of embedding the functions of the e-Navigation system. (Huh et al., 2019)

The digital models are proposed to handle the big data sets from ship performance and navigation. The models can be used for weather routing type applications in shipping (Perera et al., 2020). A maritime service website prototype named BalticWeb was intended as an aid to existing standard systems and methodologies for planning, executing, and monitoring voyages. The website provides navigational services, like maritime safety information (notices to mariners and navigation warnings), route optimization, informing the no-go areas (safety contours), and administrative service (automated Vessel Traffic Service Reporting/Ship Reporting System). Data analysis suggested that the prototype could be more suitable for a route planning stage, that the participants were familiar with similar existing solutions from other manufacturers, and that the contents of the tool would be most beneficial if integrated within the Electronic Chart Display and Information Systems (ECDISs). The website services were tested for a given route planning and navigation exercise and scenario. The results showed that the participants fear that systems and information sources are instead becoming too many and too spread out. Nevertheless, the implementation of new e-Navigation solutions in the maritime industry will have an impact on human decision-making and behavioral processes on the bridge, ship and shore stakeholder roles, and communication networks. For instance, the Vessel Traffic Services might gain capability in their role or some ways become redundant in the current way of assisting and coordinating ships from ashore. There is a need to simplify and bring the new and existing solutions together towards a one-model-fits-all that considers the human element. (Costa et al., 2018)

Proactive information service has become increasingly important in the maritime Intelligent Traffic System (ITS). Trajectory prediction is one of the kernel problems that must be addressed to realize proactive information service. An intelligent model was proposed to solve the issue of the trajectory prediction of vessels. The model is based on data mining and machine learning methods. Data mining is to cluster the historical trajectories of vessels and represents the distribution patterns of these trajectories. Machine learning is used to train the classifiers which define the pattern of the new trajectory which must be predicted. This model promotes the development of a maritime ITS. (Qi et al., 2016)

Sea traffic management (STM), one of the EU's largest e-Navigation projects, allows ships to share their monitored route with other ships, planned and/or monitored routes with shore centers, and received suggested routes from shore centers. These tools also allow ships to receive navigational warnings, vessels' expected time of arrival (ETA) updates, and chat messages from shore center services. The European Maritime Simulator Network (EMSN), consisting of twelve ship handling simulators based in seven EU countries, examines the potential impact of these services through full-scale simulations with scenarios involving up to 30 ships. The results indicate that the seafarers are positive about the idea of e-Navigation services, and believe that these services could provide additional time to plan, act, and respond to a navigational challenge. However, there were concerns related to their implementation, and the potential negative effect of digitization of current navigational processes which may lead to an increased risk for incidents related to situation awareness, miscommunication, and human error. (Aylward et al., 2018)

2.4.3.2 Port-related

Leonard Heilig et al. analyzed the digital transformation in the history and future of modern ports. They differentiate three main generations in the development of digital transformation in seaports: paperless procedures (IT), automated procedures (depend on IT/IS in container terminals), and smart procedures which are summarized and presented in Figure 2-16, 2-17, and 2-18. (Heilig, 2017)

The first digitalization is accompanying by containerization. The main technologies and their applications are EDI, PCS, and Terminal Operating System (TOS). This generation mainly supports international business and port operations. PCS provides an efficient platform for inter-organizational operations.

The second generation is to further improve terminal operations. Meanwhile, e-commerce is taken into action. The inter-organizational platforms are developed into a single-window system which is more convenient for the users. And there are technologies to improve ship navigation that enhance the safety and security of maritime shipping. The main technologies of this period are laser technology, VTS, AIS, Terminal Operation System (TAS), and RFID. These technologies improve the function of sensors which is helpful to develop automation. Data are more accurate and then the responsiveness is enhanced.

Now, it is undergoing the third generation. Customers demand to enhance to provide more value-added services. It also has to take information on the overall port level as well as considering information flows between different ports. The next step is to fix more sensors on the facilities to realize the real-time monitor and extend the business scope to an information integrator and provider.

Events	Containerization led to high requirements on efficient cargo and information flows to succeed in the new role of ports as integrated transportation systems and logistics hubs, which had to be supported by huge investments into infrastructure, superstructure, and equipment.
IT/IS	e.g., EDI, PCS, UN/EDIFACT standards, TOS.
Scope	• *Level 1*: Support of individual activities by implementing basic, usually off-the-shelf, and isolated IT functionality (e.g., booking, invoicing, accounting); creation of basic conditions for supporting inter-organizational information exchange using EDI standards. • *Level 2*: Integrated view on core business processes within terminals by developing TOS; integration of data sources necessary for supporting collaboration with external actors. • *Level 3*: Integration enables planning, management, and coordination of interdependent activities within the terminal. • *Level 4*: Paperless interactions between interacting actors in inter-organizational business processes
Impact	• Digitalization established the foundation for efficient terminal operations and automation as well as to expand the traditional business, such as by introducing new VAL. • Inter-organizational platforms in form of PCSs reduced paper-based processing, but are highly dependent on the port community's willingness to adequately participate; however, in their current form, they are limited to a passive exchange of static documents rather than supporting active interactions among actors.

Figure 2-16 Summary of the first generation of digital transformation (1980s) (Heilig, 2017)

Events	• Digitalization enabled a high degree of automation in terminal operations (e.g., ECT Delta Terminal in Maasvlakte Rotterdam, Netherlands, in 1993; CTA Container Terminal Altenwerder in the Port of Hamburg, Germany, in 2002). • First global strategic liner shipping alliances are formed in the mid 1990s. • For the first time the continuous growth in container shipping seemed to reach the limits of some major ports leading to severe traffic problems and environmental impacts in the mid 1990s. • Growing interest in e-commerce systems in the late 1990s. • Increasing demand for single-window systems in the mid 2000s. • Global economic crisis of 2008-2009 led to a more stringent evaluation and selection of ports.
IT/IS	e.g., Laser, VTS, AIS, TAS, RFID
Scope	• *Level 1:* Adoption of new handling technologies equipped with sensors and laser technologies; adoption of automatic identification technologies, for example, to accelerate authorization checks. • *Level 2:* Integration of automated equipment control software with TOS; integration of external systems, for example, to manage terminal appointments. • *Level 3:* Automation of certain processes required a complete redesign of organizational structures, policies, and business process activities as well as an efficient information management. • *Level 4:* Establishment of e-marketplaces supporting trade and collaboration in the maritime industry; port-centric coordination of truck drayage operations using TAS to mitigate traffic and environmental problems. • *Level 5:* Global alliances required a harmonization of services and IT/IS integration
Impact	• After focusing on increasing the efficiency of terminals through automation, measures for improving cargo flows within ports become increasingly important due to increasing vessel sizes and concomitant peak cargo volumes. • Port-centric platforms, like TAS, have an impact on the decision making of actors (e.g., drayage companies). • Limitations of static information are still experienced; a higher visibility and different forms of decision support based on accurate data become increasingly important to enhance responsiveness during operations.

Figure 2-17 Summary of the second generation of digital transformation (1990s – 2000s) (Heilig, 2017)

Events	• Current trends and emerging technologies in the IT sector foster an improved gathering, storing, processing, and analysis of various and large data sources. • Port-centric decision support has become essential to address inefficiencies and bottlenecks on the overall port level. • Customers increasingly demand value-added information services to get a better insight into related processes. • Information flows between different ports become increasingly important for establishing successful partnerships
IT/IS	e.g., Mobile Technologies, Sensors/Actuators, Cloud Computing, Distributed Computing/Processing, Machine Learning.
Scope	• *Level 1*: Equipping physical infrastructure and actors with sensors, actuators, and apps. • *Level 2*: Integration of real-time data sources, actuators, and external information services. • *Level 3*: Improved exploitation of available (real-time) data sources to improve responsiveness and decision making during process execution require more granular process definitions. • *Level 4*: Realization of an ongoing interaction with involved actors and controllable physical port infrastructure. • *Level 5*: Ports increasingly extend their traditional scope by acting as a port information integrator and provider.
Impact	• Shift towards port-centric decision support leads to a shift of process control from individual actors to central entities (e.g., port authority, third-party provider) requesting actors to partly give away control and follow instructions. • May facilitate just-in-time and agile logistics by a better coordination and responsiveness to changes/errors based on different sources of actual data and data-driven decision support solutions.

Figure 2-18 Summary of the third generation of digital transformation (2010s – today) (Heilig, 2017)

The port infrastructure is the base for port operations to serve the vessel, containers, and passengers that pass through ports. Cutting-edge adaptive secure communication and IT architecture (real-time information, etc.) will be introduced to the benefit of strategic traffic and port management and ship-assist infrastructure such as smart berth, towage, mooring, bunkering, etc. Port is oriented to develop as an integrated hub for ocean shipping and hinterland transportation (Waterborne, 2021). Port is developed to handle autonomous ships and implement autonomous operations (Sanchez-Gonzalez et al, 2019).

For the autonomous operations in ports, Automated Guided Vehicles (AGVs) are introduced as unmanned, software-controlled container transporters that link the quay with a yard. AGV systems have reached an age of maturity that allows for their utilization towards tackling dynamic market conditions and aligning supply chain management focus with sustainability considerations. The present study provides a critical taxonomy of key decisions for facilitating the adoption of AGV systems into supply chain design and planning, as these are mapped on the relevant strategic, tactical, and operational levels of the natural hierarchy. A Sustainable Supply Chain Cube was proposed to integrate sustainable supply chain management with the proposed hierarchical decision-making framework for AGVs. There is a lack of research on AGV's exploitation across the entire spectrum of supply chain operations, but rather automated systems are mainly used in the logistics operations focusing on warehouse management and distribution and the manufacturing division. Port authorities undoubtedly constitute the main stakeholder to have realized the exploitation of AGVs, several other sectors that share common operational characteristics, like logistics/dispatching/scheduling/planning issues, are now recognizing the potential of automated systems in their supply chains. (Bechtsis et al., 2017)

The ICTs in ports also need to upgrade to more functions. Some of the requirements come from international regulations. The Verified Gross Mass (VGM) mandate from November 2014 by the International Maritime Organization on the container create increasing pressure on port logistics. IT systems, like PCS, support the successful adoption and support of the VGM regulation. Three variables, e.g. communication channels, compatibility, and infrastructure, are considered to use the Diffusion of Innovation method to explain the influence of information technology on VGM implementation. The essence of the diffusion process is the information exchange through which one individual communicates a new idea to one or several others. The nature of the information exchange relationship between a pair of individuals determines both the conditions under which a source will or will not transmit the innovation to the receiver and the effect of the transfer. Rating communication channels in the VGM implementation, IT systems, especially PCS, are an important link in the supply chain because they tie different actors as a community. Compatibility is the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters. Regarding compatibility in the VGM, PCS is seen by actors as a facilitator since it is already in place and therefore compatible with the operations. For the infrastructure factor, adoption of innovation is often depending on the presence of some sort of infrastructure. Adapting IT infrastructure is key for the IT implementation success of VGM. PCSs are especially seen as a prerequisite for the implementation of VGM. The factors of communication channels, compatibility, and infrastructure show a positive impact on VGM adoption through PCS. Numerous seaports upgraded their PCS functionalities by incorporating a VGM module or portal to streamline and quicken the process of communication between stakeholders. (Fedi et al., 2019)

Open data, open innovation, and digitalization are often treated together. Each port develops and promotes digitalization based on its internal need. The digitalization effort, in which open-data progression belongs, requires frictionless collaboration between organizations of the port community. This requires a change for ports from providing only physical infrastructures in material transportation towards digitalized management of logistics data that could be opened to the desired extent. Data-transfer automation benefits port community members through easier means of acquiring data. Open data is either static or dynamic data. The static road and rail data is currently the most potential alternative for open data in ports because these data resources are already at least partly published. Besides, technical requirements for static data are much less demanding compared to real-time data-processing and management. Static data requires updating by the data provider frequently. The dynamic data in maritime information systems may include operative security deviances and other active sea warnings, vessel arrival/departure times, vessel location data, and vessel and port description data. The updating of dynamic data requires automation in the data-processing and data monitoring. Maritime traffic and port operations require constant information on weather and the environment. The most important and significant data for ports and vessels is the real-time location data. AIS is the current standard for obtaining this data. The distinction between “fully open data” and “partially open data” is needed to be considered in the future manuals and guides prepared for port communities. The most suitable data for full opening includes storages related to port transport infrastructure. At the moment the governance of open data is based on EU directives, principal decisions, and programs. The largest European ports are focusing strongly on data collection (from) and exchange (between) organizations and stakeholders within the supply chain. Continuous data flow is one of the key aspects in future digitalization as real-time transport. There are seven key technologies for digitalization at ports: (1) the analysis of Big Data; (2) automation and robotics; (3) cyber-security; (4) Internet of Thing (IoT) and sensor networks; (5) cloud computing and services; (6) mobile services; and (7) social media. In the survey of Finland ports, mobile services and cyber-security are considered as the most important development areas in the upcoming years. There are also three arguments hindering the progress of digitalization in ports: (1) first-ranking is a multitude of data sources and the lack of interoperability, e.g. technological fragmentation; (2) second-ranking is segmentation and silos of operations that are not communicating well enough, e.g. traditional working culture; and (3) third-ranking is slow legislation and regulation of security and environment, e.g. authorities and responsibilities. (Inkinen et al., 2019).

The multi-objective achieved simulated annealing approach is presented to address the multi-objective inter-terminal truck routing problem. It helps to solve the severe traffic problems in urban port areas associated with negative effects on both efficiency and pollution. The algorithm is embedded in a cloud-based decision support system to consider contextual data, including traffic data and the current positions of trucks (Heilig et al., 2017). A framework for simulating container repositioning and vehicle congestion is proposed to evaluate the yard crane productivity rate, amount of repositioning, and service time of a real-world port terminal. The analysis shows the container terminal operates more efficiently under the storage policy with a bay as a subblock setting (Fibrianto et al., 2020).

Analytics-driven improvements are enabled in the port transportation processes efficiency by streamlining the related information flow, i.e., by attaining shorter time frames of the information and document sharing among the export stakeholders. The implementation of information systems has enabled data collection from heterogeneous sources to feed business analytics. Process Mining (PM) was applied to a seven-month dataset from the freight export process. It identified four process inefficiencies and an issue that can jeopardize the reliability of the time performance measurements. The four processes are (1) inefficient BoL process due to the coordination issues between freight forwarders and their customers, (2) human errors in BoL's data entry, (3) inefficient BoL process, and (4) human errors in BoL's data entry and in managing the information flow. A draft of solutions was proposed as well. PM focuses on the port information flow to enhance the overall export time length, improve the vessels' turnover, reduce the corresponding operational costs, and support the potential re-design of performance indicators in process control and monitoring. The current digitalization trend and the wider data availability in port contexts strengthen the capabilities of the analytics, which can be exploited for deep and partly automatable analyses of process data. (Zerbino et al., 2019)

Information technologies can compensate physical constraints of ports like inadequate infrastructure, capacity bottlenecks, accessibility issues, environmental problems, and port operations like vessel scheduling, berth allocation, and yard planning. Multiple enabling technologies are applied in an integrated chain of logistics activities by considering several scenarios. While logistics nodes in the port facing issues concerning efficient resource allocation due to a lack of actual data, trucking companies might miss the opportunity to better utilize resources by considering potential waiting times at logistics nodes. A decision support system can be designed to inform logistics nodes and trucking companies about the forecasted truck arrival times and truck gate waiting times. Machine learning techniques are used to better utilize available sources of information for optimizing port operations, especially in a time where the amount of available data is continuously growing. ITs can be used to improve container identification and gate processes (e.g. terminal gate). The developed simulated annealing algorithm is incorporated into a web-based decision support system that processes and illustrates results using various forms of visualization including different graph representations. (Heilig et al., 2017)

Croatian container seaports have tried to simplify business processes. The Ministry of the Sea, Transport and Infrastructure has recognized the importance of digitalization and stakeholder connectivity among shippers, freight forwarders, maritime agents, etc. Consequently, concrete measures are taken to achieve digitalization and connectivity. For the researchers, the first step to transform Croatian seaports into smart ports is to develop both the PCSs and the National Single Window. The second step is to introduce smart technologies that result in benefits e.g., accelerated container manipulation. Connect multiple individual systems to a single interconnected platform that integrates data from sources such as sensors, mobile devices, and databases of different seaport stakeholders. The wireless network should connect terminal operations, warehousing, logistics, yard, and port transportation. A smart port can ultimately be a fully automated port where all devices are connected by a so-called IoT. It shifts port business to become a service provider and focuses on the connection of all stakeholders who contribute to seaport operations (Jovic et al., 2019). Smart port technology includes a variety of digital services, which consist of built-in sensors, truck pre-order systems, and platforms for data exchange (Delenclos et al., 2018).

The concept of Smart Ports aims to adopt modern information technologies to enable better planning and management within and between ports. Strong facilitators of digitalization promote information sharing and better coordination and collection. A transformation of intra- and inter-organizational activities are fostered by the use of innovative digital technologies. Previous developments have led to a high degree of digitalization and automation in port operations, it is particularly important to get a better integration of existing information systems and data sources as well as more intelligent use of data. The interfaces between seaside, terminal and landside operations are key points to improve better coordination. New digital technologies, e.g., using real-time to identify current potentials and barriers, can be used in advanced planning and decision support systems. Managerial and cultural challenges of the digital transformation, as well as a societal consideration that humans need to be trained to use digital technologies, may bring new problems. A lack of understanding about individual benefits may also lead to a failure of digitalization projects. Considering cooperative game theory, a digital platform and mobile application for organizing inter-terminal drayage operations in ports are provided, to plan and coordinate inter-terminal container transports using the real-time position of individual trucks and respective traffic prediction. However, the collaboration requires scientific support to motivate and convince different drayage operators to cooperate. The success of digital transformation lies not only in the adoption of modern technologies and advanced methods but especially in the adaptation of organizational structures. The alignment of strategies and the cooperation among stakeholders play a crucial role in transforming port operations with common goals. (Heilig, 2017).

The main tasks of inter-terminal transportation (ITT) (sea-to-sea, sea-to-land/land-to-sea to/from terminals, and between terminals) are punctual collection and delivery of containers at the desired terminals, whereas the latter is a critical factor for the performance of associated supply chains and thus has an impact on the port's reputation (Duinkerken et al., 2006). Considering ITT as a large freight transportation network connecting all terminals and shared facilities of a port, efficient coordination and execution of activities leads to significant quality improvements and cost savings – strengthening the competitiveness of a port in the long term. Efficient planning and execution of ITT activities further require up-to-date data on port operations and involved actors (e.g., location of containers and vehicles, priorities of containers, vehicle arrival times, equipment utilization, etc.) as well as on internal and external conditions (e.g., traffic congestion, trucks' waiting queue, etc.). Several aspects become measurable based on identification and sensing technologies, including positioning data, container-specific data, vehicle and equipment's specific data, gate flows, data of involved individuals (Heilig et al., 2014). The authors present a prototype system to monitor the status and location of trucks, quay cranes, and gantry cranes to support decisions on just-in-time movements and allocations (Ngai et al., 2012).

2.4.3.3 Intermodal transportation-related

Data become the basis of economic analysis, explores the patterns of functioning of modern socio-economic systems. ICTs allow to effectively interact with each other in certain industries, which allows optimizing any business processes by creating an environment equipped with measuring equipment. Information infrastructure is defined by four key trends – socialism, mobility, analytics, and clouds. Each of them is just a technology, but together they form a powerful tool for digital transformation. Modern digital technologies cause exponential growth of data flows. The main goals of digital infrastructure are to increase the speed of decision making, increase the variability of processes depending on the needs and characteristics of the client, and reduce the number of employees involved in the process. (Andriushchenko et al., 2019).

In multimodal transportation processes, the co-production of information generates value in a coordinated and integrated fashion to meet the increasing demands of users within a holistic transport system. Research has indicated that vessels often sail longer distances than necessary. For verifying the optimization tool, historic AIS data was used for analysis. The environmental sustainability of sea transport also requires other parties, especially ports, in the part of the transport chain to serve users in the shipping industry with correct and real-time data, adding value to all services involved in the transport process. A data-sharing infrastructure is proposed to achieve Sea STM. STM is a coordinative approach for just-in-time (JIT) operations in shipping and its interface to port operations. STM contains four sub-concepts which are Strategic Voyage Management, Dynamic Voyage Management, Flow Management, and Port Collaborative Decision Management. It focuses on safety, environmental sustainability, and operational efficiency. The dynamic voyage plan is published in a maritime cloud and additional information related to the voyage is continuously updated. This plan is used as a basis to propose an optimized route for the vessel. A key enabler for STM is the notion of voyage number. (Lind et al., 2015)

For the consumer-centered last-mile logistics, the simulation models allow a measurable result of a consumer decision in regards to a preferred logistics option and an adaption towards increased sustainability by keeping a high degree of individualization (Freitag et al., 2020). Though the last-mile transport is not stressed in the whole maritime transport chain at present, it may develop to an important part to improve the service quality of the whole chain. Meanwhile, the method can be learned by the hinterland transport of maritime logistics to simulate their transportation, adapting to a more consumer-centered strategy.

2.4.4 Digitalization on Regulatory Process

The ‘sea highway’ (E-Toll Laut) program is one of the policies for the Indonesia Government to quickly formulate the country’s maritime connectivity. A mechanism of blockchain port management is formulated to guarantee accountability, simplify the monitoring process, and accelerate bureaucratic processes and port transactions to reduce the time of dismantling containers at Indonesian ports. The process of dismantling containers at Indonesian ports can take more than 4 days. The dwelling time for large ports such as Makassar is still in the figure of 8-10 days. Electronic Government (e-Government) is developed in port governance to use information technology, especially the Internet, to transform relations with citizens, the private actors, and other government agencies. The blockchain technology that connects the banks into the process can be a solution. With blockchain technology, container’s waiting time in planning the distribution of goods can be reduced. Indonesia developed two pillars related to the use of related technologies in Indonesian ports: the trading system and the port system. The trading system needs optimization related to licensing documents, regulations, and information on export and import processes. The port system expects to accelerate container handling at the port. The proposed blockchain port system application will facilitate some processes in these two pillars. (Hafizon et al., 2019)

In global trade, the physical flow and information flow of goods are difficult to separate. It forms the physical infrastructure and the administrative infrastructure. On top of the physical infrastructure is the administrative one of customs. The business actors have the responsibility to report the flow of goods, and the national customs authorities have the right and obligation to perform physical control. This brings about the administrative burden of customs. The Single Administrative Document (SAD) reform was introduced as a step towards digitalizing customs operations into a process that by the EU is named e-Customs. The e-Customs project needs to find a suitable and universal standard for the exchange of data. Consequently, the reformed SAD and related legislation were introduced and taken into practice by 2007, and the format was adopted by more than 30 countries at that time. The SAD standardized data was submitted to national customs. A company could do the export clearance, issue the transport document (customs), and prepare the clearance and with one and the same operation. The e-Export system can be reached through either UN/EDIFACT messages or XML messages. E-Customs reduces the administrative burden and is welcomed by the business. (Henningsson et al., 2009).

2.4.5 Digitalization on Specific Data and Information

The main part of maritime digitalization is about data and information systems. Technologies change and improve the way to collect, store, and handle data. Information systems are developed to take advantage of data and to facilitate both administrative, logistics, and business operations. Information systems under digitalization are more designed and developed from a whole transport system view. One research branch is about the system considering multi-modal processes. Mobile technology, as well as other new technologies, influence modern information systems.

Transport infrastructure as a whole includes data collected on water areas, rail structures, roads, and buildings, structures, and their properties. This data is a basic example of static data that is slowly changing and requires updating only after modifications or changes. There is a data flow connection (or a breaking) point when the transport unit arrives from publicly owned roads and rail structures to the port vicinity, and vice versa. A large amount of data considering shipping, port operations, and hinterland transportation is transferred and handled by separated actors in the logistics chain. Researches have discussed the content, standard, openness, interoperability, analysis, and benchmark of the data considering maritime digitalization.

Digitalized shipping depends on open international standards for data formats and exchanges. Common Maritime Data Structure (CMDS), which has been defined as one of the pillars of the development of e-navigation solutions by IMO. It is based on the International Organization for Standardization (ISO) 19100 series of geographic information system standards, but not non-geographic operational data. In the navigation system, the IEC 61162 series of standards is the main defining data standard (IEC 2016). On the administrative ship data network, it is currently the ISO 28005 (ISO 2011) series of standards that are the most relevant interfacing standard for e-navigation related information. ISO 28005 covers electronic port clearance and related reporting requirements. It is important to have a common data representation to harmonize all maritime data for the realization of e-Navigation.

IMO decided to develop CMDS and to use International Hydrographic Organization (IHO)'s S-100 standard which is based on ISO 19100 as the baseline for creating a framework for data access and services. It aims to harmonize all data models related to operational exchanges, supporting both geographic and non-geographic information for use of (Geographic Information System) GIS frameworks. Traditionally, radio communication and navigational equipment for use onboard ships are exchanging data based on the IEC 61162 series of standards. In the context of the new developments within e-Navigation, the information is expected to be exchanged using the CMDS, based on S-100, when any shipborne equipment needs to communicate with a shore-based system or from another ship. For the vessel to shore reporting, it is based on ISO 28005 standards. One should also not try to replace existing and well-established standards with new specifications unless it is unavoidable. Thus, harmonization between the different standards through a common high-level data model like CMDS may be the best solution (Rødseth et al., 2017).

Information systems collect ship performance and navigation data which are always associated with large-scale data sets. The parameters are separated as data clusters. So it is important to identify the data clusters and the structure of each data cluster. The first is to identify the clusters, second is to identify the structure of the cluster. The represented structures can be used for both energy efficiency and system reliability applications under the data visualization layer. A high dimensional data space means the difficulty of visualization of models (i.e. data clusters). A data handling framework is proposed with data-driven models (i.e. digital models) to cope with the shipping industrial challenges as the main contribution, where conventional mathematical models may fail. The proposed data-driven models are developed in a high dimensional space, where the respective ship performance and navigation parameters of a selected vessel are separated as several data clusters. Hence, it identifies the distribution of the respective data clusters and the structure of each data cluster concerning ship performance and navigation conditions. (Perera et al., 2017)

CargoX's blockchain-based Smart BoL is a solution for the digital transfer of BoLs issued by any containerized cargo shipper worldwide. The test was carried out by G2 Ocean. They departed the port of loading Xingang China on April 5, 2019, and reached the port of discharge, Callao, Peru, on May 26, 2019. The distance between ports is 9,504 nautical miles. The importer received the Smart BoL after a couple of minutes. Last year, CargoX completed the official test shipment of a container with its Smart BoL. The Smart BoL was issued electronically and transferred with the help of a blockchain network (World Maritime News, 2019).

2.5 Summary

This chapter has firstly introduced the main sectors of maritime shipping and port in the maritime industry. In this thesis, the two sectors are the objectives that digitization and digitalization have worked on. Secondly, the principal actors involved in maritime shipping and port operation and management are mentioned. Among them, shipping lines, port authorities, terminal operators, and customs lead the process of digitization and digitalization in the maritime industry. It also cannot neglect the influence of international organizations and regional or countries' cooperation on promoting the process. Thirdly, the general business processes and information flows in the international supply chain and multimodal transport are summarized and presented. They present the common procedures and information flow in global maritime logistics chains. Finally, the literature review is done to analyze the influence of ICTs on the sectors and the procedures, especially on logistical and regulatory ones.

For maritime shipping, digitalization improves e-Navigation and integrated transportation chains. Navigation has always been a big issue for ocean shipping to keep the vessels on the right way and avoid collisions. Nowadays, smart sensors, data acquisition systems, and advanced telecommunications enable real-time vessel monitoring. Vessels equipped with the e-Navigation system are allowed to share routes with other ships and plan or monitor routes with shore-based centers. The technologies, such as 3S technology, AIS, telecommunication, etc. support the e-Navigation project. The services, like ship reports, trajectory prediction of vessels, etc., may all accomplish by the ICTs. Meanwhile, the information of surroundings related to shipping is monitored by IoT. The development of digital technologies brings chances to autonomous procedures and shipping widely in the future. Autonomous shipping highly depends on accurate and real-time data and computer systems. It requires changing human decision-making processes onboard and considering the communication between ship and shore. It should also attract the business and public parties to this development.

Besides ocean shipping, hinterland transportation is also improved by the process of digitization and digitalization. Containerization has contributed to intermodal transportation as containerized cargo is more convenient to transfer between different transportation modes. RFID can be used to track containers. There is a need from customers for door-to-door transportation service. And the demand drives the industry to seek for integrated transportation chain. The information flow should support the physical flow into an integrated chain. The use of EDI, PCS, and blockchain has enabled information transfer in the inter-organizational and interregional processes. The standardization of data and process documents is helpful for information sharing. To improve the efficiency and convenience of the inter-organizational and interregional processes, the concept of a Single Window is promoted to strengthen the cooperation between different authorities or information systems. The integrated platform requires accessible technologies such as web-EDI, cloud technology, and mobile applications, etc. for small- and medium-sized companies to participant in avoiding high investment in digital technologies.

Digitization and digitalization have developed the port from enhancing the efficiency and services, to automated operations, and then to the concept of Smart Port. The change to containerization and the building of large vessels put a lot of pressure on the port's capability and management. EDI-based PCS simplifies the process of information transfer among different maritime actors for cross-border trade in ports and consequently saves time for logistical and regulatory procedures. ICTs enable the automated terminals and operations in ports. Furthermore, digital technologies facilitate ports to act as hubs of information networks considering ocean shipping, hinterland transportation, and intermodal transportation. The trend to automation and cooperative networks requires further integration of the technologies and systems, as well as the interests of the business actors. In the process of digitalization, the administrative organizations provide legislative supports for the implementation of digital technologies such as electronic certificates, blockchain BoL, etc., and they also take advantage of ICTs to develop e-services.

The international or regional organizations like IMO, EU, etc, the port authorities, and shipping lines have exploited the benefits of digital technologies for the business and management all the time. This drives the process of digitization and digitalization in the maritime industry. However, there is also technology differentiation among various regions as well as maritime actors. The barriers to integrating systems may also exist in the unified standards, coordinated technologies, and different organizational structures and regulations. The outlook for the future developing trend is promising, but it also takes a long way for this traditional industry to become more intelligent.

3 IT/IS for Logistics Business and Operations

European Commission's analysis tool "Digital Transformation Scoreboard" presents key seven technologies for digitalization: (1) The analysis of big data. (2) Automation and robotics (3) Cyber-security (4) Internet of Things (IoT) and sensor networks (5) Cloud computing and services (6) Mobile services (7) Social media monitoring and management progress. Results also indicate that mobile services (applications) and cyber-security are estimated to be the most significant technology fields (Inkinen et al., 2019). This chapter mainly analyzes the information technologies and systems that are used for maritime business and logistics. For each technology and system, it is analyzed from the aspects of introduction, use description, limitation, and developing potential under digitalization.

Computer systems have largely improved the efficiency of document management, business process, and logistics operation. Technologies have different functions in business and logistics. Some focus on physical handling, some on information, some change the business process or logistics process. In the following, various technologies that have a significant impact on maritime logistics and business are analyzed from both the long-term technologies to the new emerging ones. These technologies are frequently mentioned by institutions, industry, and companies. They are categorized into three groups. The first group is the way to collect and transfer data. The second is the way to store and analyze data. The third is a new way to bring about a new business model. In the first group are basic technologies such as GPS, GIS, Remote Sensing (RS), RFID, mobile technology, and wireless technology. In the second group are applications based on computer and communication technologies such as EDI, PCS, and AIS. In the third group are the new emerging computing technologies or intelligent technologies for digitalization such as CPS, blockchain, and cloud computing.

3.1 Technologies that Influence Logistical Information Flow

3.1.1 GNSS, RS, and GIS

3.1.1.1 Introduction

Global Navigation Satellite System (GNSS), Remote Sensing (RS), and Geographic Information System (GIS) are known as 3S technology collectively. GNSS and RS get and record data from the earth, and GIS store and use these collected data.

GNSS refers to a constellation of satellites providing signals from space that transmit positioning and timing data to GNSS receivers. The receivers then use this data to determine location. Until now, the global GNSS includes Europe's Galileo, the USA's NAVSTAR Global Positioning System (GPS), Russia's Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS), and China's BeiDou Navigation Satellite System. The performance of GNSS is assessed by four criteria, which are accuracy, integrity, continuity, and availability. (European Global Navigation Satellite Systems Agency, 2020)

Among the GNSS, GPS has rapidly become the standard surveying and navigation mode. GPS is a real-time, all-weather, 24-hour, worldwide, 3-dimensional absolute satellite-based positioning system developed by the U.S Department of Defense. It can be used to position vessels. The GPS consists of two positioning services: the Precise Positioning Service which provides an accuracy of 5-10 meters, and the Standard Positioning Service which provides an accuracy of 10-20 meters in absolute positioning mode. However, for many applications, this accuracy of positioning is not sufficient enough. Differential GPS (DGPS) is a technique developed to provide relative positioning with an accuracy of a few meters to a few millimeters.

Remote Sensing (RS) is the technology to acquire information at a distance. It is the practice of deriving information about the Earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the Earth's surface (Campbell et al., 2011).

GIS is a framework for gathering, managing, and analyzing data. Rooted in the science of geography, GIS integrates many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes. With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships, and situations – helping users make smarter decisions (Esri et al., 2021).

Navigational systems are specialized kind of GISs, focused on presenting real-time positional data on a map background. From this point of view, it can be noticed that also maritime information systems are examples of GIS technology. Although it is not referred directly by IMO, IHO or the International Association of Lighthouse Authorities (IALA) in their performance standards, the basics of systems like ECDIS or VTS rely on GIS technology. The main problem in these systems is the proper handling of spatial data to provide desired cartographic products and spatial analysis results. (Kazimierski et al., 2016)

3.1.1.2 Usage

3S technologies have a large number of functions in maritime business and logistics.

Position, Navigation, and Timing (PNT) is part of the critical infrastructure necessary for the safety and efficiency of vessel movements, especially in congested areas such as the North Sea. GNSS, primarily GPS and GLONASS, has become the primary PNT source for maritime operations. The GNSS position is used both for vessel navigation and as the position source for AIS (Johnson et al., 2014).

GPS traces can also be used for container handling event identification in ports (Chen, 2015). A GPS receiver and satellite modem can be integrated with an active RFID shipment tag or Electronic Seal to provide alerts in real-time as containers move from source to destination (Siror et al., 2010).

GIS can analyze relationships between features and their associated data and provide logistics service solutions with the least cost but the shortest time. GIS applications enable the storage, management, and analysis of large quantities of spatially distributed data. These data are associated with their respective geographic features (Milla et al., 2005). All statistics could be generated by querying the database using either a single attribute or a combination of multiple attributes. The users could build their queries with a combination of any attributes and filter the data in a way to reveal the information they require. The main advantage of using a GIS system for queries is that users achieve a great visual presentation of their query results – a map. The GIS system also provides a Spatio-temporal query interface for interactive queries by drawing the Area-Of-Interest directly on the map. The query results for the vessel targets are automatically displayed as a layer and could be labeled by any attribute or a combination of attributes (Ou et al., 2008).

GIS models, software, and interfaces do not provide the functionalities to make this technology compatible with maritime transportation. With the emergence of maritime-based decision aid systems, integrating GIS with maritime navigation systems appears as one of the promising directions to explore. Several contributions to maritime GIS are presented: from the real-time monitoring of navigations for a local authority and maritime clients to the diffusion of maritime data to mobile interfaces, and the development of a relative-based model and visualization system for maritime trajectories. The navigation-based systems illustrate a variety of methods and research issues that support the exchange of geographical data between a centralized system and mobile users. The development of integrated maritime and GIS systems still requires an integration of different geographic information sources to be combined, adapted, and shared in real-time between different levels of users acting in the maritime environment. Integrating GIS information architectures and services with maritime information systems can improve the economic and technological benefits of transportation information by allowing the diffusion of traffic information to a larger community of decision-makers, engineers, and end-users. (Claramunt et al., 2007). Web-based GIS through a big data open-source computer architecture for real-time monitoring sensors of a seaport.

ECDIS is the electronic nautical charts to plan and display the ship's route for the intended voyage and to plot and monitor positions through the voyage. It is a GIS system designed for marine navigation according to the relevant standards of the IMO (Palikaris et al., 2020). The system is complex, safety-relevant, software-based with multiple options for display and integration. In 2000, IMO adopted the revised SOLAS regulation V/19 to allow an ECDIS to be accepted as one carriage requirement for shipborne navigational systems and equipment. In 2009, IMO adopted further amendments to regulation V/19, to make mandatory the carriage of ECDIS. From 1 January 2011, passenger ships of 500 gross tonnages and upwards, as well as newly built cargo ships of 3,000 gross tonnages and upwards should be equipped with ECDIS. The existing ships also phase in the requirement.

In contemporary electronic navigation, the mandatory use of official paper nautical charts is replaced by the use of ECDIS operated with Electronic Navigational Charts (ENCs). ENCs are geospatial databases that are compiled according to the strict technical specifications of the IHO. (Palikaris et al., 2020)

ECDIS can be used to communicate the intended routes by bridge crews. One of the most common causes of shipping accidents is misunderstanding each other's intentions when traveling in the ocean. Some waypoints can be sent to and presented by ECDIS. Thus, a ship's intention is visible to other ships.

3.1.2 Automatic Identification System (AIS)

3.1.2.1 Introduction

AIS is a satellite-based navigation system for maritime shipping. It promises a long-range tracking capability in geography. The AIS shipborne equipment operates in the very high frequency (VHF) maritime band. AIS VHF antenna and a GNSS antenna are installed onboard. Navigation equipment, such as ECDIS, radar, etc., should be capable of processing and displaying AIS information. The AIS presentation interface is based on IEC 61162-2 standard. It builds interfaces with sensors that providing information of the ship's position, heading, and rate of turn. Generally, sensors installed in compliance with other carriage requirements of SOLAS Chapter V should be connected to the AIS. (IMO, 2003)

Figure 3-1 provides an overview of the AIS system. The shipborne AIS transmits ship's data to other ships and VTS stations; it also receives and makes available data of other ships and VTS stations and other AIS stations, such as AIS- Search and Rescue Transponder (AIS-SARTs), AIS-Aid to Navigation (AIS-AtoN), etc. (IMO, 2015)

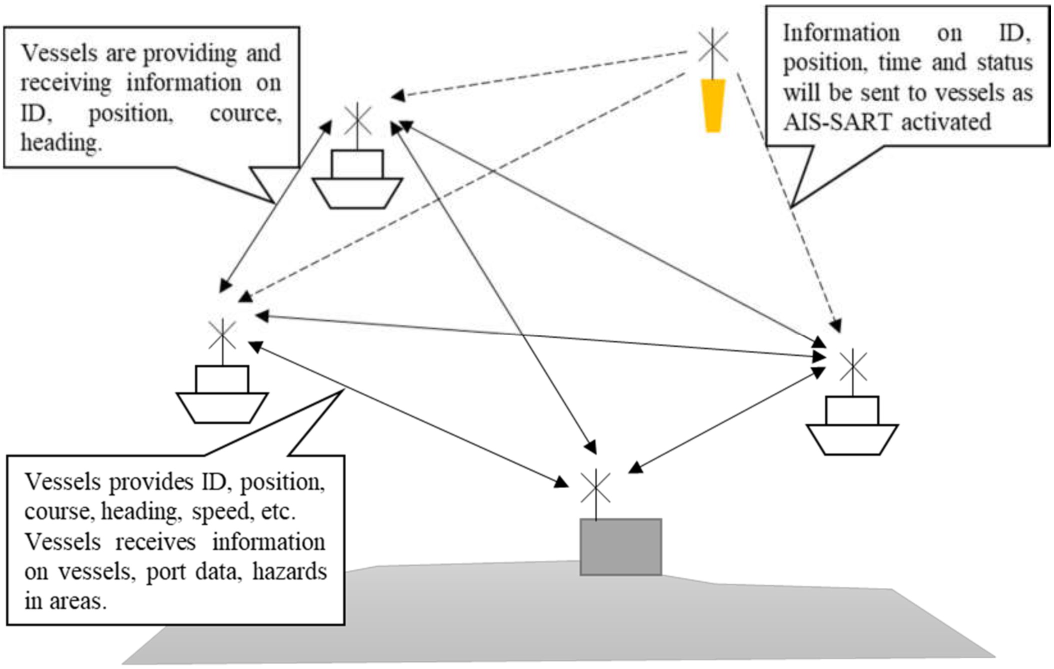

Figure 3-1 AIS system overview (IMO, 2015)

SOLAS regulation V/19 mentioned that ships constructed on or after 1, July 2002 shall be fitted with navigational systems and equipment. The regulation requires all ships of 300 gross tonnages and upwards engaged on international voyages and cargo ships of 500 gross tonnages and upwards not engaged on international voyages and passenger ships irrespective of size shall be fitted with AIS (IMO, 2019).

The regulation requires that AIS shall:

- provide information - including the ship's identity, type, position, course, speed, navigational status, and other safety-related information - automatically to appropriately equipped shore stations, other ships, and aircraft;
- receive automatically such information from similarly fitted ships;
- monitor and track ships; and
- exchange data with shore-based facilities

The AIS information transmitted by a ship contains four different types (IMO, 2015):

- static information, which is entered into the AIS on installation. The information includes the ship's call sign and name, Maritime Mobile Service Identity, IMO number, length and beam, type of ship, and location of electronic position fixing system antenna.

- dynamic information, which is automatically updated from the ship sensors to AIS. The information includes the ship's position, position time stamp, course and speed over ground, heading, navigational status, rate of turn. Some of the information might not be available.
- voyage-related information, which needs to be manually entered and updated during the voyage, such as ship's draught, hazardous cargo, destination and ETA, and route plan.
- Safety-related messages, which would be manually entered and broadcast to all ships and shore stations.

There are two classes of shipborne AIS equipment, Class A and Class B. Class A complies with relevant IMO AIS carriage equipment. Class B provides functionalities not in full accordance with IMO requirements. Class B devices may be carried on ships that are not subject to the SOLAS carriage requirements (IMO, 2015).

3.1.2.2 Usage

The Automatic Identification System (AIS) is intended to enhance the safety of life at sea, safe and efficient navigation, and protection of the marine environment (IMO, 2015). The motivation for the adoption of AIS is its autonomous ability to identify other AIS fitted vessels and to provide additional precise information about target ships that could be used for collision avoidance. The system is mainly used for the detection and identification of ships, as a complement to radar. It exchanges data regarding navigational and voyage-related information of ships and other related messages with other ships and shore stations. The information can be received by anyone equipped with a relatively low-cost receiver (Harati-Mokhtari et al., 2007).

Maritime security has become a major concern for all coastal states and the fundamental requirement is maritime domain awareness via identification, tracking, and monitoring of vessels within their waters. The AIS has gained much popularity over the past decades, and the employment of satellite-based receivers has enabled wide coverage and improved data quality. Therefore, many states are now planning to integrate the AIS into their shore-side surveillance and vessel traffic control systems for coastal security, maritime traffic management, vessel tracking, and monitoring with the help of GIS technology (Ou et al., 2008).

The application of AIS data has developed from simply navigation-oriented research to now include trade flow estimation, emission accounting, and vessel performance monitoring. The applications can be categorized into three groups, as shown in Figure 3-2, which present the basic, the extended, and the advanced functions of AIS.

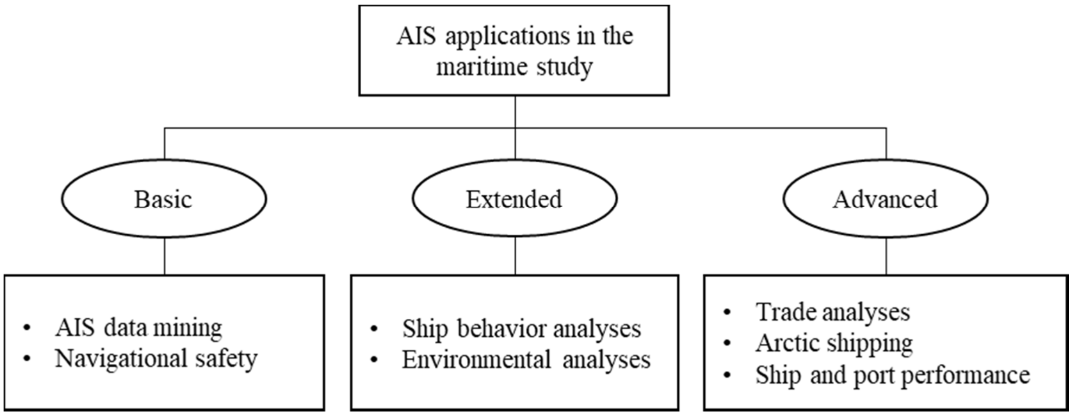

Figure 3-2 The classification of AIS applications (Yang et al., 2019)

The basic AIS applications are data mining and navigational safety. Data mining is a knowledge extraction process based on raw data. It provides the foundation for the majority of studies based on AIS data. The most common methods are trajectory extraction, trajectory clustering, and trajectory prediction. Trajectory prediction enables navigators or coastal authorities to detect possible threats and take preventive actions as early as possible. Navigation safety is to utilize AIS data to avoid shipping accidents. It develops into two directions, which are collision avoidance for ships and traffic surveillance enhancement for coastal authorities.

The extended applications include ship behavior analyses and environmental analyses. Ship trajectories include information about ship behavior, namely fishing activities, and ship behavior in open waters and restricted waters. AIS data can be used to monitor illegal, unreported, and unregulated fishing activities. For ship behavior in open waters, the data is used to analyzing the spatial and temporal distributions of traffic. For behavior in restricted water, it tends to analyze detailed navigation patterns of ships in a certain shipping channel and helps to evaluate the service level of the navigation infrastructures. The environmental analyses may include ship emission analysis, oil spill risk analysis, ecosystem impact analysis, and proposing green shipping strategies.

The advanced applications of AIS data are categorized into three groups: trade analyses, ship and port performance evaluation, and Arctic shipping. AIS data can provide more detailed and timely trade statistics compared with the traditional data sources. It can also be used to evaluate the performance of ships by factors like ship utilization, speed, and voyage cost. For port performance, ship positions can be used to derive the ship traffic, container throughput, berth utilization, and container terminal productivity. It can also be used to assess the resilience of port operations following major disasters and other disruptive events and the dwell time of ships at different ports. (Yang et al., 2019)

The future development of AIS may focus on the improvement of technology and information and its integration with other systems. It is going to reduce satellite revisit time to get the full reporting rate afforded by AIS and to improve the quality of data entered into the system as more accurate and real-time. In most cases, some optional information fields of the AIS such as destination and ETA are not updated. This may be because they are not being regarded as important information for navigation. However, they are important information for port operations. Therefore, it needs to improve the complete information to be recorded. As AIS is useful in enhancing navigational decision making on the bridge, the main areas of concentration should be diverted toward its correct installation, its integration with other navigational equipment, the accuracy of manual data being input into the system, the presentation of information, and the ability of the mariners to correctly interpret the information received. (Harati-Mokhtari et al., 2007)

3.1.2.3 Vessel Traffic Services

VTS contribute to the safety of life at sea, safety and efficiency of navigation, and protection of the marine environment, adjacent shore areas, worksites, and offshore installations from possible adverse effects of maritime traffic. VTS is shore-side systems, ranging from the provision of simple information messages to ships to extensive management of traffic within a port or waterway. The VTS control center tracks ships by radio when ships enter a VTS area. The VTS operator will send navigational information or other warnings to ships. Port authority may establish VTS based on the volume of traffic and the degree of risk around ports.

A VTS is a marine traffic monitoring system established by harbor or port authorities, similar to solutions used in air traffic control. VTS is based on radar systems and AIS to keep track of vessel movements, and improve navigation safety in a given maritime area (Claramunt et al, 2007).

Take Dalian VTS for example, the configurations and functions of VTS include:

- Radar Surveillance Sub-system, effective tracking and replaying within a range of 30 miles
- AIS Sub-system: identifying ships automatically, sending and receiving AIS messages within a range of 30 miles
- VHF Communication Sub-system, multi-channel recording within a range of 30 miles
- VHF Direction Finder Sub-system, identifying ships' positions within a range of 30 miles

- Ship Data Processing Sub-system, processing ship data under in a capacity of 5,000 ships
- Meteorology monitoring Sub-system, monitoring meteorology real-time data at the observation point
- CCTV Surveillance Sub-system, assisting surveillance of terminals and the movements of ships
- Data recording and playback Sub-system, recording data and presenting audio, visual, and radar image.

VTS provide traffic services and pilot services. VTS center can provide traffic information, weather information, navigational assistance on request, supporting joint actions, traffic organization, and broadcast navigational warnings.

Ships need to submit three kinds of reports to the VTS center: (1) ship declaration and berth schedule declaration, including pre-arrival declaration, declaration for berth schedule, and declaration for piloting schedule; (2) movement report, including entry report, fixed point report, shift report, departure report, and exit report; and (3) incident report or abnormality report, including security incident report, incident report, and abnormality report. (Dalian Maritime Safety Administration of P.R.China, 2013)

3.1.3 RFID

3.1.3.1 Introduction

RFID uses electromagnetic fields to automatically identify and track tags attached to objects. An RFID tag consists of a tiny radio transponder, a radio receiver, and a transmitter. There are two types of tags, the passive one and the active one. Passive tags are powered by energy from the RFID reader's interrogating radio waves. Active tags are powered by a battery and thus can be read at a greater range, up to hundreds of meters, from the RFID reader.

3.1.3.2 Usage

RFID tags are used in many industries. It has sometimes been labeled as the next generation of bar codes however it offers much more; such as track items in real-time to yield important information about their location and status.

RFID can be used for tracking objects in transportation. For example, an RFID tag attached to an automobile during production can be used to track its progress through the assembly line, and implanting RFID microchips in livestock and pets enables the identification of animals. RFID is seen as one of the pivotal enablers of the IoT.

RFID can be used for terminal management. RFID is compatible with GPS and Enterprise Resource Planning (ERP) to achieve transparent and real-time information flows using the internet. It can be used in fields like reports, documentation, inventory, and warehouse. Terminal operators develop better knowledge of the whole terminal through RFID technology, which improves the planning of terminal operations (Banks et al., 2007). RFID can be used to give higher flexibility to AGVs as the decision of AGVs routing will be based on real-time location and detection which before follows predefined paths. RFID can be used in a freight container management system deployed throughout the terminal. This system allows for container traceability, efficient reservation and vehicle management, automatic loading plan calculation, and fault tolerance (Barro-Torres et al., 2010).

RFID can be used for container operations and management. RFID-based smart seals or electronic seals are methods to protect containers from tampering. They are smart seals. The whole container is further secured using an active RFID shipment tag or electronic Seal that is integrated with a GPS receiver and satellite modem to provide complete visibility, providing alerts in real-time as containers move from the origin to destination. RFID tags equipped with sensors can monitor information such as the container's temperature, humidity level, change in the light, etc. Besides, the tag stores a lot of valuable data like the container's content, origin and loading date, and destination. These data can be communicated wirelessly to the port authority and the customs before arriving at the port and submitting the container manifest. Consequently, the vessel's berth and stowage planning can be coordinated and generated automatically (Hakam et al., 2012). By using RFID middleware, acquired maritime data can be integrated and exchanged to XML-based information. Further, it can be used by enterprises to improve container transportation and management (Zhao et al., 2014). RFID in combination with sensor nodes further supports bilateral communication and interaction between autonomous entities, for instance, to allow automatic handling of containers between automated stacking cranes and automatic transport vehicles (Heilig et al., 2014).

RFID can be used for administration. Pre-shipment inspection is usually undertaken by customs administrations and standards bureaus to address security, smuggling, tax evasion, and counterfeit goods challenges of imports. The process has predominantly been undertaken using manual-based methods which have considerable shortcomings. RFID can be used for intelligent pre-shipment inspection. The system supports tracking of containers from origin to destination using Real-Time Location Tracking System using active RFID technology, GPS, and satellite modems. Many industries have used the technology for the automated handling of goods and automatic identification and data capture. The technology has been used considerably in the supply chain for business-to-business e-commerce where goods movement is tracked and reported automatically. (Siror et al., 2010).

3.1.4 Big Data, Cloud Computing, and Internet of Thing

3.1.4.1 Introduction

Big Data is a term for massive data sets having a large, more varied, and complex structure with the difficulties of storing, analyzing, and visualizing for further processes or results. Massive amounts of data may reveal hidden patterns and correlations between companies or organizations with their clients (Sagiroglu et al., 2013). Big Data is generated from an increasing plurality of sources, including Internet clicks, mobile transactions, user-generated content, and social media as well as purposefully content through sensor networks or business transactions such as sales queries and purchase transactions (George et al., 2014). Companies that learn to take advantage of big data will use real-time information from sensors, RFID, and other identifying devices to understand their business environment at a more granular level, to create new products and services, and to respond to changes in usage patterns as they occur. Organizations that capitalize on big data stand apart from traditional data analysis environments in three key ways: (1) paying attention to flows as opposed to stocks, (2) relying on data scientists and product and process developers rather than data analysts, (3) moving analytics away from the IT function and into the core business, operational and production functions (Massachusetts Institute of Technology, 2012).

The data center hardware and software is called a cloud. A public cloud refers to a cloud available to the general public in a pay-as-you-go manner, and utility computing is the service being sold. Private cloud refers to internal data centers of a business or other organization, not made available to the general public when they are large enough to benefit from the advantages of cloud computing. Cloud computing is the sum of Software-as-a-Service (SaaS) and utility computing but does not include small or medium-sized data centers, even if these rely on virtualization for management. Three aspects are new in cloud computing: (1) the appearance of infinite computing resources available on-demand, quickly enough to follow load surges; (2) the elimination of an up-front commitment by cloud users; and (3) the ability to pay for use of computing resources on a short-term basis as needed and release them as needed. (Armbrust et al., 2010)

The formal definition of cloud computing is as follows: “It is an information technology service model where computing services (both hardware and software) are delivered on-demand to customers over a network in a self-service fashion, independent of device and location. The resources required to provide the requisite quality-of-service levels are shared, dynamically scalable, rapidly provisioned, virtualized, and released with minimal service provider interaction. Users pay for the service as an operating expense without incurring any significant initial capital expenditure, with the cloud services employing a metering system that divides the computing resource into appropriate blocks.” Computing resources in the cloud can accede from a variety of platforms through the internet. Cloud computing can be provisioned using an organization’s servers, or it can be rented from a cloud provider that takes all the capital risk of owning the infrastructure. Cloud-based applications allow information sharing, something that has not been a design consideration for many traditional applications. (Marston et al., 2011)

The IoT paradigm is based on intelligent and self-configuring nodes (things) interconnected in a dynamic and global network infrastructure. In the IoT scenario, RFID plays a key role to identify anything automatically, assigning objects unique digital identities, and integrating them into a network. Wireless Sensor Network (WSN) is another key component in the IoT environment, which is composed of possibly a large number of sensing nodes communicating in a wireless multi-hop fashion. It can cooperate with RFID systems to better track the status of things, getting information about the position, movement, temperature, etc.

In many industries, companies are currently testing and adopting IoT technology. A variety of IoT systems is used and gets interconnected with existing or newly developed application systems. Due to the integration of IoT and the related cloud systems, existing enterprise architecture (EA) models have to be extended. Another factor is addressing. It should enable unique identification among a large number of objects. Middleware is a key role between the things and the application layer, whose main goal is the abstraction of the functionalities and communication capabilities of the devices. IoT will be one of the main sources of big data, and Cloud will enable to store it for a long time and to perform complex analyses on it. In general, IoT can benefit from the virtually unlimited capabilities and resources of the Cloud to compensate for its technological constraints (e.g. storage, processing, and communication). Cloud can benefit from IoT by extending its scope to deal with real-world things in a more distributed and dynamic manner, and for delivering new services in a large number of real-life scenarios. CloudIoT gave birth to a new set of smart services and applications, such as smart cities and communities, automotive and smart mobility, smart logistics, etc. (Botta et al., 2016)

3.1.4.2 Usage

Big data, Cloud, and IoT can be used for autonomous shipping and automated port.

The emergence of IoT in the maritime industry has led to the introduction of the Internet of Ships (IoS) paradigm. The corresponding applications of IoS are smart ships, smart ports, and smart transportation. Real-time IoS platforms already exist in the maritime industry such as Waterway Information Network of USA, e-Navigation of IMO, Ship Area Network of Korea, River Information System of Europe, etc. IoS are mainly used to enhance safety, plan and optimize routes, make collaborative decisions, detect faults automatically and maintenance preemptively, track real-time containers, monitor container environment, monitor environment, improve energy efficiency, and berth automatically. (Aslam et al., 2020)

A two-layer framework is proposed for offshore support vessels. The two layers are vessel Big Data Analytics (BDA) and land BDA. The vessel BDA layer consists of the vessel's local data processing and analyzing facilities for real-time needs. This layer is used to support ship operations. It could be further decomposed as the Industrial IoT components and the BDA modules. The Industry IoT includes a variety of monitoring/sensing and actuating equipment such as RFID readers, sensors, actuators, cameras, and GPS. It uses different protocols to communicate with the BDA modules. They are used to collect real-time data for vessel BDA. The land BDA layer focuses on the analytics task of large batch historic vessel data for maintenance and future ship design and development. (Wang et al., 2015)

IoT technology unites the RFID systems to generate data-based benefits for the logistics network. Another modern IoT utilization is the GPS labeling of shipping containers to support the handling of their movement through transportation hubs. (Lacey et al., 2015)

The increasing problems are significant traffic, congestion, and vehicle safety. Cloud computing and the IoT have provided a promising chance to address these problems. For example, an Intelligent Transport System Cloud was planned to enhance vehicle-to-vehicle communication and road safety (Ashokkumar et al., 2015). A Vehicle Cloud is proposed which includes three layers: in-car transport Cyber-Physical System, V2V network, and V2I network (Wang et al., 2011). The ITS-Cloud includes three layers: cloud layer, communication layer, and end-users layer. The three-layer style permits heterogeneous devices, networks, and services to exchange information and collaborate in a very amount manner (Bitam et al., 2012). IoT explains a future during which a range of physical objects and devices, such as numerous sensors, RFID tags, GPS devices, and mobile devices, and is going to be associated with the web and permits these objects and devices to attach, cooperate, and communicate among social, environmental, and user contexts to succeed in common goals (Atzori et al., 2010).

A multilayered vehicular data cloud platform by using cloud computing and IoT technologies to develop two innovative vehicular data cloud services, i.e. an intelligent parking cloud service and a vehicular data mining cloud service in the IoT environment. An intelligent parking cloud service collects and analyzes geographic location information, parking availability information, parking space reservation and order information, traffic information, and vehicle information through sensor detection. To improve the overall efficiency and quality of port operations, innovative information systems for gathering and processing operational data based on an integration of RFID, WSN, and mobile technologies are required to enhance the visibility of operations in information systems (Ashokkumar et al., 2015).

A network consisting of devices and systems autonomously communicating with each other based on sensor and identification technologies is commonly referred to as IoT. Cloud computing seems to solve the barriers for small and medium-sized enterprises to involve in Inter-Terminal Transportation against huge monetary investments and a high IT expertise (Heilig et al., 2014).

3.1.5 Cyber-Physical System (CPS)

3.1.5.1 Introduction

CPS is a systematical deployment in the manufacturing industry in which information from all related perspectives is closely monitored and synchronized between the physical factory floor and the cyber computational space. This is transforming the manufacturing industry to the next generation which is called Industry 4.0.

In general, a CPS consists of two main functional components: (1) the advanced connectivity that ensures real-time data acquisition from the physical world and information feedback from cyberspace; and (2) intelligent data management, analytics, and computational capability that constructs cyberspace.

Figure 3-3 presents the five levels of the architecture of CPS. The first is the smart connection level, where manage data acquisition procedure and transfer data to the central server. The second is the data-to-information conversion level, where meaningful information has to be inferred from the data. The third is the cyber level which acts as a central information hub of machines network. This provides self-comparison among the fleet and predicts the future behavior of the machinery. Once the cyber-level infrastructure is in place, machines can register into the network and exchange information through cyber interfaces. The fourth level is the cognition level where generates a thorough knowledge of the monitored system and supports the correct decisions. The fifth level is the configuration level which acts as a resilience control system to apply the corrective and preventive decisions which have been made in cognition level to the monitored system. (Lee et al., 2015)

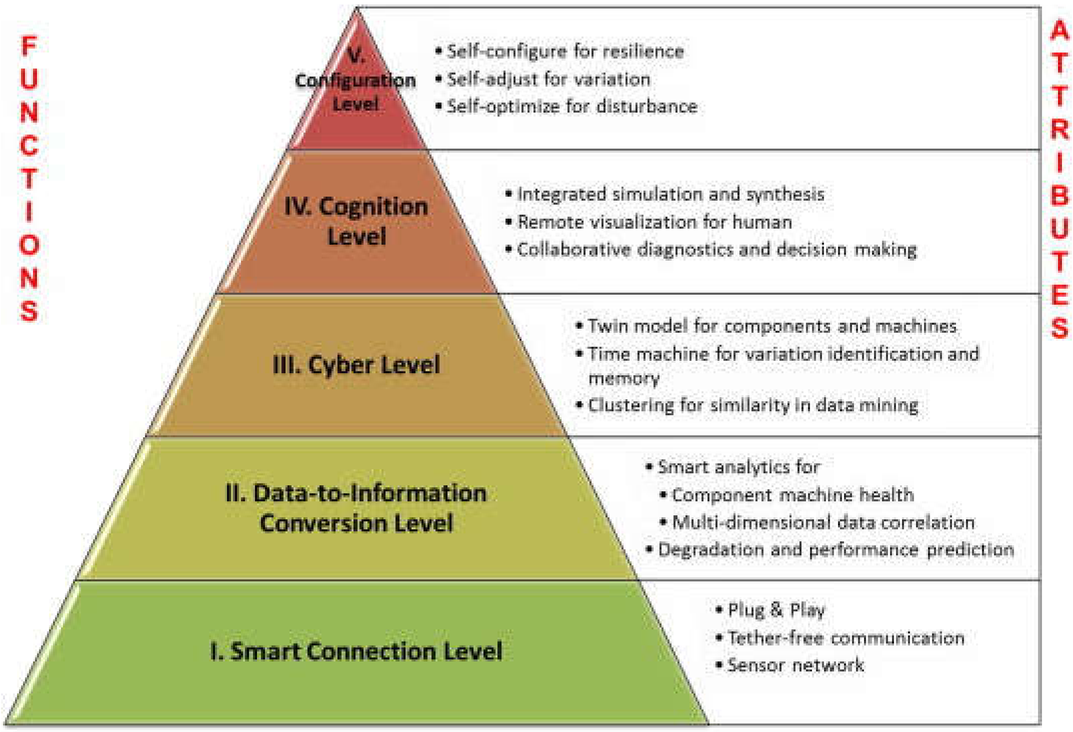

Figure 3-3 The 5-level architecture for the implementation of CPS (Lee et al., 2015)

With this development in the production industry, the maritime industry also strides to the era of 4.0. Cyber-Physical Systems (CPS) as transformative technologies for managing interconnected systems between their physical assets and computational capabilities (Baheti, 2011). The ever-growing use of sensors and networked machines has resulted in the continuous generation of high volume data which is known as Big Data (Lee, 2013). In such an environment, CPS can be further developed for managing Big Data and leveraging the interconnectivity of machines to reach the goal of intelligent, resilient, and self-adaptable machines (Krogh, 2008).

3.1.5.2 Usage

CPS are integrations of computation and physical processes. Transportation systems could benefit considerably from better-embedded intelligence in automobiles, which could improve safety and efficiency. Large-scale services systems leveraging RFID and other technologies for tracking of goods and services could acquire the nature of distributed real-time control systems. However, without improved reliability and predictability, CPS will not be deployed into such applications as traffic control, automotive safety, and health care (Lee et al., 2008).

CPS has been used in the electronic power grid to coordinate control and system sensing and monitoring to maintain correct operation and to detect and react to faults and attacks, in environment protection, in an emergency evacuation, and assistive devices.

There are also challenges in trusting and applying this technology. Firstly, the precision of computing must interface with the uncertainty and the noise in the physical environment. Secondly, the lack of perfect synchrony across time and space must be dealt with. Thirdly, robustness, safety, and security of CPS; uncertainty in the environment, security attacks, and errors in physical devices may bring problems to the overall system. Fourthly, a new calculus must merge time-based systems with event-based systems for feedback control. Fifthly, physical properties should be captured in a composable manner by programming abstractions. (Rajkumar et al., 2010)

3.2 Technologies that Influence Commercial and Regulatory Information Flow

3.2.1 Electronic Data Interchange (EDI)

3.2.1.1 Introduction

The concept of EDI was developed to reconcile the data that came from a vast number of different files at the beginning. Since the 1960s, EDI was used to edited and transferred documents in digital versions. It represents and paves the way for the first digital transformation in the maritime industry. When standards were introduced into the process in the early 1970s, EDI became a more simple and reliable system to automate the exchange of documents in specific industries or regions. Until 1987, the international EDI standard – EDIFACT was developed by the United Nations which was approved as the ISO standard. Later on, EDI has largely been used in a business which is also prompted by governments. EDI is generally defined as the computer-to-computer exchange of intercompany business documents and information through standard interfaces that require hardware, software, and communications technology that permit those computers to transfer the data electronically, such as purchase orders, invoices, medical claims, and price lists. (Threlkel et al., 1999)

Direct EDI is an approach in which an organization must communicate with each business partner individually, managing hundreds or thousands of separate connections (EDI Basics, 2021). This is a cost-consuming and complicated method to handle the documents. Thus, Value-added networks (VANs) technology was developed and applied in the EDI system. The traditional EDI based on VAN is widespread within the airline, banking, credit card, and motor industries that are large enough to invest in this costly system. VANs have stimulated EDI growth by reducing the entry cost and complexity while providing a conduit for the electronic transaction itself. VANs have improved transaction costs while simultaneously ensuring data reliability and security. VANs have stimulated EDI growth by reducing the entry cost and complexity while providing a conduit for the electronic transaction itself. VANs have improved transaction costs while simultaneously ensuring data reliability and security. (Threlkel et al., 1999).

Then Internet-based EDI comes out later, moving the EDI transaction from the VANs to the vast public network of the Internet. It has opened new doors for those companies using EDI so that they may reap the benefits of this technology by expanding the scope of their trading partners and simplifying the process of communication while reducing costs further. Internet-based EDI is essentially moving the EDI transaction from the dedicated, secure, and proprietary lines of VANs to the vast public network of the Internet. (Threlkel et al., 1999).

In the Internet-based EDI, it has to solve the compatible problems of different communication protocols among users, the security of data transfer, etc. Applicability Statement 2 (AS2) is a specification about how to transport structured business-to-business data securely and reliably over the Internet. Security is achieved by using digital certificates and encryption. It is one of the most popular methods for transporting data, especially EDI data, securely and reliably over the Internet. It essentially involves two computers – a client and a server – connecting in a point-to-point manner via the web. AS2 creates an "envelope" for the EDI data, allowing it to be sent securely – using digital certificates and encryption – over the Internet. EDI via AS2 requires the receiving organization's server to be always "listening out" for messages addressed to it. Many organizations decide to use an EDI network provider to provide AS2 connectivity and thus always be available to receive the EDI transmissions. File Transfer Protocol (FTP) over Virtual private network (VPN), SSH File Transfer Protocol (SFTP), and FTP Secure (FTPS) are also among the most commonly-used communication protocols for the exchange of EDI documents via the Internet. Any of these can be used to connect to business partners directly (Direct EDI) or to connect to them via an EDI Network Services Provider. Both protocols encrypt the data while in transit, keeping it safe while moving over the Internet, and then decrypt it upon arrival at its destination. However, neither provides non-repudiation or message management. (EDI Basics, 2021)

Web EDI conducts EDI using a standard Internet browser. It enables small- and medium-sized businesses to create, receive, turn around and manage electronic documents using a browser. Many companies, especially smaller-sized businesses, may not have the internal IT resources to manage their EDI environment and for this reason, they will choose to use hosted- or Software-as-a-Service-based EDI offerings instead. Mobile EDI is an emerging area to enable the exchange of EDI documents via mobile devices. However, it has limited adoption, partly because of the security concerns, but mainly due to the restrictions with the mobile devices, such as the screen quality and size. (EDI Basics, 2021)

There are three levels of EDI depth, which are file-to-file, application-to-application, and coupled work environment. In the file-to-file case, an electronic document is generated in one organization and transmitted to partners electronically. However, the document is downloaded in an offline mode and must be entered into partners' systems manually. In the application-to-application case, the receiving EDI-based application acknowledges the receipt of the document electronically and the document is processed directly by the application. In a coupled work environment, trading partners can directly access data maintained within the computer-based systems of other partners. Computer-based applications automatically handle specific operational transactions (Massetti et al., 1996).

3.2.1.2 Usage

EDI is used to exchange documents electronically with trading partners. The use of EDI is not only limited to an organization's externally originated transaction flows but also to move information between geographically dispersed business units in a more efficient way. EDI has been used in marketing, purchasing, finance, and logistics by companies (Massetti et al., 1996). For example, the seller's computer will translate the purchase order into the EDI structured format which will contain the seller's and buyer's name and identification number. The EDI format will be transmitted to the buyer as an EDI envelope. The buyer will verify the authenticity of the EDI message and acknowledges the receipt of the information. If documents such as a bill of lading or bay plan or manifests are to be sent to the recipient then the EDI will be really handy since, without any human intervention, the documents can be handled efficiently. From the port's point of view, the most important documents to be transmitted through EDI would be cargo manifest and customs declarations. (Rengamani et al., 2019).

EDI can be used for a bay plan. A stowage plan of a container vessel is called a bay plan by which container vessels are loaded with containers of specific standard sizes. It is used to maximize the economy of shipping and safety on board. In an EDI format, a bay plan is called BAPLIE. The EDI data can be sent directly into the computer systems of ports instead of manual work. This saves lots of time and decreases errors. The service enables shipping lines and container terminals to exchange a stowage plan quickly and clearly. The BAPLIE of a container ship can be handled worldwide by different ports. The information is integrated into the port's operational computer system and the status of containers' loading and unloading are updated in real-time by the port system. It supports ports to develop paperless systems for the release of containers to inland transport companies. The shipping line can also control its movements out of the port by train. They can send messages from their operational computer system to the port control center to allocate containers to particular trains. (Garstone et al., 1995)

EDI and other similar technologies save money for companies by providing an alternative to facilitate information flow that requires a great deal of human interaction and paper documents. It reduces the handling costs of sorting, distributing, organizing, and searching paper documents. EDI and similar technologies allow a company to take advantage of the benefits of storing and manipulating data electronically without the cost of manual entry. In real business, paper documents are still maintained in parallel with EDI exchange, e.g. printed shipping manifests. Another advantage of EDI is the opportunity to reduce or eliminate manual data entry errors, such as shipping and billing errors, because EDI eliminates the need to re-key documents on the destination side. One very important advantage of EDI over paper documents is the speed at which the trading partner receives and incorporates the information into their system greatly reduces cycle times. For this reason, EDI helps to improve just-in-time operations.

3.2.2 Port Community System (PCS)

3.2.2.1 Introduction

In the past, port users usually used paper-based methods, such as sending fax or handing in documents directly for the delivery of containers. Later, they sent the documents via email by the internet channel (Srour et al., 2008). However, the information and data are required to be typed again every time in the port's information systems. This way to handle the documents wastes a lot of time and increases the risks of mistakes at the same time (Keceli et al., 2008). PCS is developed based on EDI technology which information and data can be exchanged automatically among users. As container ships continue to enlarge their size, there are more container operations and import or export documents in ports. Large ports must handle all these tasks efficiently and economically. Ports use IT/IS to develop the PCSs to handle port operations and to facilitate customs operations. The most frequent reasons for developing PCS are the following ones:

- To optimize the flows of information (efficiency and effectiveness)
- To allow for better control of the import/export activity by customs services
- To generate a more competitive advantage for the port (Carlan et al., 2016)

PCS can be defined as holistic, geographically bounded information hubs in global supply chains that primarily serve the interest of a heterogeneous collection of port-related companies (Srour et al., 2008). The range of PCS key users consists of private companies such as shipping agents, terminal operators, freight forwarders, Customs brokers, public or government agencies i.e. Customs, port authorities, etc. In terms of the user structure, shipping lines and freight forwarders play the most important role, followed by importers and exporters in general or Customs and shipping agents. The number of users differs and ranges from about 280 to 2,000 in one PCS (European Port Community Systems Association, 2011).

PCSs are concentrated on large ports and particularly to the container ports where the annual container volume is 1 million TEUs or more. In most cases, the PCSs have initially been established to serve the needs of the government authorities and port authorities (G2G and B2G) but a considerable number of the systems have been extended to cover the needs of the business life (B2B) as well. In the United States, the tendency has been to develop port community systems that serve many ports and terminals simultaneously, and thus, the number of different kinds of PCSs is considerably small in the US. Highly advanced port community systems can be found, for example, the DAKOSY system in the Port of Hamburg, the Portbase system in the Ports of Amsterdam and Rotterdam, the TradeNet/TradeXchange system in the port of Singapore, and the national PORT-MIS system in Korea. At the initialization stage, the PCSs are usually voluntary or even sponsored for their users, but later on, some of these systems have become chargeable and/or compulsory. It has been reported that with the national PORT-MIS system used in Korea, the logistics cost has saved 100 million USD. The TradeNet system used in the port of Singapore has, in turn, improved the productivity of the port by 20–30 % and declined personnel expenses by 50 %. (Posti et al., 2011)

Before using PCS, the information flow among maritime actors are complicated. The information may be submitted repeatedly to different actors. With PCS, each actor connects to the platform, and the platform handles the information forwarding to another actor. Figure 3-4 takes the Spanish ePortSys which was launched in mid-1999 as an example to present the simplifying information flow by using PCS. Most of the PCSs seem to be based on the Centralized Information Model (CIM). CIM is run by an independent operator that provides centralized information services to store, forwards, and retrieves all information (Posti, 2011).

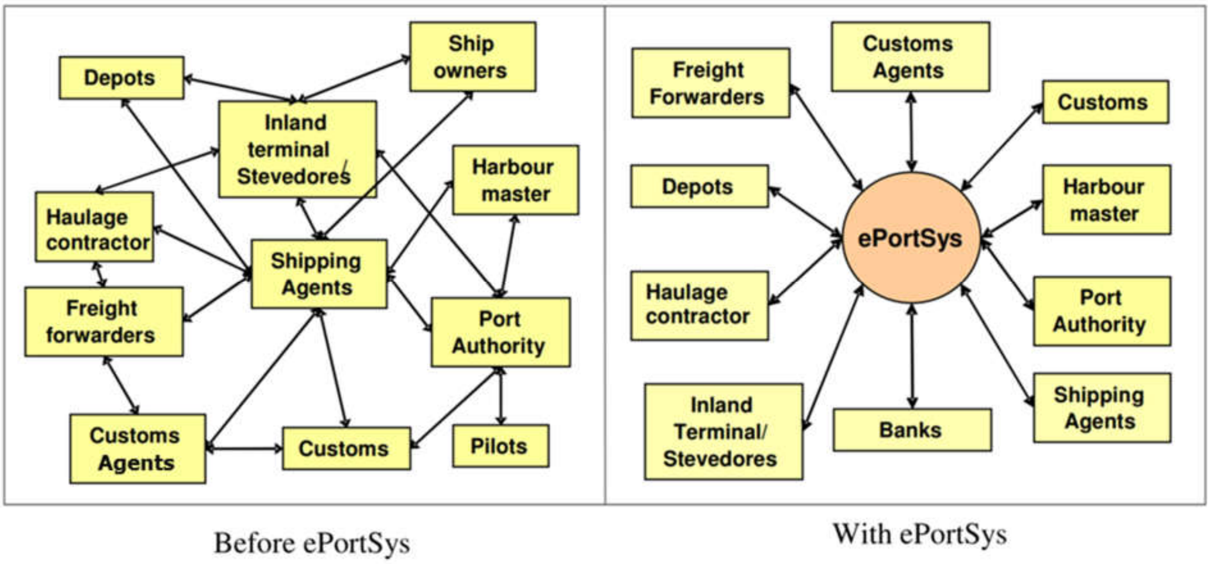

Figure 3-4 Spanish PCS (Rodon et al., 2006)

3.2.2.2 Usage

The primary documentary requirements, the manifest, and the customs declaration relied on the availability of personnel (particularly Customs) to process them. The manifests submitted to the PCS are used by Customs for all fiscal control purposes and manifests submitted to the system in CUSCAR format are forwarded to the central customs anti-smuggling system, for profiling purposes. An extract of the manifest is also sent to the port operator's computer system, for operational purposes. The manifest data is stored on the PCS database and amendments can be made by the carriers without the need to obtain prior approval, with notification of sensitive amendments being immediately notified to Customs. As clearance messages are received from the customs declaration processing system, the PCS sends a message to the appropriate Forwarding Agent/Broker and the port, thus eliminating the paper customs release note. During discharge of the vessels, the port operator's computer system sends messages to the PCS as each container (or BoL for general containers) is landed and the PCS, in turn, sends messages to the carrier's in-house system and records the status on its database (Long et al., 2009)

Similar to PCS, the air transport sector also introduced Airport Community Systems (ACS) or Cargo Community System (CCS). UNECE (2012) notices that most airport community systems have their internal standards, but they communicate with other such systems or trade communities using international air-specific standards, in particular International Air Transport Association (IATA) standards for EDI and XML. Therefore, the types of benefits gained by the corresponding stakeholders involved in both types of systems are assumed to be similar. In the maritime sector, each stakeholder has individually developed its type of communication platform with its customers to increase its efficiency. Given their diversity and difficulty to integrate, these pre-existing systems are now seen as the main hurdle that hampers the way forward for implementation of most PCS. PCS are individual platforms that incorporate different functionalities of one specific port. These functionalities are being supported by applications of different modules that deal with more specific tasks. The stakeholders involved in the port activity can either use the entire range of functionalities of a PCS, or only a part of them, as well as use information available through individual PC modules. A modular approach contributes largely to the successful implementation of a PCS. The advantage of this approach is that the information flow destined for different purposes is processed through different applications. (Carlan et al., 2016)

As shown in Figure 3-5, the functionalities of already developed PCS platforms are covering areas like logistics, customs clearance, navigation, and dangerous goods declaration. In different functions, they contain separate application modules. Maritime commercial, logistical, and regulatory actors may participate in different modules due to the business process.

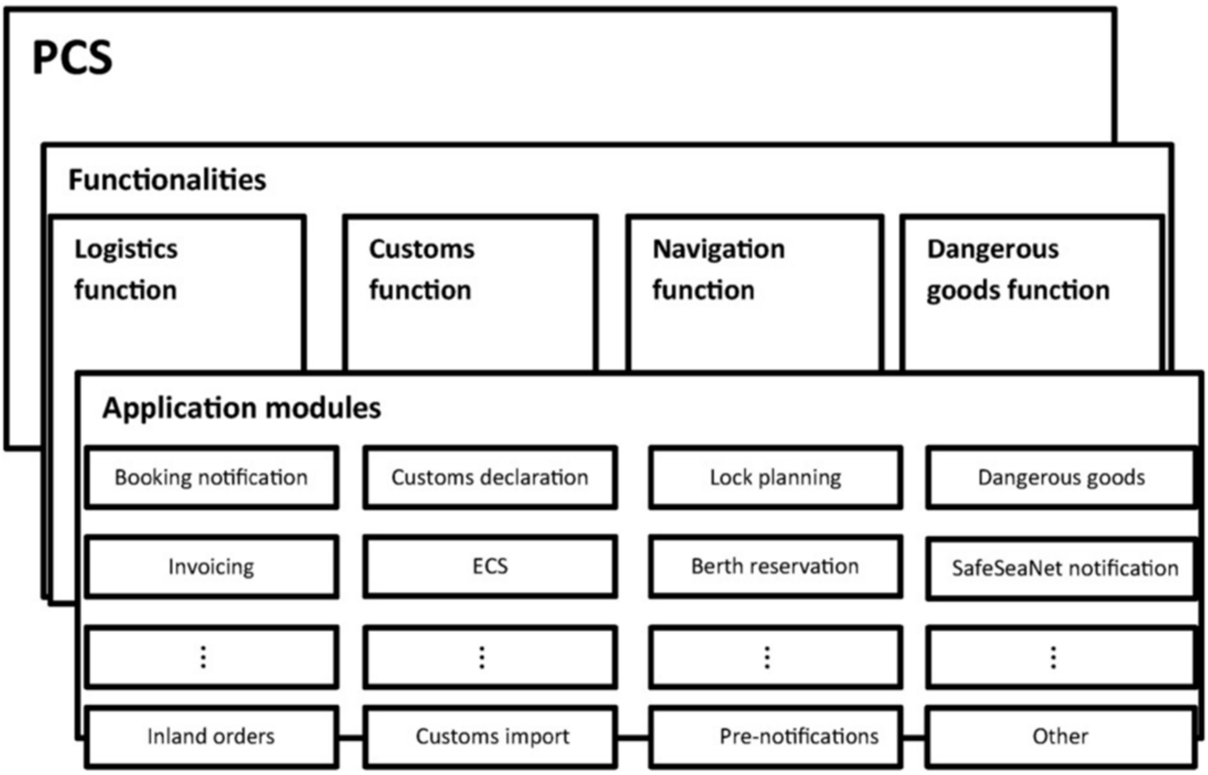

Figure 3-5 Multi-layer structure of PCS functions and modules (Carlan et al., 2016)

Antwerp Port Community System (APCS) followed a bottom-up approach. This means that a central authority did not impose the development of this communication platform, but it was created starting from the needs of the port users. The main aspects that contributed to the development of APCS were the navigation and customs services. The users in the port of Antwerp can benefit from a wide range of applications by joining the APCS. For example, The Export Control System (ECS) module is implemented as a customs clearance functionality within the APCS system. The ECS module is dedicated to the use of the following port stakeholders: terminal operators, freight forwarders, and Customs. While the application is accessible by all freight forwarders that are using the port of Antwerp as a shipping point, not all the terminals joined this module. More than half of the modules which are functional under APCS are open for the use of ships' agents (57%) and shipping lines (52%). Freight forwarders can benefit from 45% of the modules and terminal operators enjoy 41% of the modules. Finally, 30% of the applications are open for the use of the port authority (Carlan et al., 2016). It points out that the strong involvement of terminal operators in building the communication infrastructure throughout all the development stages of ECS was a critical condition for its success (Vanelslander et al, 2015).

The business community can re-use the information already stored in the PCS for business-to-business purposes such as discharge lists, informing shippers and forwarders of the arrival and departure of their containers, etc. This ensures data integrity not only towards governments but also in the business area and vice versa. (European Port Community Systems Association, 2011).

The PCS in Felixstowe, the UK's premier container port started its life in 1981 to streamline the container processes which caused delays to the movement of goods facing the explosive growth of containers. An increase in physical capacity and throughput would lead to an increase in the documentation. To implement a PCS is to eliminate the number of paper documents, often in multiple copies. The PCS has made an impact in the cross-border environment. They have encouraged data transfer and the single submission of data for multiple uses in the business-to-business area of port operations.

A PCS increases port efficiency by connecting the ICT systems of each member, thereby facilitating their communication. To quantify the costs and benefits of PCS, the case study shows there is a positive cost-benefit balance for every stakeholder adhering to a PCS. PCS users manage to gain higher net benefits and have a competitive advantage over other port stakeholders outside the community. The enhanced sharing of information between port stakeholders regarding containers, the preannouncement of vessel/vehicle arrival at ports/terminals, or the secure electronic transfer of official documents are only a few examples of functionalities provided by PCS that bring a competitive advantage. (Carlan et al, 2016)

PCS act as a connecting system to an information hub, to encourage cooperation. It facilitates vertical integration as well as horizontal integration. Vertical integration refers to the collaboration between logistics service providers at a different level with a specific supply chain (De Borger & De Bruyne, 2011; Van de Voorde & Vanelslander, 2014). Horizontal integration refers to logistics players focus on partnerships for freight consolidation matters or sharing the same infrastructure capacity. (Cruijssen et al., 2007; Leitner et al., 2011). There is a three-stage strategy for the integration considering both horizontal and vertical: integrating port operators and port authority (harbormaster), integrating other authorities or service providers (e.g. customs, pilotage), integrating commercialize value-added services (Keceli et al., 2011).

The obvious abilities of PCSs are to integrate information processes, to provide technological inter-organizational infrastructures, and to coordinate interests in the network (Van Baalen et al., 2009). Port professionals, including both the public sector and the private sector, would like to focus more on traffic or port relationships with surrounding areas. The academic sector, on the other hand, believes that port management is more important to competitiveness (Castillo-Manzano, 2009). PCSs provide services not only to the port community but also to organizations with the logistics chain of all modes, sea, inland water, rail, and road. Each mode has its challenges and many PCS operators (PCSOs) provide specific services for inland terminals, dry ports, multimodal hubs, and interchanges.

As shown in Figure 3-6, PCS is one of the implement to realize the National Single Window (NSW). This Single Window, linking SafeSeaNet, e-customs, and other electronic systems, shall be the places where all information is reported once and made available to various competent authorities and the Member States. The Single Window is a facility that allows parties involved in trade and transport to lodge standardized information and documents with a single entry point to fulfill all import, export, and transit-related regulatory requirements. In practical terms, the Single Window aims to expedite and simplify information flows between trade and Government and bring meaningful gains to all parties involved in cross-border trade. (European Port Community Systems Association, 2011).

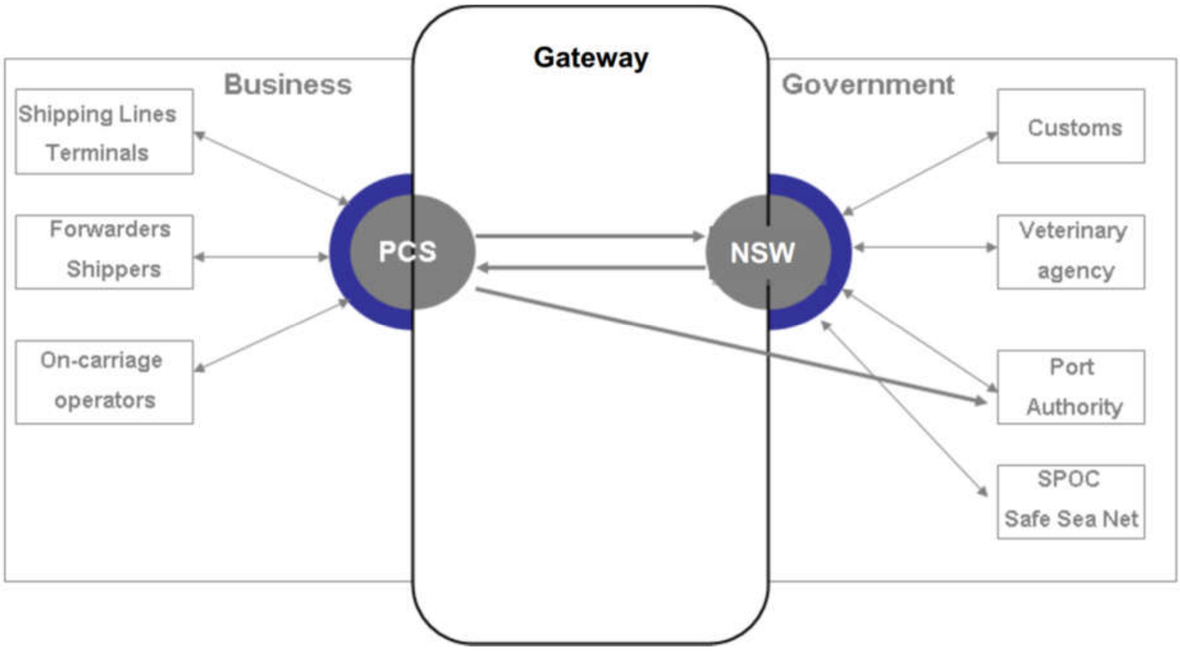

Figure 3-6 Schematic overview of the gateway to the NSW (EPCSA, 2011)

The integration of PCS and Single Window presents in the use of cargo manifests. Cargo manifests have traditionally been received by the PCS primarily for port operational purposes and customs fiscal controls. Almost 100% of manifests are now received electronically into the PCS, predominantly using the UN/EDIFACT CUSCAR message, replacing the seven copies that were previously circulated the port on paper. A screen input facility is available for the very few companies that cannot send data electronically. However, the data included in the manifest received by the PCS enables it to fulfill other regulatory requirements on behalf of the ports and carriers, while enabling the carriers to submit data only once. Waste disposal and port dues declarations can also be sent electronically to the harbormaster/Port Authority based on the same information. (European Port Community Systems Association, 2011).

3.2.3 Blockchain

3.2.3.1 Introduction

Blockchain was created in 2008 by Satoshi Nakamoto. It is a sequence linking many digital signatures, confirmed by a timestamp server. The timestamp server, the ledger distribution, and the proof-of-work concept constitute the consensus model, which is blockchain's validation system (Nakamoto, 2008). Blockchain is defined as a shared, distributed ledger that facilitates the process of recording transactions and tracking assets in a business network. It is a time-stamped tampering-proof ledger that may disable intermediaries and eliminate business frictions that disrupt innovation adoption (IBM Institute for Business Value Analysis, 2016).

There are three types of blockchain: public (Bitcoin, etc.), federated or consortium (i.e., Maersk/IBM), and private (company internal) (Gausdal et al., 2018). The first one is the public and anonymously created technology, which is permission-less, meaning that there is no requirement for software, allowing anyone to participate, thus, completely decentralized. This public chain uses a proof-of-work consensus system to validate and maintain the nodes, while the other two are types are also decentralized within their users, or in other words, centralized to the permitted users to access the network, and require a solution provider to develop the chain. (Czachorowski et al., 2019)

The eight design principles of implementation of blockchain are immutability, decentralization, security, privacy, compatibility, scalability. It has the potential to redefine the way digital information is exchanged thanks to the immutability which is absent in other information technology systems. Blockchain technology is a solution for exchanging documentation in the shipping industry. Reallocation of benefits might thus be necessary to contemplate when introducing a blockchain-based system (Loklindt et al., 2018).

The blockchain network architecture allows its participants to share a ledger updated through peer-to-peer replication when a new transaction occurs. These replications mean that each node acts as both a publisher and a subscriber of the ledger, which are allowed to send or receive transactions to and from other nodes, while the data is synchronized across the network as the transactions occur (Gupta et al., 2017). Due to its characteristics, a blockchain network allows trust within the chain for all of the users. Blockchain can be used for cost reduction and supply chain improvement, adapting to bigger players.

Blockchain is a shared immutable ledger for recording the history of transactions. This concept behind blockchain technology has tremendous potential for creating cost-effective and efficient business networks for trading anything of value between and among interested traders without requiring an intermediary party or central authority. Some of the important techniques and technologies that have come together in this ensemble include public and private communication networks, distributed databases, state machines and logs replication, cryptography, consensus algorithms, concurrency control, etc. (Olson et al., 2018)

Blockchain is not a single technology but rather it benefits from several other enterprise technologies and practices, Figure 3-7 shows a few of the ways currently popular technologies can help augment blockchain's functionality (Shirani et al., 2018).

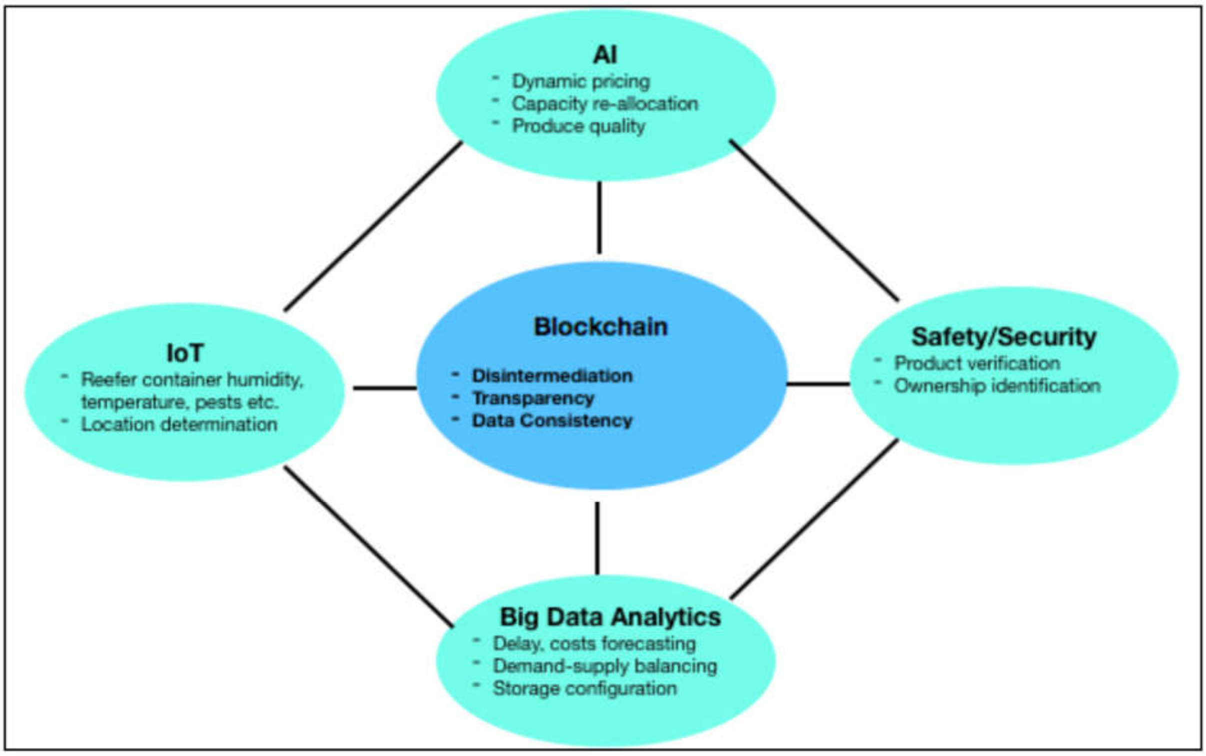

Figure 3-7 Blockchain's synergy with other technologies (Shirani et al., 2018)

3.2.3.2 Usage

Blockchain technology has been adopted by global shipping companies to save operation time and cost and to improve the transparency of the shipping business by effectively removing intermediaries. Since many freight forwarders typically charge by a percentage of the total cost, they have the incentive to increase rather than reduce total costs. A blockchain can help eliminate unnecessary steps in the process and shed light on the entities and steps that may be responsible for unnecessary costs and delays (Shirani et al., 2018). A proof of concept performed by IBM and Maersk demonstrates a 15% cost saving enabled by IBM's Blockchain technology Hyperledger (Groenfeldt et al., 2017).

Blockchain can support regulatory bodies by enabling them to issue necessary certificates in electronic form secured by a unique blockchain-locked code that is impossible to counterfeit (DNV GL, 2020)

Blockchain technology allows fulfilling transactions without the help of the banking sector. It is impossible to counterfeit transactions in the blockchain since all of them are marked with a timestamp. Different certificates are issued which ensure that a company's processes comply with norms and regulations. These certificates are easily forged, which can undermine the system. The usage of blockchain technology could overcome this problem. A classification society creates a digital ID for each certificate, which is saved and can be accessed through blockchain. According to some informants, the amount of engineering documentation has increased tremendously. The utilization of blockchain allows the removal of the problem of document duplication and the duplication of quality control standards. It is much faster and will reduce bureaucracy to get data.

In its initial phase, the partnership created and implemented a blockchain-based BoL, which showed an administrative cost reduction to as high as 15% of the shipped goods' value in early tests. The greatest opportunity for blockchain applications lies in securely connected steps to optimize the chain as a whole and create value from it. Blockchain has great potential in organizing people and operations, such as projects, payments, information, and communication in smarter and more efficient ways, and in developing better and safer documentation and control systems. The IoT should connect devices to suppliers, anticipating demands, and creating useful data from them. Blockchain's applicability to this architecture allows companies to keep an encrypted, immutable ledger of transactions, which can be trustfully shared within the selected network due to the peer-to-peer proof-of-work concept, eliminating the third parties involved, and thus saving money through reducing costs (Gausdal et al., 2018).

In permission blockchain, the users have special permission to access the chain, working as a guarantee that only the allowed users can access the chain or specific parts of it, based on their assigned roles. The permission types apply the concept of smart contracts, which is an agreement or set of rules that govern a business transaction. It is stored on the blockchain and is executed automatically as part of a transaction. Smart contracts may have many contractual clauses that could be made partially or fully self-executing, self-enforcing or both. Their purpose is to provide security superior to traditional contract law while reducing the costs and delays associated with traditional contracts. (Czachorowski et al., 2019)

Walmart recently tested a blockchain-based produce tracking application using which an employee can scan a single piece of fruit such as a mango in a Walmart store in the US and knows the farm where it came from. More than one million items on sale or sold in Walmart stores are said to be currently on the blockchain. Last year, British Airways tested a blockchain-based flight information system to ensure data consistency to prevent displaying inconsistent information at different locations such as airline gates, airport monitors, and the company's websites. A major global shipping company, Maersk, is said to be using the blockchain technology developed by IBM to track sea-borne containers and expedite customs clearance. PricewaterhouseCoopers (PwC) plans to offer an auditing application to validate blockchain-based transactional systems. It is currently testing an application that is meant to audit and verify its clients' blockchain-based systems to ensure that they are compliant with the legal and regulatory requirements. (Shirani et al., 2018)

In a global supply chain, the multiple political jurisdictions, disparate technologies and business practices, and competing interests may become major challenges for adopting a business blockchain. It should consider the right of each participant to create, read, update, and delete records. For example, in a maritime blockchain, exports would have the permissions to read and create records of their assets for export; importers would have permissions to read as well as accept or reject the transfer of assets from exports; port authorities would have read privileges to perform their job responsibility such as inspect assets, agree or disagree the transfer of assets, and calculate duties and charges; and shipping companies and their authorized agents would have privileges to read records and the inspection status of assets. (Shirani et al., 2018)

3.3 Technologies that Improve the Information Infrastructure

3.3.1 Mobile Technology

3.3.1.1 Introduction

Mobile technology consists of portable two-way communication devices, computing devices and the networking technology that connects them. Currently, mobile technology is typified by internet-enabled devices like smartphones, tablets, and watches. The communication networks that connect these devices are loosely termed wireless technologies. They enable mobile devices to share voice, data, and applications (mobile apps). The types of mobile networks include cellular networks, 3G/4G/5G networking, WiFi, and Bluetooth. (IBM, 2021)

3.3.1.2 Usage

From the 1990s onwards, there is a great shift from traditional commerce to electronic commerce. People can simply use mobile handheld devices such as Personal Digital Assistants (PDA) and mobile phones to conduct various e-commerce activities. Not only in the economic sphere but also the administrative area, the rapid development of mobile technologies such as internet-enabled mobile phones, Wi-Fi, and wireless networks, has spurred the development of the Mobile Government Model (Yang et al., 2010).

Mobile-commerce applications require the support of technology from the foundation of wireless user infrastructure, mobile middleware, and wireless network infrastructure (Mennecke et al., 2003). The applications of mobile commerce may provide location-based services, mobile advertising, mobile entertainment services and games, mobile financial applications, product locating and searching, and wireless reengineering (Ngai et al., 2007).

In recent years, the primary focus of many major ports was on the development of mobile apps to allow the dissemination of relevant information to port actors for performing and assisting job orders, for instance, information on booked appointments, available parking slots in the port, container locations, and information about the current status to support drayage truck drivers. It could inform people about the release status of containers. For improving the data quality, apps further allow informing port actors about incorrect or incomplete data entries, for example, during the preregistration of truck operations, to accelerate gate and terminal procedures. The adoption of apps might trigger a slight redesign of the internal business processes of involved actors as more accurate status information can be used to optimize activities. However, it requires port actors to adopt the necessary hardware and apps and to integrate them with their internal systems. Although the adoption barrier and costs are low compared to the introduction of EDI systems, it is important that actors understand and highly evaluate the benefits of the solution and can use it productively. (Heilig et al., 2017)

The popularity of mobile devices like smartphones or tablets, enforced the maritime community to employ these devices also at sea. It has shown that mobile information systems at sea are mostly commercially sold support systems for non-conventional users, mainly tourists, sailors, and leisure boat owners. Mobile navigation MOBINAV is an example of GIS designed for mobile devices. (Kazimierski et al., 2016)

The traditional inland port report and inspection rely on manual operations, working procedures of which are complicated and inefficient. Nowadays, the harbor report platform is based on mobile technology and the mode of service innovation. The service efficiency and the satisfaction of boat runners are improved by reporting harbor via short message. The mobile messaging platform is designed to deal with urgencies. The efficiency of approvals and other processes can also run at high efficiency through the change of management model caused by mobile technology. M-Government may be seen as a subset of e-Government. The modules of a mobile-government system are proposed (Yang et al., 2010).

There are also issues to be improved in both communication and computing sides for mobile applications.

(1) From the mobile communication side:

- Low bandwidth. Bandwidth is one of the big issues in the Management Communication

Channel (MCC) because the radio resource for wireless networks is much scarce as compared with the traditional wired networks.

- Availability. Mobile users may not be able to connect to the cloud to obtain a service due to traffic congestion, network failures, and out-of-signal.
- Heterogeneity. Mobile cloud computing will be used in highly heterogeneous networks in terms of wireless network interfaces. Different mobile nodes access the cloud through different radio access technologies such as WCDMA, GPRS, WiMAX, CDMA2000, and WLAN. As a result, an issue of how to handle the wireless connectivity while satisfying MCC's requirements arises (e.g., always-on connectivity, on-demand scalability of wireless connectivity, and the energy efficiency of mobile devices).

(2) From the computing side:

- Computing offloading. As explained in the previous section, offloading is one of the main features of MCC to improve the battery life for mobile devices and to increase the performance of applications. However, there are many related issues including efficient and dynamic offloading under environmental changes.
- Security. Protecting user privacy and data/application secrecy from an adversary is a key to establish and maintain consumers' trust in the mobile platform, especially in MCC. In the following, the security-related issues in MCC are introduced in two categories: the security for mobile users and the security for data. Also, some solutions to address these issues are reviewed.
- Enhancing the efficiency of data access. With an increasing number of cloud services, the demand for accessing data resources (e.g., images, files, and documents) on the cloud increases. As a result, a method to deal with (i.e., store, manage, and access) data resources on clouds becomes a significant challenge. However, handling the data resources on clouds is not an easy problem because of the low bandwidth, mobility, and the limitation of resource capacity of mobile devices. (Dinh et al., 2013)

3.3.2 Wireless Communication Technology

3.3.2.1 Introduction

Wireless communication is the transfer of information over a distance without the use of enhanced electrical conductors or "wires". The distances involved may be short (a few meters as in television remote control) or long (thousands or millions of kilometers for radio communications) (Bhalla et al., 2010).

The current wireless systems include cellular telephone systems, cordless phones, wireless local area networks, wide-area wireless data services, broadband wireless access, paging systems, satellite networks, low-cost and low-power radios (Bluetooth and ZigBee), and ultrawideband radios. (Goldsmith et al., 2005)

Existing technologies include Wi-Fi (IEEE 802.11xx), WiMAX (IEEE 802.11xx), Long Term Evolution (LTE), wireless sensor networks, wireless ad hoc networks, and particularly future fifth-generation (5G) technologies will highly focus on the development of intelligent transportation systems of terrestrial and aerial vehicles. (Briso-Rodríguez et al., 2017)

3.3.2.2 Usage

Wireless communication technology plays an important role in automated transport systems. For example, it is widely used in a high-speed train (HST) network for critical and non-critical communications. Critical communications between HST and infrastructure are used for the control signaling to increase speed, efficiency, safety, and reliability. To guarantee this performance, it is necessary to achieve very high-quality communications systems with redundancy and improved reliability. GSM-R is widely used in HST. Currently, railway operators want to improve the performance of the trains and move to automatic driving so that they need a new high-capacity wireless communication system able to include high-quality video transmissions from train to control center. Non-critical communication links can be used for several purposes like video transmission for railway incidents or infrastructure monitoring, or as a moving relay for emergency communication. Wireless sensors and ad hoc networks used for security and monitoring are now being used to provide supplementary services to vehicles. Furthermore, the use of millimeter-wave (mmWave), terahertz (THz), and satellites will be relevant in the future to provide vehicle-to-vehicle communications, radar sensors, and onboard communications for different vehicle applications. As transportation systems become more automated, vehicles have an increasing demand for communications and are being equipped with more wireless communications services and sensors. (Briso-Rodríguez et al., 2017)

Connected vehicles can use wireless communication to exchange sensor data, allowing them to enlarge their sensing range and improve automated driving functions. It needs to develop a communication approach for high bandwidth connected vehicles as vehicles are being equipped with more sensors generating even higher data rates. Millimeter-wave (mmWave) is an approach on top of dedicated short-range communication or 4G for fully connected vehicles. It is likely to be a part of 5G cellular. The use of mmWave provides access to high bandwidth communication channels, leading to the potential for gigabit-per-second data rates and realizing raw sensor data exchange among vehicles and infrastructure. (Choi et al., 2016)

A wireless networking system is proposed for remote container monitoring. The system integrates RFID, sensors, ZigBee, cellular mobile network, and satellite mobile network to support both local data collection and remote data transmission. When the containers are transported at sea, long-distance wireless communications technology needs to be available. The cellular mobile network and the satellite mobile network are two long-distance data transmission methods that can be used for ships. (Bai et al., 2010)

Wireless vehicular networks play an important role for Intelligent Transport Systems to shape multimodal logistics. The usage is investigated in a multimodal case of a port terminal handling bulk material transported by sea. Among the various technologies used to support ITS, wireless vehicle networks represent a fundamental component, which will influence future transportation and logistics operations. The wireless vehicle networks used in ITS are in the form of Dedicated Short-Range Communication (DSRC). DSRC, as the platform, can be used to support data exchange among different port users, such as road haulers, shipping lines, and port operators. (Mondragon et al., 2012)

3.4 Summary

The technologies mentioned above have a great influence on the process of digitalization in the maritime industry. Technologies like 3S technology, AIS, EDI, and PCS already have well-established applications for the shipping lines, port authorities, etc. Applications of RFID, Big Data, Cloud, and IoT in this industry are still under development to a mature phase. The shipbuilding companies, shipping lines, and port authorities have the interest to use them to improve their logistics and business. And these applications may have lower barriers for small- and medium- companies to use. Technologies like blockchain and CPS may not only improve but also change the business process in the future. For each technology, we may evaluate it by the Technolgy-Portfolio according to Pfeiffer and analyze the relations between the technology and process innovation by the portfolio according to Lager.

As shown in Figure 3-8, technology attractiveness refers to the technical-economic advantages that can be gained, considering three indicators, i.e. further development potential, range of application, and compatibility. Resource strength means to what extent the evaluated company has the prerequisites compared to its potential competitors to successfully implement the technological alternative, considering three indicators, i.e. technical-qualitative degree of mastery, potentials, and action speed.

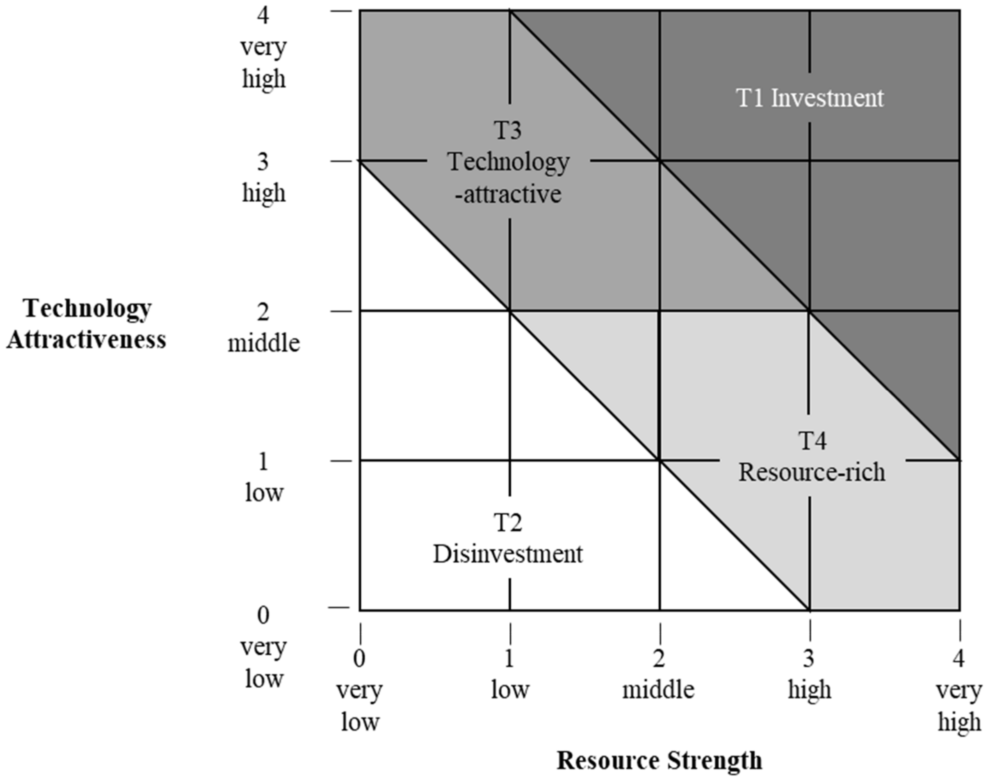

Figure 3-8 Pfeiffer technology portfolio with recommendations for action (Wikipedia)

3S technology, used for monitoring and navigating vehicles and tracking containers, has high technology attractiveness for shipping companies. It brings a lot of benefits when integrating with other technologies, such as RFID, maritime navigation systems, etc. As a result, this technology has already been largely used by the shipping industry.

AIS is used for navigating vessels. AIS data is also available for trajectory prediction and ship performance analysis. The integration of AIS with other systems like shore-side traffic control systems brings more potentials to the logistical procedures. Due to the need to enhance the safety of shipping, AIS is required to install on all ships of 300 gross tonnages and upwards engaged on international voyages and cargo ships of or above 500 gross tonnages by IMO.

RFID is taken as the next generation of bar codes as well as one of the pivotal enablers of the IoT. It is compatible with GPS to track objects and with terminal management systems to manage containers. Consequently, RFID is a very highly attractive technology for developing Smart Port. The real-time information from RFID, sensors, and other devices forms the Big Data. It can be stored and computed by the Cloud. The nodes of sensors, RFID, and other devices are interconnected by WSN and provide an IoT environment. And when it is developed to a self-configuration level, the CPS is implemented. These technologies collaboratively contribute to autonomous shipping and automated port and are all highly technology attractive for the shipbuilding industry and port authorities.

As shown in Figure 3-9, the newness of a process to the world (technology innovation) is distinguished into three degrees, i.e. the low degree means the process technology is well known and proven; the medium refers to an improvement of previously known technology; the high degree represents completely new and innovative. The newness to the company (process innovation) is also evaluated by three levels, i.e. the low means the process technology can be used in existing process plants; the medium requires plant modifications or additional equipment; the high requires a completely new process plant or production unit (Lager et al., 2002). In maritime shipping, digitalization may influence the business process of each maritime actor as well as the whole maritime logistics chain.

The four areas in the matrix classify the process development into four categories. The group of optimization opportunities refers to the refinement of an existing process but not the development of a new process. The group of technology transfer is to improve the process based on proven technology, applying it in part or as a whole in the company production plant. The radical and risky category is a real process innovation and should be with caution by a small company. The competitive and cheap category is an attractive area for process development and initiatives should be encouraged (Lager, 2002).

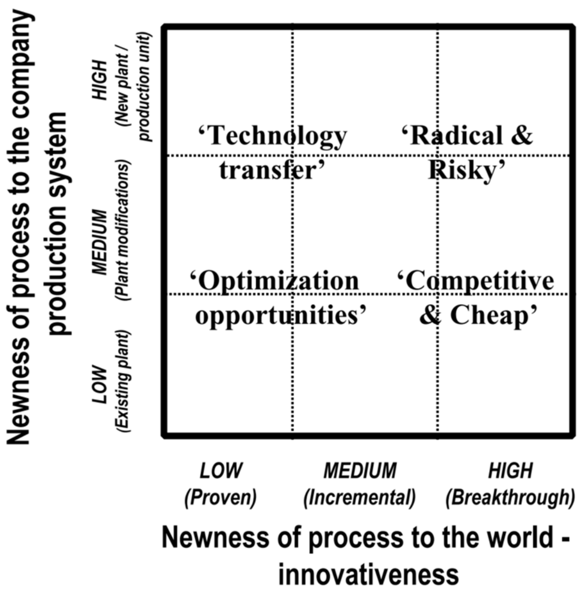

Figure 3-9 Four areas of process development in the process matrix and their denominations (Lager et al., 2002)

EDI and PCS are not new technologies to the world as well as to the maritime actors, and they have been used in the maritime business for over 30 years. These technologies can be classified into a group of optimization opportunities. The development of the technologies will better support and improve the commercial and regulatory process in maritime shipping. Blockchain technology is grouped into the radical and risky category. The use of this technology in the maritime industry is highly recommended but mature applications and functions are still under exploration.

Mobile technology extends the e-commerce to mobile-commerce and the e-Government to mobile-Government. Ports have developed their mobile apps to perform and assist port services. Hinterland transportation companies are the main users of these apps. A mobile navigation system is also designed and mainly used by tourists, sailors, etc., but not for shipping lines at present. Mobile technology is not new, but the functions of applications for the maritime industry are still under exploration and enlargement. Online services may all have chances to develop their mobile apps. Consequently, this technology is in the technology-attractive group according to Pfeiffer's matrix and brings a technology transfer in the process development considering Lager's categorization.

Wireless communication technology is an information infrastructure supporting IoT, mobile applications, e-Navigation, autonomous shipping, automated ports, etc. It is a proven technology but undergoes several generations with more developed techniques to achieve higher data rate and quality, longer-distance communication, and more formats of information. This technology is highly attractive and should be invested in the era of automation. And the investment usually performs a technology transfer from one generation into another one.

4 Developed Concepts that Improve the Information Flow

4.1 Single Window

4.1.1 Background

In international trade, an extensive range of information and documents are prepared and submitted to governmental authorities to comply with the import, export, and transit-related regulations. These requirements place a heavy burden on the resources of companies and can constitute a serious barrier to the development and efficiency of international trade, especially for small and medium enterprises. Facilitated by the ICT development, the time and cost of these regulatory procedures have been largely improved as authorities have introduced and run their computer systems for the operations respectively. Government agencies are traditionally organized through a variety of separate departments, which may have limited connection with each other either technologically or in the way their services are delivered. Therefore, the interoperability of each system also harms the benefits and efficiency. To further development, the Single Window concept is recommended by UN/CEFACT to avoid the repeated submission of the same information to different systems and to add in more services on the platform such as providing facilities for payment of relevant duties, taxes, and fees. (United Nations Centre for Trade Facilitation and Electronic Business, 2005)

UN/CEFACT's mission is to improve the ability of business, trade, and administrative organizations through the simplification and harmonization of processes, procedures, and information flow for developed, developing, and transitional economies to exchange products and relevant services effectively, and so contribute to the growth of global commerce. In international trade, various government agencies participate in the legislative powers and cross-border processes. These authorities control and manage different levels of regulation about health, plant and animal quarantine, sanitary and phytosanitary, food and drug safety, defense, etc. Agencies other than Customs that are involved in the regulation of cross-border trade are termed Other Government Agencies (OGAs). There are often between 20 and 40 of OGAs involved in cross-border trade, but the number varies among countries.

In 2005, UN/CEFACT enacted the document Recommendation No. 33 to enhance the efficient exchange of information between trade and government. (United Nations Centre for Trade Facilitation and Electronic Business, 2005)

To improve the implementation of Single Window, besides the agreements among governments, three other aspects should be considered and improved, which are data simplification and standardization, legal framework, and system interoperability. Recommendation 33 on implementing a Single Window has been widely received as the reference on the subject and is used as the basis for many other organizations' work as well as the cornerstone of many national implementations around the world. Recommendation 34 provides guidelines for data simplification and standardization for international trade. Recommendation 35 in 2013 is about the topic of establishing a legal framework for an International Trade Single Window. Following the World Trade Organization's (WTO) Trade Facilitation Agreement (TFA) in 2013, an increasing number of governments are demanding interoperability between NSWs. Recommendation 36 in 2017 is proposed to improve the Single Window interoperability.

The TFA among WTO members has worked on the cross-border process in international trade. In article 10.4.3, it requires members to endeavor to establish or maintain a Single Window, enabling traders to submit documentation and/or data requirements for importation, exportation, or transit of goods through a single entry point to participating authorities or agencies. After examination of the documentation and/or data, the results shall be notified to the applicants through the Single Window promptly. The same documentation and/or data requirements shall not be requested by participating authorities or agencies except in urgent circumstances and other limited exceptions. Until now, the TFA implementation rate for the entire WTO membership stands at 69.7% based on developing and Least-Developed Country (LDC) members' notification as well as developed members' commitments. Figure 4-1 below equates to a 100% implementation rate by developed members, 70.2% among developing counties, and 35.6% among LDC members.

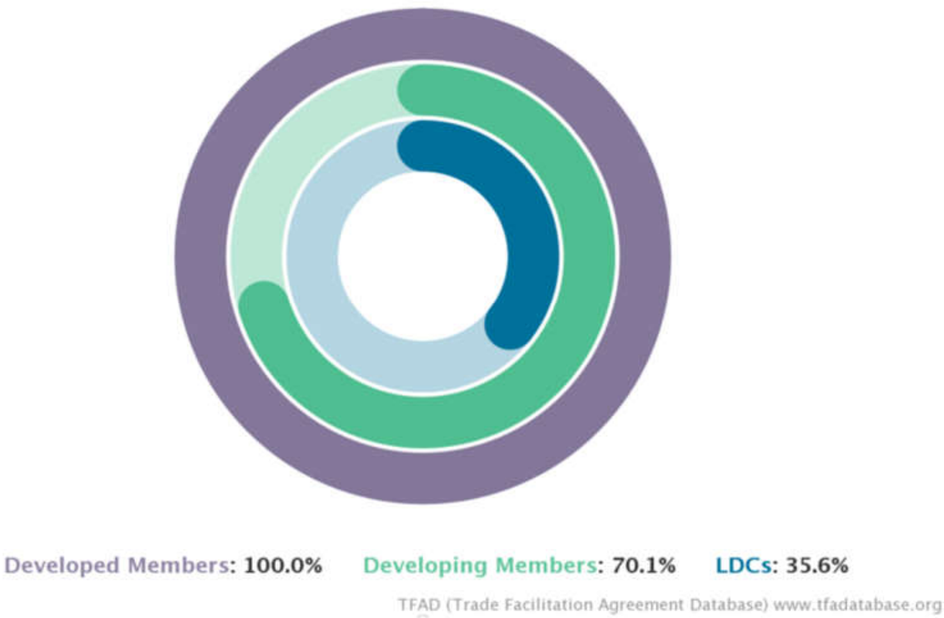

Figure 4-1 Rate of implementation commitments

Many countries have recognized that the Single Window can greatly improve the implementation of standards, techniques, and tools for simplifying and expediting information flows between traders and the government. It can also simplify processes, harmonize data, and improve the sharing of relevant information across governmental systems. The initial concept according to which the trading community can submit information and documents to government authorities in compliance with regulatory requirements implies a national or countrywide facility for all trade transactions. Single Window has been largely promoted and implemented over years by different authorities and organizations, such as port authorities, national governments, regional organizations, World Customs Organization (WCO), etc.

4.1.2 Concept and Characters

In Recommendation 33, the Single Window concept refers to “a facility that allows parties involved in trade and transport to lodge standardized information and documents with a single entry point to fulfill all import, export, and transit-related regulatory requirements. If information is electronic, then individual data elements should only be submitted once.” Recommendation 33 states that “a Single Window should represent a close cooperation between all involved governmental authorities and agencies and the trading community”. It challenged the conventional “compartmentalized” approach to regulatory control of the movement of goods. (United Nations Centre for Trade Facilitation and Electronic Business, 2005)

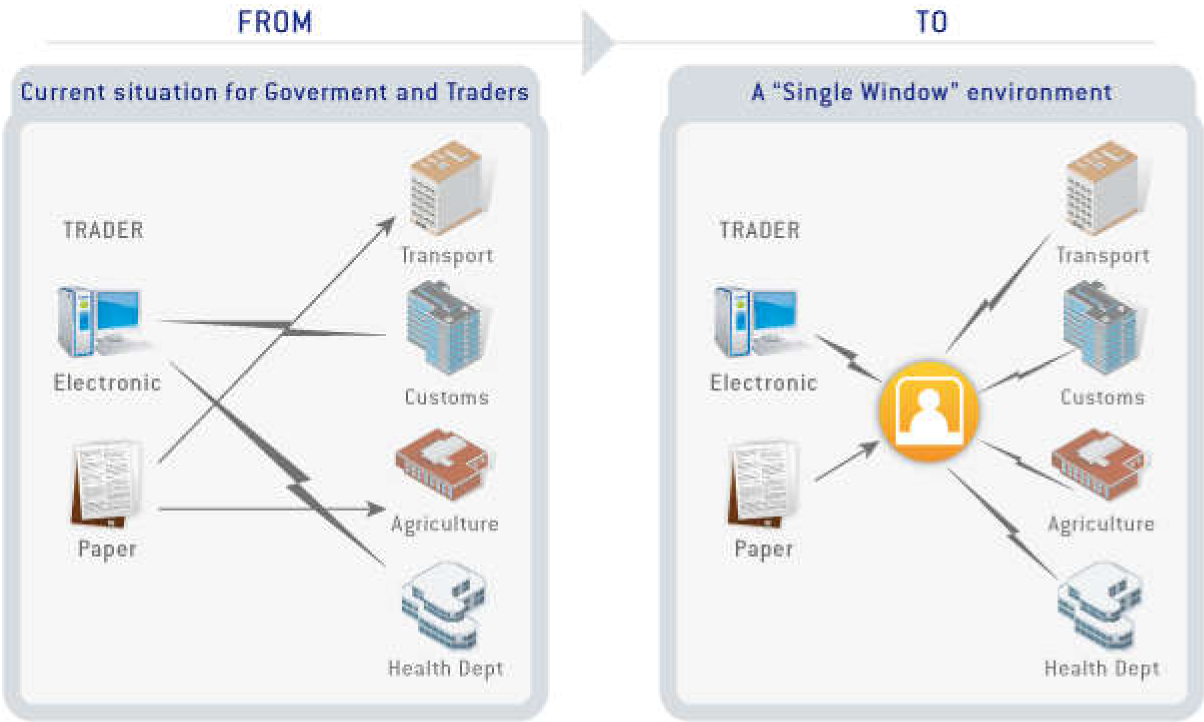

Figure 4-2 Comparison to a Single Window environment (United Nations, 2012)

Based on these definitions as well as analysis of regional best practice cases, the following key features of the Single Window can be drawn: single entry; single submission; paperless environment; standardized documents and data; sharing of information (information dissemination); centralized risk management; coordination of agencies and stakeholders; analytical capability; and electronic payment. (Ten Years Single Window)

4.1.3 Models

Recommendation 33 has introduced three basic models for the Single Window which are a Single Authority Model, a Single Automated System Model, and an Automated Information Transaction System. For the Single Automated System Model, there are three sub-models, i.e., integrated one, interfaced one, and a mixed one.

1) A Single Authority Model

A single authority model, as shown in Figure 4-3, means that one authority receives information, either on paper or electronically, disseminates this information to all relevant authorities, and coordinates controls in the logistical chain. The single authority may behalf on or cooperate with other authorities on the regulatory procedures. For example, the Sweden Customs has a long-standing tradition of being the only public service at Swedish borders, performing several tasks for other public services such as the National Board of Trade and the Swedish Board of Agriculture. Thus it was a natural process of involving all such partner agencies in the design and development of IT systems supporting the overall process of foreign trade. Customs duties can be paid automatically between the Swedish Customs and the National Debt Office, and also the European Commission through the system.

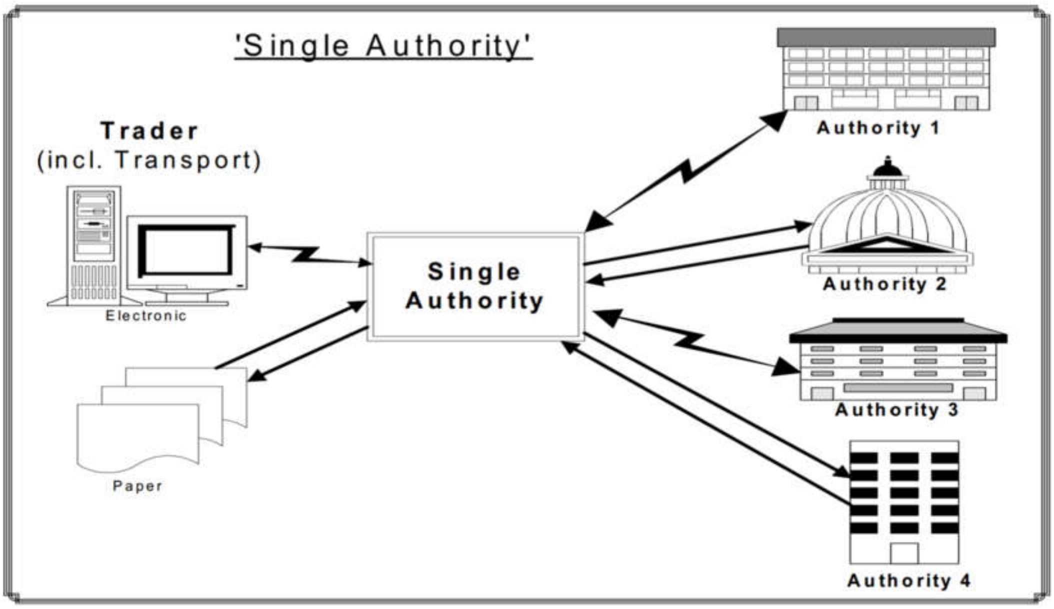

Figure 4-3 A single authority model (UN/CEFACT, 2005)

2) A Single Automated System Model

A single automated system, as presented in Figures 4-4 and 4-5, means a platform (either public or private) collects, integrates, uses, disseminates, and stores the information related to the border trade. The platform may integrate with or provide interfaces to the related authorities' systems. For example, the US International Trade Data System (ITDS) is an interagency program to establish a single window through which data required by government agencies for international trade transactions may be submitted. The technology backbone for ITDS is the Automated Commercial Environment (ACE). ACE provides centralized online access to connect US Customs and Border Protection, the trade community, and Partner Government Agencies. It will ultimately become the single window for all trade and government agencies involved in importing and exporting. For the interfaced system, it is common in the Regional Single Window that several government authorities cooperate to improve the interoperability of their NSWs in the circumstance of the economic community.

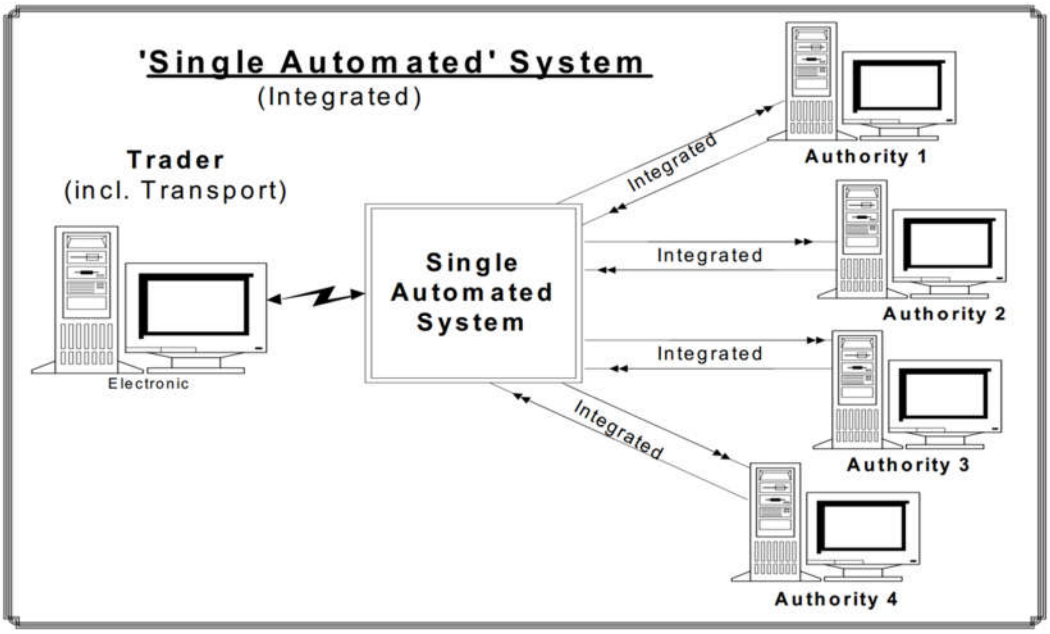

Figure 4-4 A single automated integrated system (UN/CEFACT, 2005)

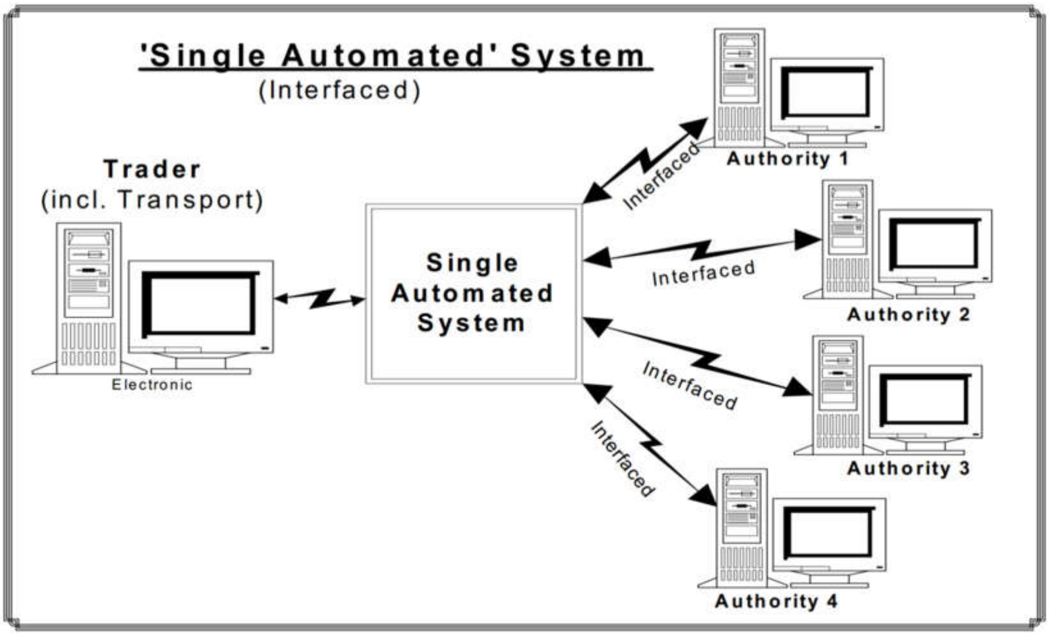

Figure 4-5 A single automated interfaced system (UN/CEFACT, 2005)

3) An Automated Information Transaction System Model

An automated information transaction system, as shown in Figure 4-6, refers to an application where traders submit electronic trade declarations to various authorities for processing and approval. Approvals are transmitted electronically from the government authorities to the trader's computer in the system. For example, TradeNet is Singapore's National Single Window for trade declaration. Through TradeNet, Singapore Customs and other Competent Authorities monitor the movement of goods and enforce health, safety, and other regulatory requirements.

It expedites the clearance of containers and allows fees and taxes to be deducted electronically. Furthermore, the Singapore government introduced a Networked Trade Platform (NTP), which is a one-stop trade and logistics ecosystem that supports digitalization efforts and connects players across the trade value chain. With NTP, the approved TradeNet permit can be directly returned in structured data format to the trader's NTP data repository for data reuse for other service transactions via NTP. The relation of TradeNet and NTP is shown in the figure. NTP functions as the second model – a single automated system. (Singapore Customs, 2021)

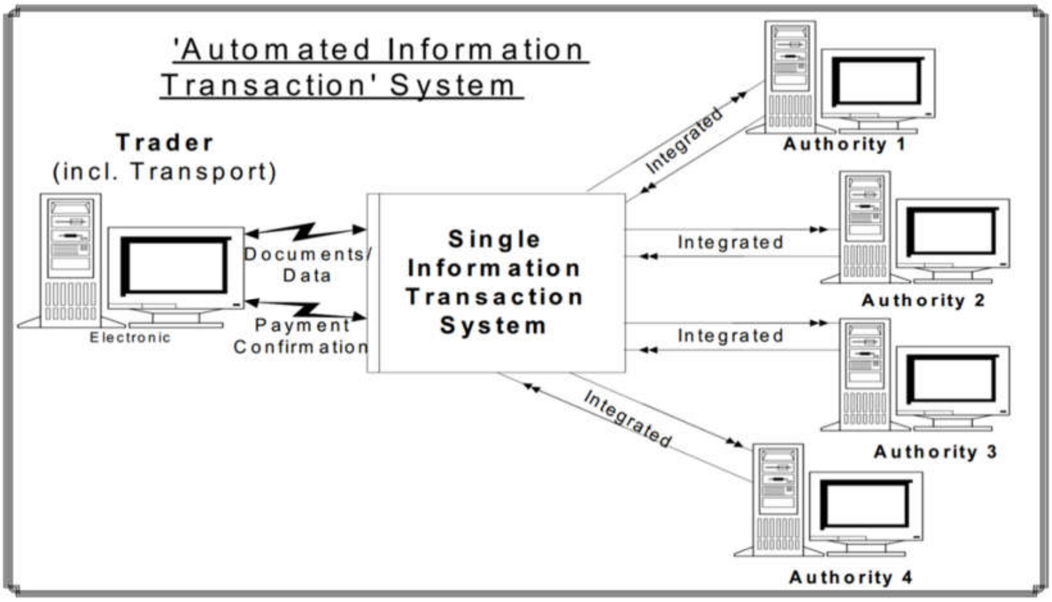

Figure 4-6 A automated information transaction system (UN/CEFACT, 2005)

From above, we can see the Single Window can be public or private. It can function as an information center or a trade transaction center. It largely simplifies the information flow between traders, customs, and other government agencies. Consequently, the time and cost for border trade processes are both decreased.

4.1.4 Standards

The use of international standards for import, transit, and export formalities is an important trade facilitation tool, and it is central to the Single Window interoperability. To build a NSW, it is necessary to create a national dataset that will harmonize and standardize the data to meet the needs of multiple agencies with a single economy. The national datasets should be aligned to the recognized international standards. Then it will be used to meet domestic trade needs, as well as for incorporation into other NSWs in any bilateral arrangements or regional trade agreements.

A dataset is a sort of library or dictionary with all of the information requirements for a particular application, system, or purpose. It is important to eliminate all repetition and redundancy in the dataset. UN/CEFACT has developed the Core Component Technical Specification (CCTS) 2.01 to make a common set of semantic building blocks for representing the general types of business data in use, creating new business vocabularies, and restructuring existed ones. At the dataset level, Core Component Library (CCL) has been developed, as well as other standards that are conformant to the CCL, such as the World Customs Organization Data Model, the International Air Transport Association's CargoIMP, and CargoXML standards. At the business process level, UN/CEFACT has established a modeling methodology based on the Unified Modelling Language (UML) which is called the UN/CEFACT Modelling Methodology (UMM). At the messaging level, UN/EDIFACT has been developed for over 20 years and is widely used. UN/CEFACT also has an XML schema library. Another prominent syntax for Single Window development is the World Customs Organization's Data Model which is directly aligned with UN/EDIFACT. (Recommendation 36)

4.1.5 Information Technologies

ICT and the Internet are the basic technologies to realize the Single Window. In international trade, EDI technology has changed the documents from the paper version to the electronic version. The charted international EDI standard, UN/EDIFACT, has developed a structure for exchanging information between public administrations and private companies of all economic sectors worldwide. Single Window system has also developed from the EDI-based system to the web-based system.

Before the widespread of the Internet, Single Window systems would require front-end clients for traders, which are software programs that have to be installed at the traders' premises. Then it needed continued support and maintenance of the front-end clients. These incur an additional cost for the traders and become a barrier for a large number of small- and medium-sized enterprises that have no enough investments in EDI systems. Today, the pervasiveness of the Internet and its associated technologies have paved the way for Single Window implementation and development. More web-based services imply lower entry costs, thus more preferential for service users.

Another ICT innovation that significantly impacts the Single Window is the Services-Oriented Architecture (SOA). An SOA utilizes methodologies for designing and developing software to enable interoperability. Designing the Single Window using SOA principles will enable a web-based Single Window environment to integrate widely disparate systems and applications and to use multiple implementation platforms. Hence, a Single Window using the SOA integration approach provides a flexible integration model for online and transactional processing through a messaging architecture.

Three more significant advances in ICT development are expected to dominate the Single Window development landscape in the coming years: cloud computing, mobile computing, and blockchain.

- Single Window and Cloud Computing

The public or private actors who run the may use cloud infrastructure to outsource the chore of building and maintaining a data center. Companies, like Amazon, Google, Alibaba, etc., all have services to supply the cloud infrastructure. For the cloud computing application, the single window platform either resides in a web browser or runs as a separate application on the users' computer and directly communicates with servers in the cloud. The single window system may use cloud computing to integrate, synchronize, and share data to provide different services. For example, the file synchronizing and sharing function of the cloud can be applied to intra- as well as extra- organizations. Advanced uses of the cloud aim at improving efficiency and providing value-added services that the single window operator could consider to improve and enlarge the scope of the services for the cross-border trade from all the commercial, logistical, regulatory, and financial perspectives. (Hayes et al., 2008; Arnold et al., 2013)

- Single Window and Mobile Technology

The ubiquitous mobile computing and RFID is a phenomenon that will change the way trade transactions will be done in the coming years. The combination of smart devices, tablets with scanners, and wireless technology will transform the logistics and supply chain into dynamic, highly traceable, and visible environments. Data and information shall be captured in real-time while the container is on the move. All these will also transform the Single Window landscape drastically. The government could develop mobile apps for cross-border procedures as mobile-EDI is also a developing trend.

- Single Window and Blockchain

Blockchain and smart contracts cloud help administer border procedures and national single windows in a more efficient, transparent, and secure manner, and improve the accuracy of trade data, thus facilitating business-to-government (B2G) and government-to-government (G2G) processes at the national level. Blockchain has large potential to facilitate cross-border G2G interactions, moving to a truly global paperless blockchain-based single window system.

Blockchain could facilitate national G2G and certain B2G border procedures in the single window system. By blockchain technology, the information exchange is in real-time, highly secure, decentralized, and automated through the use of smart contracts. For certain B2G procudures, it could prove useful to the following aspects: (1) B2G and national inter-agency coordination, all information is shared on a common platform replacing it in a sequential manner in the traditional system; (2) certification and licensing, it streamlines the approval workflow of certificates, avoids the request for a replacement certificate for the split shipment as blockchain transactions include a reference to previous transactions, administers import and export licenses more efficiently as storing licenses for importers and exporters that allow customs authorities to check easily, and issues the electronic certificate of origin especially when the blockchain traceability uses become more widely implemented; (3) release and customs clearance of goods, it enhances the efficiency and reduced the need for manual verification by submitting requests for advance rulings, facilitating pre-arrival processing, optimizing risk management, etc.; (4) temporary admission of goods, it moves away from today's paper-intensive process for the temporary admission procedure; (5) revenue collection and accuracy of trade data, payment of customs duties could be automatic transferred by encoded smart contracts using an "if…then…" formula, or colleted by permitted intermediaries on behalf of governements; (6) post-clearance audit, the immutable nature of blockchain makes it possible to easily track and audit transactions; (7) compliance management; and (8) identity management, blockchain could facilitate the vertification of identities of businesses and individuals, including authorized economic operators (AEOs). For cross-border G2G processes, blockchain's decentralized nature is seen by many actors in the field as an opportunity to help overcome some of the challenges that make the processes complex or risky. It helps to alleviate the risks associated with certain types of processes, such as the sharing of information related to AEOs, thus facilitates the implementation of AEO mutual recognition agreements.

The implementation of blockchain technology largely relies on national legislation which has to be examined and adjusted to provide a conducive regulatory framework for e-authentication methods and give legal recognition to e-signatures, e-documents, and e-transactions. In conclusion, governments need to work on technical interoperability issues, a conducive regulatory framework, and data simplification and standardization. All aspects of cross-trade transactions should be digitalized, and the semantics are aligned, i.e., what specific information is communicated by the data elements. International organizations such as the International Chamber of Commerce (ICC), International Organization for Standardization (ISO), United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT), and the WCO, have created working groups to initiate discussions to look into the issue and develop interoperability standards. (Tsen et al., 2011; Ganne et al., 2018)

4.1.6 Forms and Cases

1) Forms

Many developed countries do not have a National Single Window or have only started to work on Single Window implementation. Most countries of the European Union have no National Single Window. On the other hand, many countries in Africa, Asia, and Latin America have started or completed National Single Windows.

Figure 4-7 shows different forms of Single Windows and their evolution. In the beginning, the Single Window can be customs-centered or port-centered, which refers to Customs Single Window (CSW) and PCS. These are limited Single Windows that do not support all the regulatory procedures in cross-border trades and have their individually focused tasks. To expedite the customs clearance procedure, PCS is connected with CSW to improve the sharing of information as well as provides services to support cross-border transactions. This form of Single Window has a B2G character. As PCS and CSW are long-existing systems along under the technology development like EDI, Internet, etc., it brings challenges to integrate them into a National Single Window.

Before evolving into a NSW, there are also cases of Local Single Windows (LSW) especially in the nation with a large area. Local trade communities and regulatory agencies can be grouped into the Customs Single Window at a city or provincial level. The next form of the Single Window evolution is a NSW, which is a facility at a national level that provides a single portal for the government agencies, the trading community, the logistical companies, and the financial agencies to submit standardized information only once, and to fulfill all the import, export, and transit-related regulatory requirements. Singapore is one of the leading countries to establish a NSW. The LSW and NSW both have B2G and G2G characters, and they also develop to include the B2B communication. NSW also relates with the new concepts of electronic-Government and mobile-Government. However, government agencies are traditionally organized to develop their systems in a separate way. It brings technical challenges to integrate their systems as well as keep their independent characters.

Regional Single Window and Global Single Window may be connections of Customs Single Windows, such as EU Single Window Environment for Customs and the ASYCUDAWorld customs system that is now running in more than 70 countries and territories around the world. They can also be a decentralized center for National Single Windows in a region, such as ASW from ASEAN, and a Single Window platform for the Pacific Alliance.

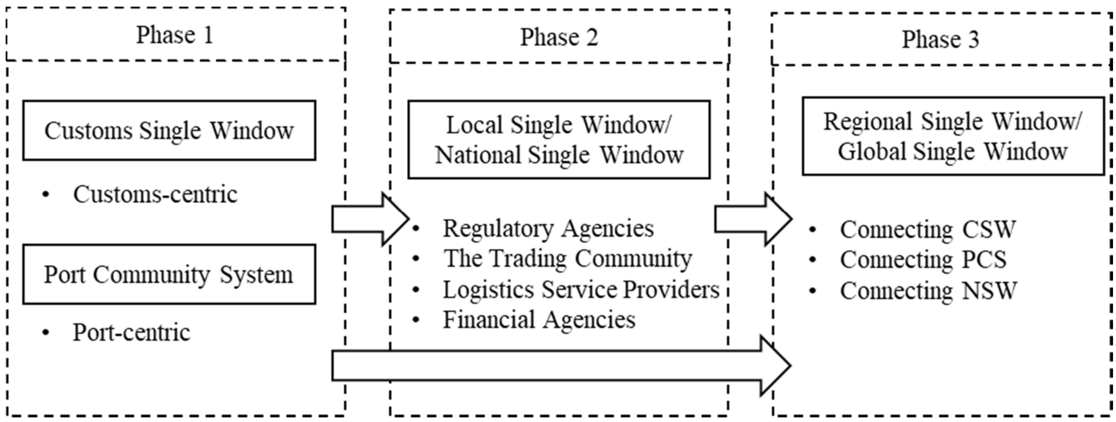

Figure 4-7 The evolution of the Single Window

2) Cases

Firstly, cases of CSWs are introduced. They are implemented either on a national level or a global level. Usually, the systems are initiated by government authorities directly or an international organization, and they could also be run by private companies like the case in Hong Kong. Secondly, cases of NSWs in Singapore and Korea have been introduced as well as their CSWs and the relations between the two forms of SWs. Finally, the examples of Regional Single Window (RSW) are represented under the circumstances of the regional economic community, such as ASEAN, East African Community, Pacific Alliance, and EU.

- ASYCUDA

ASYCUDA is a computerized customs management system provided by UNCTAD. The system handles manifests and customs declaration, accounting procedures, transit, and suspense procedures. Besides, the generated trade data from the system can be used for statistical economic analysis. From 1981 to current, ASYCUDA has undergone four versions which are ASYCUDA V1, ASYCUDA V2, ASYCUDA++, and ASYCUDAWorld. In the beginning, it is a tool proposed by UNCTAD due to the request for assisting in the compilation of foreign trade statistics from the Economic Community of Western African States. After decades of development, the new version ASYCUDAWorld has become a Global Customs Single Window, being implemented in over 90 counties, territories, and regions shown in Figure 4-8.

Figure 4-8 A map overview of countries using ASYCUDA

ASYCUDA is based on WCO Data Model to define a set of standardized data usable by both Customs Administrations and all trade operators, for electronic data exchange within the customs clearance process, i.e., manifest, permits, customs declarations, etc. The SAD is used as the customs declaration forms.

- Hong Kong SAR, China

The Government appointed three service providers (SPs) to offer Government Electronic Trading Services (GETS) from January 2019 to December 2024. The three SPs are appointed by an open tendering exercise, which are Brio Electronic Commerce Limited, Global e-Trading Services Limited, and Tradelink Electronic Commerce Limited.

GETS is an electronic service platform through which the trading community submits trade-related documents to the Government for customs control, trade declaration, trade control, and statistics compilation purposes. GETS SPs collect data electronically from traders or carriers, confirming their identities, and validating and transmitting the data to the government's backend systems. They offer services for the submission of import and export declarations, dutiable commodities permits, cargo manifests, and certificates of origin, as well as for converting paper submissions into electronic ones. Within the six years' contract, GETS is expected to transit from a CSW to a Trade Single Window (TSW) upon its full implementation in the future.

- Korea

UNIPASS and uTradeHub are two Single Windows in Korea, which refer to CSW and NSW respectively. UNIPASS is a web-based customs clearance portal where traders and customs brokers can conduct customs clearance business free of charge. It is a 100% electronic clearance portal system. The uTradeHub, as shown in Figure 4-9, has been launched in 2007 under a project to build e-Trade (paperless trade) services as a part of the e-Government agenda by the Ministry of Knowledge Economy and the Korea International Trade Association (KITA). Trading companies can use the uTradeHub to fulfill trading processes such as marketing, market research, customs clearance, logistics, banking, and negotiations.

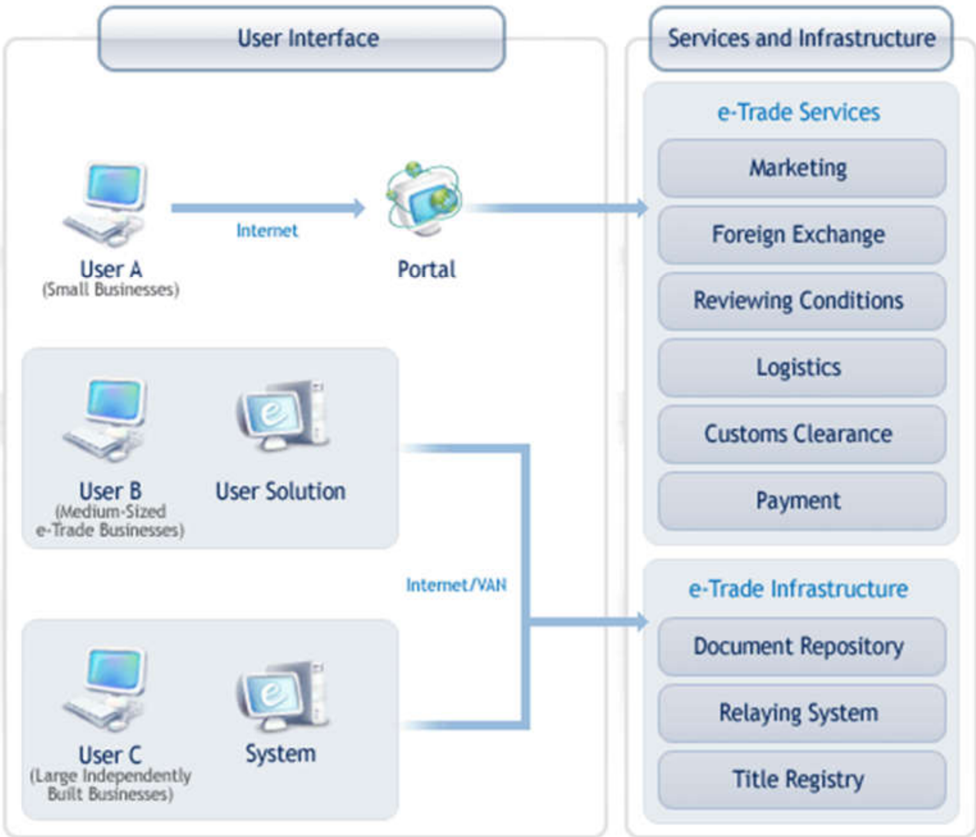

Figure 4-9 The user interface of the uTradeHub

Currently, UNIPASS and uTradeHub are providing a paperless trade environment covering all trade procedures. However, there is no strong institutional arrangement for harmonization and coordination of these two gigantic national platforms. The new system will be adapting the concept of a platform with open innovation and features for cross-border e-commerce. (ESCAP, 2018)

- Singapore

Singapore's TradeNet is a nationwide Customs Single Window integrating import, export, and transshipment documentation processing procedures and enables the trade and logistics communities to fulfill their trade formalities. With a single point of entry for the submission of a single declaration to multiple regulatory agencies, TradeNet reduces the cost and time to prepare, submit and process trade documents.

The NTP is a one-stop trade and logistics ecosystem that supports digitalization efforts and connects players across the trade value chain in Singapore and abroad. It works as a National Single Window facilitating e-Government objective.

Traders submit permit applications through TradeNet Frontend solutions to TradeNet for Singapore Customs to process, and TradeNet returns the approved permit to the trader via the TradeNet Frontend. With NTP, the approved TradeNet permit can be directly returned in structured data format to the trader's NTP data repository for data reuse for other service transactions via NTP. Both TradeNet and NTP currently exist in parallel. Figure 4-10 shows the work process of this trade permit application.

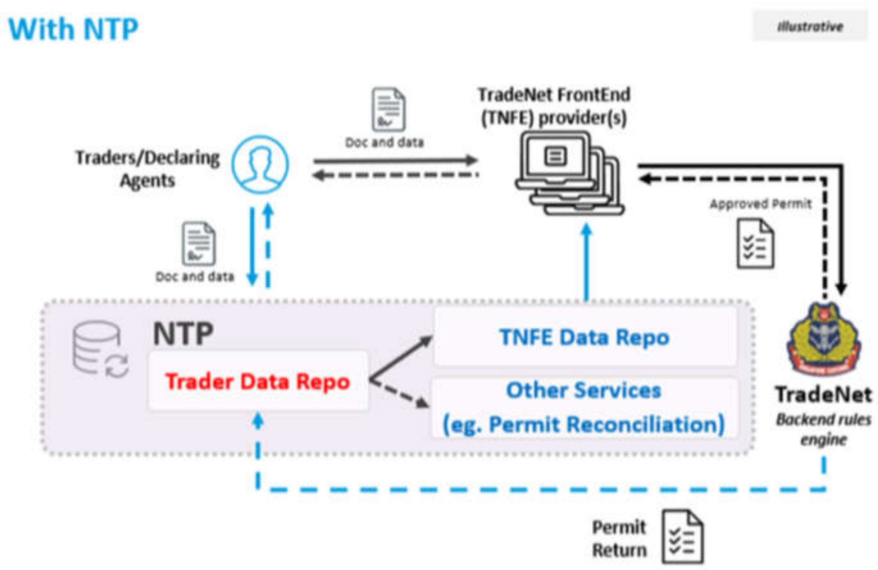

Figure 4-10 Trade permit application experience with NTP

- ASW – ASEAN Single Window

ASEAN is an economic community made up of Southeast Asian Nations, namely Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam. The ASEAN Single Window (ASW) is a regional initiative that connects and integrated the National Single Window (NSW) of the member states. The NSW of each member is connected with its customs and OGAs, transport community, and bank and insurance agencies respectively. The ASW's objective is to expedite container clearance and promote economic integration by enabling the electronic exchange of border trade-related documents among members. The preferential tariff treatment would be granted based on the

Electronic Certificate of Origin exchanged through the ASW Live Operation. To improve integration further, documents, such as ASEAN Customs Declaration Document (ACDD), electronic Phytosanitary Certificate (e-Phyto), electronic Animal Health Certificate (e-AH), and electronic Food Safety Certificate (e-FS) Certificate, are also planned to be exchanged through the ASW. Up till now, ACDD is undergoing tests and is expected to begin within 2020, and the e-Phyto Certificate is in the preparing process (ASW Home, 2021).

- East African Community

East Africa Community, composed of six economies – Burundi, Kenya, Rwanda, South Sudan, Tanzania, and Uganda, formed a Customs Union to ensure member economies have a common tariff on goods originating from non-member economies and free of customs duties on goods originating from within its members. The second version platform, Revenue Authorities Digital Data Exchange (RADDEx 2.0), has expanded to include business functions and technical improvements, including transport logistics, and near real-time transmission of customs information and support documents to authorized government agencies, economic operators, and other private sector users. RADDEx 2.0 is architecturally designed as a centralized model. The central server is located at the East African Community headquarters in Arusha, Tanzania. The servers located in each economy communicate only with the central server and not with each other (APEC, 2018). However, linking two or more information technology systems through a common interface is not always a simple process. For example, integrating Kenya's Simba system with Uganda's ASYCUDA++ through the RADDEx system has taken several years.

- Pacific Alliance

The Pacific Alliance (PA) is a regional integration comprised of Chile, Colombia, Mexico, and Peru. In the Latin American and Caribbean regions, these four countries account for 36% of the GDP and 58% of the total trade. All these four members have their Single Window System (SWS) for border-related regulatory procedures. Chile's SWS Sistema Integrado de Comercio Exterior (SICEX) was implemented in May 2013, which has achieved domestic interoperability of eight agencies, including the National Customs Service, the Agriculture and Livestock Service, and the Institute of Public Health. Colombia's SWS Ventanilla Unica de Comercio Exterior (VUCE) was first implemented in November 2006. It has streamlined 135 procedures and 35 forms needed for importing into just "one step" for traders. Mexico's and Peru's SWS solutions were launched in January 2012 and in July 2010 respectively. Now they are promoting further regional integration of individual SWS beyond the national level (APEC, 2018).

The Pacific Alliance framework and its members have adopted a hybrid model, meaning that each economy has its Interoperability Platform for exchanging trade information and documents. A central server is required for hosting mostly non-confidential and non-sensitive data for transactional record-keeping purposes and systems monitoring. This model is like a derivation of model 2 of the Single Window in Recommendation 33, that the hybrid central platform provides interfaces for the individually operating system. The cloud service is a choice to build the central server. Figure 4-11 presents the architecture of the hybrid model.

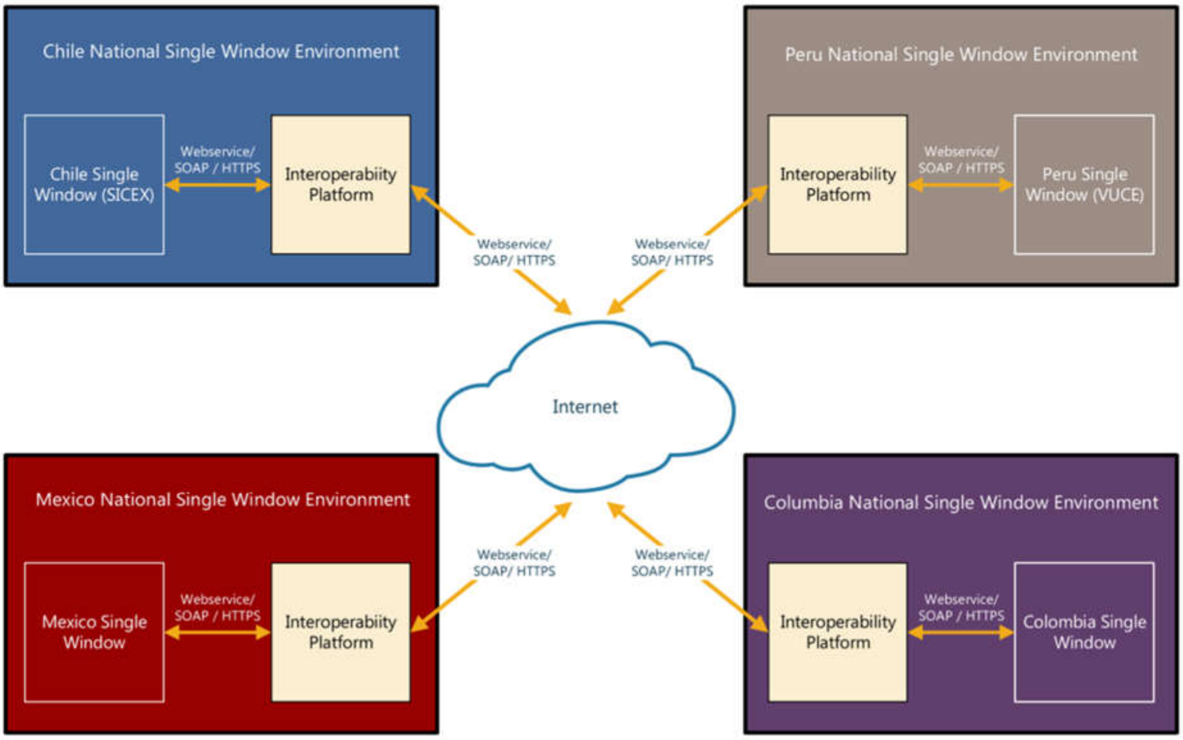

Figure 4-11 Pacific Alliance conceptual architecture (APEC, 2018)

- EU Single Window Environment for Customs

Currently, the formalities required at the EU's external borders often involve many different authorities in charge of different policy areas, such as health and safety, the environment, agriculture, fisheries, cultural heritage and market surveillance, and product compliance. As a result, traders have to submit information to several different authorities, each with its portal and procedures. The EU Single Window Environment for Customs will support the automatic verification of non-customs formalities for goods entering or leaving the EU. This proposal is to create a digital framework for enhanced cooperation between all border authorities through one Single Window. Firstly, each member state should set up its National Single Window portal, through which businesses can upload the information related to the goods they are bringing in or out of the EU. It enables traders to provide data in one single portal in an individual member state. Customs and other authorities will then be able to collectively use this data. These national portals will then link up through the EU digital framework so that all relevant authorities can access the relevant data and collaborate more easily on border checks. Ultimately, the aim is that National Single Windows will replace the multitude of different portals used by different authorities responsible for border checks. A Customs 2020 Project Group was set up in December 2016 to tackle the global vision of the EU Single Window environment for customs including the coverage for the automated acceptance and verification of certificates supporting the customs declaration, the necessary legal basis, as well as the Action Plan to establish such environment. Up till now, the Common Veterinary Entry Document and Common Entry Document certificates, which are submitted with customs declarations, are automatically verified by interconnecting the member state customs systems with the certificates' database. And this automated verification works in 9 member states. More certificates, such as Forest Law Enforcement, Certificate of Organic Inspection, Common Health Entry Document for Plant Protection, etc., are considered to be check automatically (Taxation and Customs Union – European Commission, 2020).

With the framework of its Union Customs Code, the European Union is planning at possible centralized clearance which would allow traders in one member state to make declarations in multiple member states through the Single Window platform of their own country. The member states then exchange the required data for the full import declaration.

4.1.7 Developing Trends

By recording the time and cost (excluding tariffs) of documentary compliance, border compliance, and domestic transport within the logistical process of exporting and importing goods, the world bank represents a rank list of the top 10 countries in 2019 about trading across borders' performance. There are various practices to improve the process of exporting, importing, transiting shipments, such as electronic submission and processing of information required by customs, electronic single windows, risk-based inspections, regional cooperation, trade logistics infrastructure upgrade, etc. Among these methods, submitting and processing electronic information has been one of the most common and effective ways to reduce delays in the trading process as presented in Table 4-1. Today, traders can submit all trade documents electronically in more than half of the Organization for Economic Co-operation and Development (OECD) high-income economies with no need to provide hard copies. Meanwhile, economies have increasing interests and requirements to connect not only traders and customs authorities but all agencies involved in international trade through an online single window system. The practices from Korea and Singapore are good examples to prove the benefits of the NSW.

Table 4-1 Top-performing economies through port (doing business – trading across borders, 2019)

	Economies exporting through port	Economies importing through port
1	Korea, Rep	Korea, Rep
2	Latvia	Singapore
3	Singapore	Hong Kong SAR, China
4	United Kingdom	Iceland
5	Greece	Ireland
6	Malaysia	Cyprus
7	Cyprus	Malaysia
8	Turkey	Montenegro
9	Japan	Thailand
10	Israel	China

The developing trends of Single Window are concluded below.

- About the documents and automated processes

Various documents are simplified and standardized into one document that contains all the basic and necessary information for customs declaration. For example, the UN/EDIFACT CUSCAR cargo manifest, replacing the seven copies that were previously circulated the port on paper; the e-Form D used among the ASEAN countries; and the Single Administrative Document C88 for the exportation and importation of goods.

More documents and certificates will have electronic versions and be processes automatically. Based on the differential level of technical implementation as well as regulatory requirements, SW may provide services or appoint other service providers to transmit documents from the paper version to the electronic version. The way to submit web-EDI and mobile-EDI documents should be promoted in the system. Technologies and legislations are expected to improve the use of electronic certificates, which means more e-Documents are approved by the authorities and have legal guarantees. And the systems can verify the e-Documents automatically.

- Extention of Customs Single Window/Port Community System

Customs Single Window has the potential to extend the services by building interfaces with OGAs to cover all the regulatory procedures in the cross-border trade. Customs could enable the online payment function by connecting the financial party on the Single Window. If there is a NSW, CSW should be technically connected with the NSW.

PCS can also be either as a gateway or as an integral part of a National Single Window. It encompasses exports, imports, transshipments, consolidations, hazardous cargo, and maritime statistics reporting. PCS, linking SafeSeaNet, e-customs, and other electronic systems, can enable all information to be reported once and available to various authorities. For example, data in the cargo manifest received by the PCS can be used to fulfill other regulatory requirements on behalf of the ports and carriers. As a result, the physical border is no longer that important, as it can be extended to another air, sea, or inland port, and customs procedures can be performed before exiting that physical gate and therefore acting in a national framework. (EPCSA, 2011)

While the landscape in Europe is characterized by a network of existing Port Community Systems and Customs Single Windows, the challenge for Europe is to build upon these long-established existing systems and turn them into the fuller national Single Windows that correspond to the “single entry point” criteria. The challenges also exist in other countries where the CSW and PCS are maturely developed. (Tsen et al., 2011)

- From CSW/PCS to NSW

NSW is a potential trend for countries to further build the channels for G2G, B2G, and B2B communication. It will largely facilitate the commercial, logistical, regulatory, and financial processes for both domestic and international trades. Korea and Singapore have already proved the benefits of the implementation of NSW. The European Commission also promotes the member states to build their NSWs to construct the Single Window Environment for Customs. Meanwhile, NSW is also a way to fulfill the e-Government objective. Therefore, more and more countries will recognize the benefits of NSW and put effort to build it.

- Deepening Regional Single Window

Before the NSWs connect to a global level. The countries in different regions may cooperate to integrate their systems under agreements of the individual economic community, such as the ASW for the ASEAN community, RADDEx 2.0 for the East African Community, and the

Single Window project in the EU. The actions should be considered and taken from all the standard, technique, and legislation aspects to improve the system interoperability.

- SW with new technologies such as cloud computing, blockchain, and mobile technology

The Single Window has long been constructed based on EDI technology. New technology such as cloud computing and blockchain can improve the construction and implementation of SWSs. The cloud provides a hybrid place for storing a large amount of data produced in the business process, and cloud computing can improve the full exploitation of these data and may create more value-added services. Blockchain is another technology that will transform the business process, as trades and regulatory authorities can get the guaranteed real-time data of the process directly without intermediaries. It provides correct and timely tracks of information flow for documents or shipments through platforms amongst the blockchain users. Mobile technology makes the NSW services more available with the applications. All these technologies may improve the build of NSW in the future.

4.1.8 Obstacles

As the number of OGAs, participating in the cross-border process, varies from 20 to 40 over different counties, and it's rare to find a Single Window facility covering all OGAs. Many implementers have found that the challenge of coordinating the procedural and data requirements of these different agencies into coherent and simplified procedures that could be automated is often more political than technical.

Single Window implementation on a countrywide scale is an extremely complex and costly undertaking. Creating a National Single Window requires tremendous effort, cost, changes of mindset, and more importantly, strong political will. Therefore, most governments choose an incremental step-by-step rather than a one-step approach to their Single Window projects.

The use of new technologies may bring about a set of new issues and challenges on the operation as well as legislation. They are not mature in business applications and still under exploration for business use. In the era of explosive and easily accessible data, cybersecurity and legal use should be considered. It also presents challenges on the technology development to realize the real-time flow of all the data and information on a national, regional, or even global level and to interconnect the Single Window and external systems with all related devices and appliances. Information management at the speed of thought would be the new operating envelope.

4.2 Digitalization on Maritime Shipping

4.2.1 E-Navigation by IMO

4.2.1.1 Introduction

IMO is the United Nations specialized agency as well as the global standard-setting authority with responsibility for the safety and security of shipping and prevention of marine and atmospheric pollution by ships. The IMO has defined e-Navigation as the harmonized collection, integration, exchange, presentation, and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment.

Maritime traffic accidents are caused by human error, technical failure, and external factors. One of the most important aims of e-Navigation is to prevent human error by the implementation of new tool kits and systems, supporting ship's decision making of shore-based and onboard operators (Baldauf et al., 2016). E-Navigation relies heavily on the integration of the latest navigational systems and the incorporation of global navigational satellite systems for communication, positioning information, and surveillance (OL et al., 2007).

The e-Navigation Strategy Implementation Plan (SIP) concludes 5 prioritized solutions for achieving e-Navigation, which are: S1 – improved, harmonized, and user-friendly bridge design; S2 – means for standardized and automated reporting; S3 – improved reliability, resilience, and integrity of bridge equipment and navigation information; S4 – integration and presentation of the available information in graphical displays received via communication equipment; and S5 – improved communication of VTS Service Portfolio (not limited to VTS stations). For each solution, there are required regulatory framework and technique requirements for implementation.

4.2.1.2 Architecture and Solutions

A vision of e-Navigation is embedded in the expectations for the onboard, ashore, and communications elements. The shipboard technical equipment refers to navigation systems. Core elements of such systems engage navigators to carry out the duties and prevent distraction efficiently. The ashore element refers to manage vessel traffic and related services by shore-based operators through better provision, coordination, and exchange of comprehensive data. The communication technology should guarantee seamless information transfer onboard ships, between ships, between ship and shore, and between shore authorities and other parties with many related benefits. The overarching e-navigation architecture is shown in Figure 4-12.

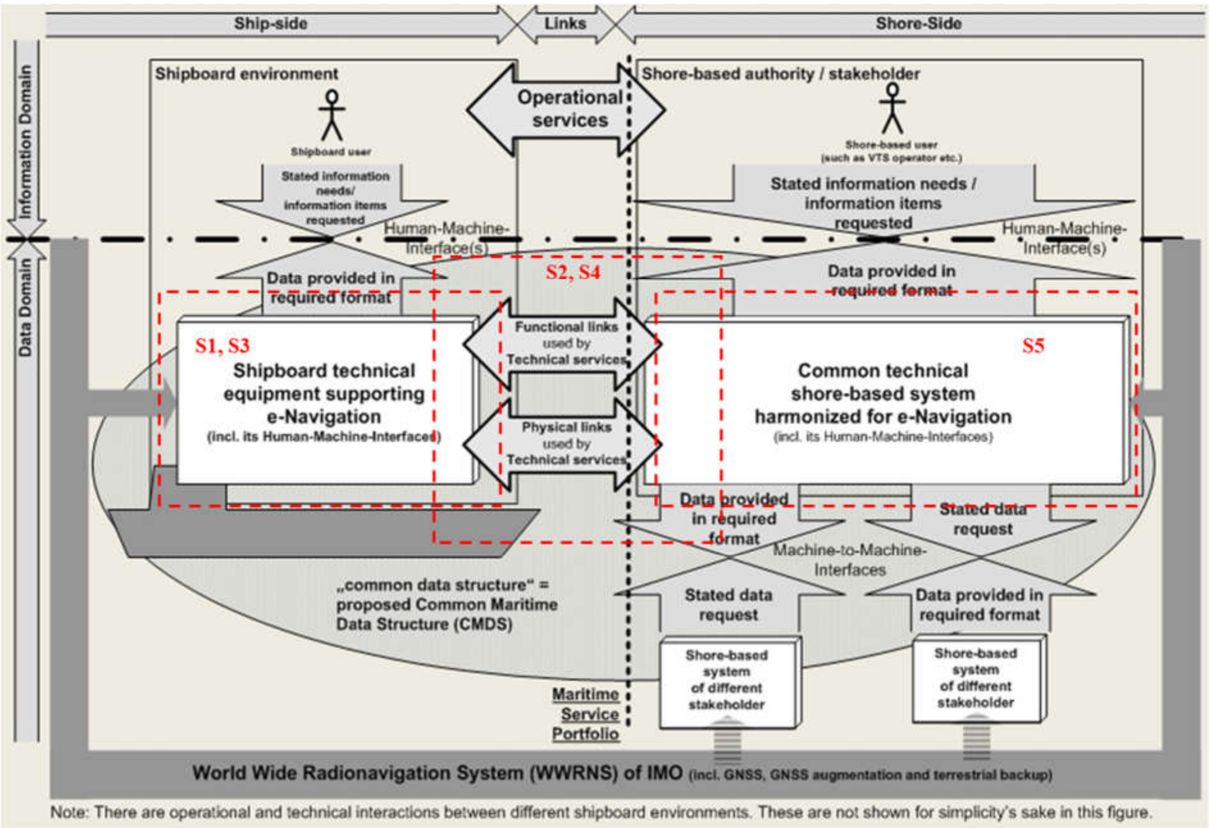

Figure 4-12 Overarching e-navigation architecture (IMO, 2018)

Based on the architecture, it can differentiate that S1 and S3 are focused on ship-side operations, promoting the workable and practical use of the information and data onboard; S2, and S4 work on ship-shore communication, improving the efficient transfer of marine information and data between all appropriate users; and S5 focus on the shore-side techniques. Table 4-2 presents an analysis of the five solutions and their enabling technologies.

Table 4-2 Analysis of the e-Navigation solutions

Focused sides	Solutions	Information Technologies and Systems
Onboard (Ship-side)	S1 – improved, harmonized, and user-friendly bridge design	ENC, ECDIS, GIS
	S3 – improved reliability, resilience, and integrity of bridge equipment and navigation information	
Ship-shore Communication	S2 – means for standardized and automated reporting	Common Maritime Data Structure (CMDS), VHF Date Exchange (VDE), digital HF/MF, satellite-based communication, etc.
	S4 – integration and presentation of the available information in graphical displays received via communication equipment	
Ashore (Shore-side)	S5 – improved communication of VTS Service Portfolio (not limited to VTS stations)	DGPS stations, AIS stations, etc

For each solution, there are different task actions as shown in Table 4-3. We can see that S1 focuses on the display of navigational information based on ECDIS, radar, Inertial Navigation System (INS), or other information systems. The aim is to standardize and integrate the data on each system, to provide graphic and reliable information for operations onboard. S2 considers reports from the ship to the shore in digital formats automatically and through a Single Window system. S3 is to ensure the reliability of bridge equipment and navigation information so that the navigator can rely on the continuous update of the ship's situation with the regard to navigational awareness. It focuses on the level of integrating the sensors, equipment, displays, and assistance systems installed on the ship's navigational bridges. S4 is to integrate the various information received via communication and to present the outcome on bridge navigational graphical displays. The objective is to avoid plotting additional information about the current situation of the ship. S5 makes sure of the availability of the Maritime Service Portfolio (MSP).

Table 4-3 Task actions of the five solutions

Solution	Task Actions
S1	• To build human-centered e-Navigation systems • To test, evaluate and assess e-Navigation systems • To extend the use of standardized and unified symbology for relevant bridge equipment • To develop the concept of eletronic manuals and provide an easy way to get familiar with relevant equipment in digital format • To specify the performance or technical standards of related equipment functions • To ensure all bridge equipment to follow IMO BAM (Bridge Alert Management) performance standard. • To demonstrate information accuracy and reliability technically • To develop a harmonized display system indicating reliability levels • To improve the access of Integrated bridge display system to shipboard information • To integrate GMDSS into one common interface
S2	• To provide single-entry of reporting information in single window environment • To collect internal ship data automatically for reporting • To improve automated or semi-automated digital distribution/communication of required information • To apply internationally standardized digital reporting formats such as IMO FAL Forms or SN.1/Circ.289.
S3	• To develop equiment with standardized self-check/built-in integrity test (BIIT) • To vetificate endurance, quality, and integrity of bridge equipment, inclusing software • To test and monitor information integrity of INS • Improved reliability and resilience of onboard PNT information and other critical navigation data by integration with, and backup of, external and internal systems
S4	• To integrate information on different graphical displays (including MSI, AIS, nautical charts, radar, etc.) • To implement a Common Maritime Data Structure (CMDS) for Maritime Service Portfolios • To develop standardized interfaces for data exchange from communications equipment to navigational systems (INS) • To provide mapping of specific services to specific regions • To provide a system for automatic source and channel management on board for the selection of most appropriate communication means according to criteria such as bandwidth, content, integrity and costs • To route and filter information on board • To ensure that all data is reliable and based on a consistent common reference system (CCRS) or converted to such before integration and display • To implement harmonized presentation considering human elements and ergonomic design principles • To develop a holistic presentation library to support accurate presentation across displays • To provide alert functionality of INS • To harmonize conventions and regulations for navigation and cmmunication equipment
S5	• To identify possible communication methods and test the best one concerning operation in different areas (e.g. deep sea, coastal, and port)

4.2.1.3 Standards

S-Mode is the standardization of functions and displays for electronic navigation equipment, i.e. ECDIS, Integrated Navigation System (INS), and radar, aiming to reduce variation in navigation systems and equipment through the standardization of some aspects of the user interfaces. It helps users with timely access to essential information and functions that support safe navigation. (IMO, 2017)

The S-100 Standard is a CMDS framework that is intended for the development of digital products and services for hydrographic, maritime, and GIS communities. It comprises multiple parts that are based on the geospatial standards developed by the International Organization for Standardization, Technical Committee 211 (ISO/TC211). (IHO, 2021)

The IHO Hydrographic Services and Standards Committee (HSSC) allocates S-1XX numbers to be used for the development of S-100 dependent products developed by the IHO. The S-101 to S-199 number range has been allocated for IHO product development. Higher number ranges have been allocated for use by other organizations. Figure 4-11 shows a simplified overview of S-100 dependent products.

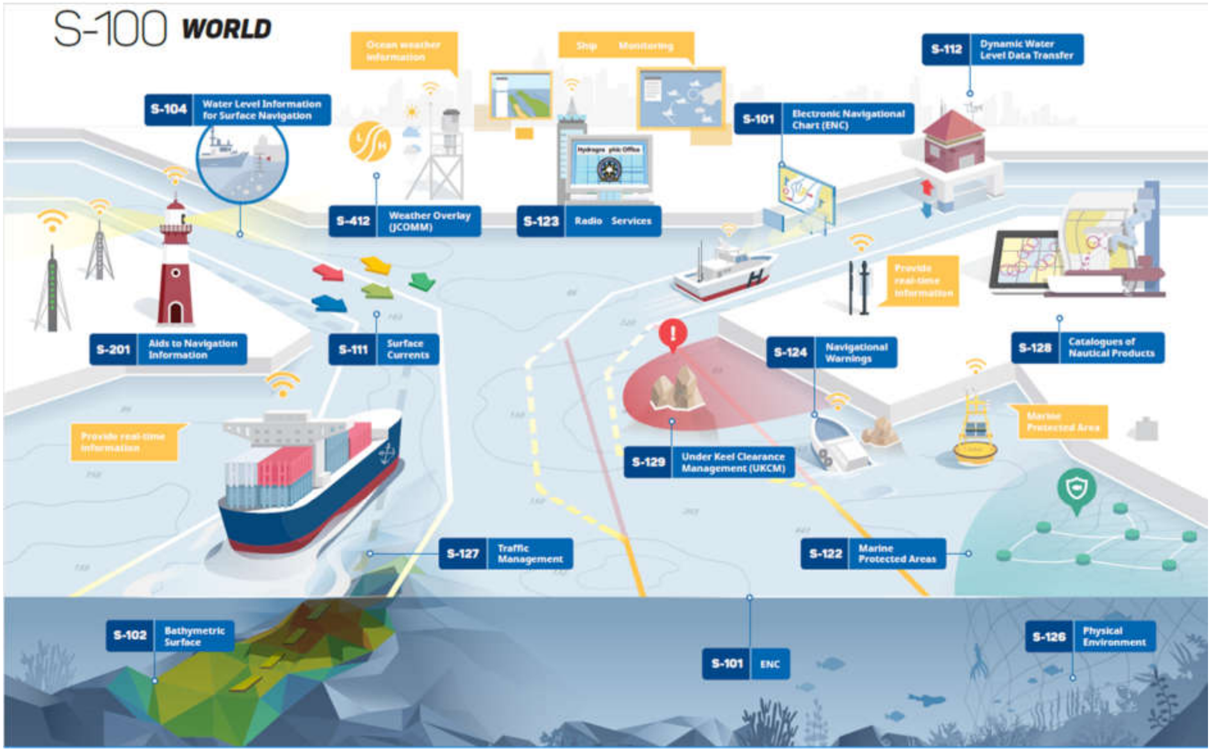

Figure 4-13 A simplified overview of S-100 dependent products (IHO, 2021)

A list of known product specifications under development is provided in Table 4-4.

Table 4-4 A list of S-100 dependent products (IHO, 2021)

Organization	S-100 dependent products
International Hydrographic Organization (IHO) (S-101 to S-199)	S-101 Electronic Navigational Chart (ENC) S-102 Bathymetric Surface S-103 Sub-surface Navigation S-104 Water Level Information for Surface Navigation S-111 Surface Currents S-112 Open - (See Decision HSSC9/38) S-121 Maritime Limits and Boundaries S-122 Marine Protected Areas S-123 Marine Radio Services S-124 Navigational Warnings S-125 Marine Navigational Services S-126 Marine Physical Environment S-127 Marine Traffic Management S-128 Catalogue of Nautical Products S-129 Under Keel Clearance Management (UKCM) S-130 Polygonal Demarcations of Global Sea Areas S-131 Marine Harbour Infrastructure S-164 IHO Test Data Sets for S-100 ECDIS
International Associateion of Light Authorities (IALA) (S-201 to S-299)	S-201 Aids to Navigation Information S-210 Inter-VTS Exchange Format S-211 Port Call Message Format S-230 Application Specific Messages S-240 DGNSS Station Almanac S-245 eLoran ASF Data S-246 eLoran Station Almanac S-247 Differential eLoran Reference Station Almanac
Intergovernmental Oceanographic Commission (IOC) (S-301 to S-399)	-
Inland ENC Harmonization Group (IEHG) (S-401 to S-402)	S-401 IEHG Inland ENC S-402 IEHG Bathymetric Inland ENC
Joint Technical Commission for Oceanography and Marine Meteorology (WMO/IOC JCOMM) (S-411 to S412)	S-411 JCOMM Ice Information S-412 JCOMM Weather Overlay S-413 Weather and Wave Conditions S-414 Weather and Wave Observations
International Electrotechnical Commission - Technical Committee 80 (IEC-TC80) Numbers (S-421 to S-430	S-421 Route Plan
NATO Geospatial Maritime Working Group (GMWG) for Additional Military Layers (AML) Numbers (S-501 to 525)	-
Other S-100 Related Resources	S-100 Github Repository - UML Model and Schemas Base Camp - Collaborative Web Worksite S-100 brochure (May 2017) S-99 Operational Procedures for the Organization and Management of the S-100 Geospatial Information Registry IHO GI Registry

4.2.1.4 Services

To improve the provision of services to vessels through e-Navigation, maritime services have been identified as the means of providing electronic information in a harmonized way. Maritime Service Portfolio (MSP) is a set of operational maritime services and associated technical services provided in digital format. Table 4-5 lists the information about the MSP, including the services of each maritime service and its coordinating authority and responsible service provider. Six areas have been identified for the delivery of MSP, which are port areas and approaches, coastal waters and confined or restricted areas, open sea and open areas, areas with offshore and/or infrastructure developments, polar areas, and other remote areas, and 16 maritime services are in the MSP to be digitalized to achieve the e-Navigation. (IMO, 2018). The maritime services are not separated. The information provided by one service may supplement other services.

Table 4-5 List of proposed maritime services for use in MSP

Service No	Identified services	Domain coordinating body	Indentified responsible service provider
1	VTS Information Service	IALA	VTS Authority
2	Navigational Assistance Service	IALA	VTS Authority
3	Traffic Organization Service	IALA	VTS Authority
4	Local Port Service	IHMA	Local Port/Harbour Authority
5	Maritime Safety Information Service	IHO	National Competent Authority
6	Pilotage service	IMPA	Pilotage Authority/Pilot Organization
7	Tug service	TBD	Tug Authority
8	Vessel Shore Reporting	TBD	National Competent Authority and appointed service providers
9	Telemedical Assistance Service	TBD	National Health Organization/dedicated health Organization
10	Maritime Assistance Service	TBD	Coastal/Port Authority/Organization
11	Nautical Chart Service	IHO	National Hydrographic Authority/ Organization
12	Nautical Publications Service	IHO	National Hydrographic Authority/ Organization
13	Ice Navigation Service	WMO	National Competent Authority/Organization
14	Meteorological Information Service	WMO	National Meteorological Authority/Public Institutions
15	Real-time hydrographic and environmental information Service	IHO	National Hydrographic and Meteorological Authorities
16	Search and Rescue Service	TBD	SAR Authorities

- VTS Information Service (INS)

The INS is provided by broadcasting information at fixed times and intervals or when deemed necessary by the VTS or at the request of a vessel, and may include for example reports on the position, identity and intentions of other traffic, waterway conditions, weather, hazards, or any other factors that may influence the vessel’s transit. The information may include navigation situations (including traffic and route information), navigational warning, meteorology, meteorological warnings, hydrography, electronic navigational aids, and other information. In the context of e-Navigation, the purpose is to provide data in a digital format, thus reducing administrative burden and information overload, reduce miscommunication due to external interference, simplify work procedures, promote sustainable shipping, and increase navigational safety.

- Navigational Assistance Service (NAS)

The NAS is especially important in difficult navigational or meteorological circumstances or in case of defects or deficiencies. This service is normally rendered at the request of a vessel or by the VTS when deemed necessary. For example, when a vessel deviates from the planned route, the VTS operator informs, warns, and if necessary, advises the vessel to change its course to the right one, and continues to monitor the vessel’s voyage.

- Traffic Organization Service (TOS)

TOS is a service to prevent the development of dangerous maritime traffic situations and to provide for the safe and efficient movement of vessel traffic within the VTS area. It concerns the operational management of traffic and the planning of vessel movements to prevent congestion and dangerous situations and is particularly relevant in times of high traffic density or when the movement of special transports may affect the flow of other traffic. The service may also include establishing and operating a system of traffic clearances or VTS sailing plans or both concerning priority of movements, allocation of space, mandatory reporting of movements in the VTS area, routes to be followed, speed limits to be observed, or other appropriate measures which are considered necessary by the VTS authority.

- Local Port Services (LPS)

It is a digital service in support of a ship calling at a port. It provides information necessary to organize and support the port call and varies depending on the local needs.

- Maritime Safety Information Service (MSI)

The MSI service is the internationally and nationally coordinated network of broadcasts containing urgent information that is necessary for safe navigation, received on ships by equipment that automatically monitors the appropriate transmission, displays information relevant to the ship, and provides a print capability. The provided information includes navigational and meteorological warnings, meteorological forecasts, and other urgent safety-related messages. MSI is part of the Global Maritime Distress and Safety System (GMDSS).

- Pilotage Service

The information provided through this service is not piloting information as pilotage is a service physically performed onboard ships by duly qualified and certificated or licensed maritime pilots. Information regarding the pilotage service, such as local regulations, contact, notices, means of boarding, boarding point, limitations, or pilot booking procedure, is provided by electronic means, where available.

- Tug Service

This maritime service ranges from small vessels with limited capacity and service in ports and rivers to ocean-going vessels built for complex operations and salvage. This service contributes to the safety of navigation, protection of the marine environment, and efficiency of marine transportation by conducting different types of operations, such as ship assistance, towage, oil spill response, etc.

- Vessel Shore Reporting

Communication between a shore-based authority and a participating ship should be limited to information essential to achieving the objectives of the system and the information should not be used for any other purpose. The initial report required from a ship entering the system should generally be limited to the ship's name, call sign, IMO identification number, if applicable, and position. Other supplementary information may also be requested in the initial report if justified in the proposal for adoption as necessary to ensure the effective operation of the system. Such supplementary information may include, for example, the intended movement of the ship through the area covered by the system, any operational defects or difficulties affecting the ship, and the general categories of any hazardous cargo on board. It is considered to improve the automated and electronic way of ship reporting to reduce ships' reporting burden.

- Telemedical Assistance Service (TMAS)

TMAS supports and advises seafarers in case of sickness, accidents, maritime agencies, and other incidents onboard that require medical advice. Standardization of reporting and registering of medical events will also make a much better basis for the advancement.

- Maritime Assistance Service (MAS)

The MAS is provided by coastal states in the following situations: (1) the ship is involved in an accident (e.g. loss of containers, unintentional release of oil) which does not affect its seaworthiness but must be reported; (2) in the opinion of the captain, the ship needs support but is not in an emergency (e.g. immediate sinking, fire, etc.) that requires people to be taken off the board; and (3) the ship is in an emergency, but the people on board have already been recovered and there are only those on board who are entrusted with handling the situation.

- Nautical Chart Service

This maritime service provides current geospatial information (in digital and/or printed format) to support safe maritime navigation. The types of information depicted in nautical charts include the configuration of the shoreline and seafloor, water depths, locations of dangers to navigation, location and characteristics of aids to navigation, anchorages, and other features relevant to maritime navigation. A Nautical Chart Service should support functions such as voyage planning, pilotage, collision avoidance, vessel traffic management, etc.

- Nautical Publications Service

This service delivers a set of nautical information available for a particular marine area. The service aims to provide information as a support to the navigation process, complementing nautical charts, such as information on ports and sea area, as well as the contact information of authorities and services for a sea area or port. It further describes regulations, restrictions, recommendations, and other nautical information applicable in these areas.

- Ice Navigation Service

It is to provide ice navigation information to ships in and in the vicinity of possible ice infested regions, to assist ships operating in ice. The service provides information related to ice conditions (as an ice chart), ice reports and bulletins, routing aids, and navigation planning.

- Meteorological Information Service

The service provides meteorological information digitally to ships. There are two types of marine meteorological information, forecasts and warnings for the high seas and coastal, offshore, and local areas (including ports and harbors).

- Real-time hydrographic and environmental information services

It provides oceanic and inland water level information that is essential for the determination of under-keel clearance required for safe navigation and real-time water level information that is important for applications such as route planning port entry and the determination of tidal prediction.

- Search and Rescue Service

The International Convention on Maritime Search and Rescue, 1979 (SAR Convention) was aimed at developing an international SAR plan to ensure that everywhere in the world, the rescue of persons in distress at sea would be coordinated by a responsible SAR organization or by cooperation between neighboring SAR organizations. Following the adoption of the 1979 SAR Convention, IMO's Maritime Safety Committee divided the world's oceans into thirteen search and rescue areas, with provisional SAR plans in place for each of these areas. In each area, the countries concerned have search and rescue regions for which they are responsible.

4.2.1.5 Testbeds

There are 9 active and 41 complete testbeds of e-Navigation. The active testbeds include (1) DatAcron and (2) Pilot Project for the Transmission of SBAS Corrections via IALA Beacons and AIS for Maritime and Inland Waterways Domain in Europe, (3) EMIR in Germany, (4) HERMITAGE and (5) Intelligent Fairway in Finland, (6) MARIOT from Denmark, (7) Second Generation SBAS in Australia and New Zealand, (8) SHEBA Project at Baltic area, and (9) Smart Navigation Project in the Republic of Korea. More detailed information about these projects is described in Table 4-6. Among these projects, five objectives are identified and summarized: (1) counties like Russia, Finland, and Korea are at a phase of fixing up their e-Navigation systems in part of areas, and Korea has extended the services to non-SOLAS ships; (2) three projects work on the test of their satellite-based systems, which are MARIOT, Pilot Project for the Transmission of SBAS Corrections via IALA Beacons and AIS for Maritime and Inland Waterways Domain, and Second Generation SBAS; (3) DatAcron focuses on the management of data sources; (4) EMIR is mainly for simulating the maritime system; and (5) SHEBA Project focuses on improving the environment.

Table 4-6 List of active testbeds of e-Navigation

Name	Basic Information	Description and Objective
DatAcron	• Location of project: European • Time and duration of Project: January 2016 until December 2019 • Status: Ongoing	To advance the management and integrated exploitation of voluminous and heterogeneous archival data and streaming data sources, so as to advance the capacities of systems to promote safety and effectiveness of critical operations for large numbers of moving entities.
EMIR	• Location: German Bight; Jade/Weser/Elbe approach • Duration: July 2013-2023 • Status (planned, completed or on-going): ongoing	• To simulate bridge, full ship, realistic traffic, dynamic physical systems, typical sensor systems and data processing, etc for better understanding maritime systems • To offer a virtual and physical testbed for system/component development, verification, and validation
HERMITAGE	• Location of testbed: The Eastern part of the Gulf of Finland – the Neva River – Lake Ladoga – the Svir River • Time and duration of testbed: 2016-2020 • Status (planned, completed or on-going): On-going	To follow the e-Navigation guideline and complete the technical assignment in the context of the E-Maritme R&D implemented by Kronstadt Group by order of the Ministry of Transport of Russia with the framework of the Federal target program GLONASS.
Intelligent Fairway	• Location of testbed: Finland, south coast and west coast • Time and duration of testbed: 2017-2018, 24 months	• To inform mariners about the prevailing conditions and vessel movements in the fairway • A step towards autonomous vessel traffic
MARIOT	• Submitting Organization: Sternula ApS, Aalborg, Denmark	• To develop a satellite-based maritime IoT network • To demonstrate selected maritime/Arctic services using our own MARIOT-1 satellite
Pilot Project for the Transmission of SBAS Corrections via IALA Beacons and AIS for Maritime and Inland Waterways Domain	• Location of testbed: Europe • Time and duration of testbed: 09/2017-01/2019 • Status (planned, completed or on-going): Ongoing	To demonstrate the operational performance of the transmission of the European satellite-based augmentation system (SBAS) corrections via IALA beacons and Inland waterways domain, while providing a detailed cost benefit analysis of the solutions proposed.
Second Generation SBAS in Australia and New Zealand	• Location of testbed: Australia and New Zealand • Time and duration of testbed: 2017-2018 • Status (planned, completed or on-going): Planned	• To overcome the current gaps in the mobile and radio communications and, when combined with on-ground operational infrastructure and services • To ensure that accurate positioning information can be received anytime and anywhere within Australia.
SHEBA Project	• Location of testbed: Baltic • Time and duration of testbed: 2015-2018 • Status (planned, completed or on-going): Ongoing	• To improve sustainable Shipping and Environment of the Baltic Sea region • To offer Strategic and operational risk management for wintertime maritime transportation system
Smart Navigation Project	• Location of testbed: Republic of Korea • Time and duration of testbed: March 2016 – December 2020	• To implement the concept of IMO's e-Navigation • To providing additional services for Non-SOLAS ships such as fishery boats,coastal vessels and ferries.

4.2.2 E-Maritime by EU

4.2.2.1 Introduction and Projects

The e-Maritime concept aims at promoting the competitiveness of the European maritime transport sector and more efficient use of resources through better use of ICT tools. From April to June 2010, the European Commission organized a public online consultation on the EU e-Maritime initiative. It gathered 102 pieces of feedback on the e-Maritime initiative from both public and private stakeholders to assess the possible actions that could help meet the e-Maritime objectives. The participants evaluated the key applications which they considered as the essence of the e-Maritime initiative. As a result, 11 top ranking applications were identified concerning five domains in maritime shipping shown in the table below. (European Commission, 2010a, 2010b, 2020). Table 4-7 shows the information about these applications.

Table 4-7 List of the top 11 applications

Rank	Application	Domain
1	Support for National Single Windows, one-stop-shop developments or a European Single Window including common reporting interface and dynamic integration with existing ones	Administration
2	Establishing co-operative transport networks and integration of short-sea shipping into logistics	Transport logistics
3	Support for compliance to and enforcement of regulations	Administration
4	Improved interoperable maritime surveillance/monitoring systems for traffic, ship and cargo facilitating EU and national administrations to collaborate in safety, security and environmental risk management in support of proactive or remedial operations	Administration
5	Integrated systems for monitoring, evaluating and managing situations including improved risk assessment and decision support systems	Administration
6	Improved automation in ship reporting	Ship operation
7	Solutions for more effective and coordinated controls and inspections	Administration
8	Fleet and ship routing and scheduling	Ship operation
9	Integration of Port Single Windows with national and international web portals	Port / Terminal operations
10	Delivering an EU system for statistical data on maritime transport	Administration
11	e-Learning and e-training for career development both at sea and in land	Life-at-sea

From above, it can be identified that what works have to been focused on to achieve the e-Maritime in each domain. In the administration domain, the industry expected one portal entry

Single Window to support reporting. The platform would support operators to comply with regulations, improve interoperability surveillance systems for safety, security, and environmental risk management, build integrated systems for risk assessment and decision making, and provide a unified system for storing statistical data. In the transport logistics domain, two points were highlighted. One was a cooperative transport network and the other was the integration of short-see shipping into the network. In the ship operation domain, the demands were to improve automatic shipping reports, ship routing, and scheduling. It followed the aim of e-Navigation by IMO. In the port operation domain, integrating PSW with NSW/RSW/GSW was promoted. The last public domain was to improve the careers of the crews in the maritime industry.

In July 2010, the public e-Maritime stakeholder conference was held to present the online consultation. During the conference, the e-Maritime initiative was welcomed by the public stakeholders. Four action plans were concluded, which are the e-Customs project presented by Directorate-General for Customs and Customs Union (DG TAXUD); the SafeSeaNet project presented by European Maritime Safety Agency (EMSA); the e-Freight project presented by Directorate-General for Mobility and Transport (DG MOVE); and the e-Navigation approach presented by Norwegian Coastal Administration (European Commission, 2010c).

4.2.2.2 SafeSeaNet

1) Introduction

SafeSeaNet is a vessel traffic monitoring and information system for maritime data exchange, linking together maritime authorities from across Europe. It is the central platform for all the member states, hosted and operated by EMSA. It enables European Union Member States, Norway, and Iceland, to provide and receive information on ships, ship movements, and hazardous cargo. The countries participating in SafeSeaNet are shown in Figure 4-14.

The main objects of the system are to enhance maritime safety, port and maritime security, marine environment protection, and the efficiency of maritime traffic and maritime transport. It aims at preventing accidents at sea and marine pollution. Additionally, it allows for the exchange and sharing of additional information facilitating efficient maritime traffic and maritime transport.

Figure 4-14 Countries participating in SafeSeaNet (2014)

2) Information

The notification reports submitted to the system include ship notifications, port notifications, Hazmat notifications, incident reports, waste notifications, security notifications, etc. They are stored in the SafeSeaNet central server. Table 4-8 lists the details of the main reports.

Table 4-8 The main information elements in the SafeSeaNet system

Main Report	Information
Ship Notifications	• Near-real-time ship positions every 6 minutes based on AIS • Information from AIS-based ship reports (e.g. identification name/number, flag, dimensions, course, speed, destination, and ship type)
Port Notifications	• Estimated/actual times of arrival/departure
Hazmat Notification	• Details of hazardous goods carried on board
Incident Reports	• Safety-related incidents affecting ships
Waste Notifications	• Details of waste carried onboard/to be offload (from June 2015)
Security Notifications	• Ship security-related information (from June 2015)
Other	• Archived historical ship positions over several years • Pollution-related incidents affecting ships • The location of remaining single-hulled tankers • The location of ships that have been banned from EU ports • Digital map layers (containing information on depths, navigation aid, traffic separation schemes, anchorages, AIS station locations, etc.)

The information is reported and made available to various competent authorities in the different participating Member States, including National Competent Authority (NCA), Local Competent Authority (LCA), and other EU bodies and Member State institutional users.

3) System

SafeSeaNet (SSN) is a map-based GIS system. Users can zoom in and out to display the images from EU-level to individual quays in ports. On a screen, the users can: (1) see the position of any vessel transmitting an AIS signal; (2) find out what hazardous cargo it is carrying; (3) see all high-risk ships (within a list of categories); (4) ascertain what is wrong with a ship when it reports an incident; (5) see the complete track of a ship (showing where it was at different times); (6) zoom in from an EU level view to individual quays at any selected port (and anywhere in between), and (7) see which port a ship will arrive at (and when). (EMSA, 2016)

Figure 4-15 shows the information flow of the SafeSeaNet system. The core of the system's architecture is the European Index Server (EIS) as central SSN. There is an interface between the central SSN and the national SSN. It works as a hub and spoke system shown in the figure below. The EIS can locate and retrieve information on vessels related to one Member State in the response to a request by another.

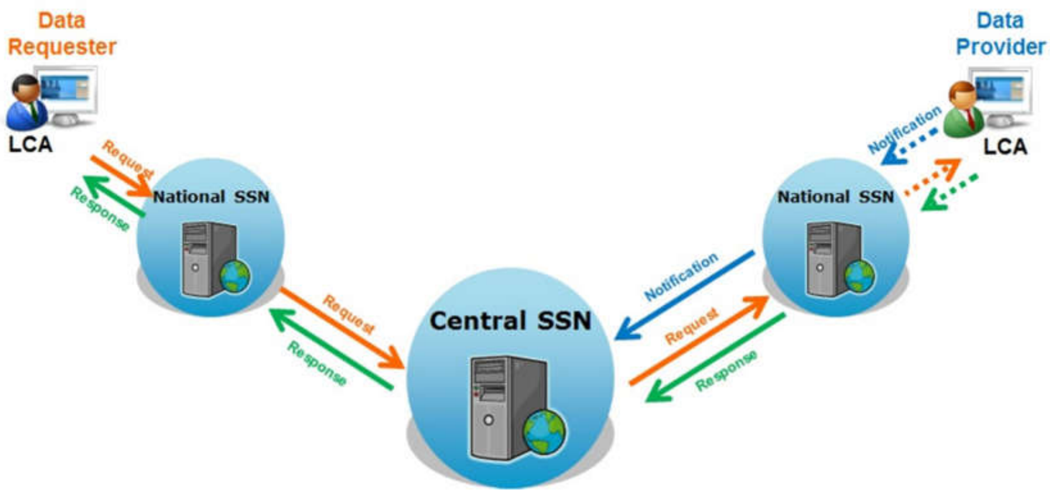

Figure 4-15 SafeSeaNet system - information exchange

4) Application – SEG

The SafeSeaNet Ecosystem Graphical User Interface (SEG) is a web interface providing access to EMSA's maritime applications and data sets including SafeSeaNet, Integrated Maritime Services (IMS), Long Range Identification and Tracking (LRIT), and CleanSeaNet. It is designed for both mobile and desktop/laptop devices. It was developed in 2010 as a graphic interface named GUI that allows users to quickly get an overview of ship activities on nautical charts. SEG is the new and updated version of GUI. The structure of SEG is shown in Figure 4-16.

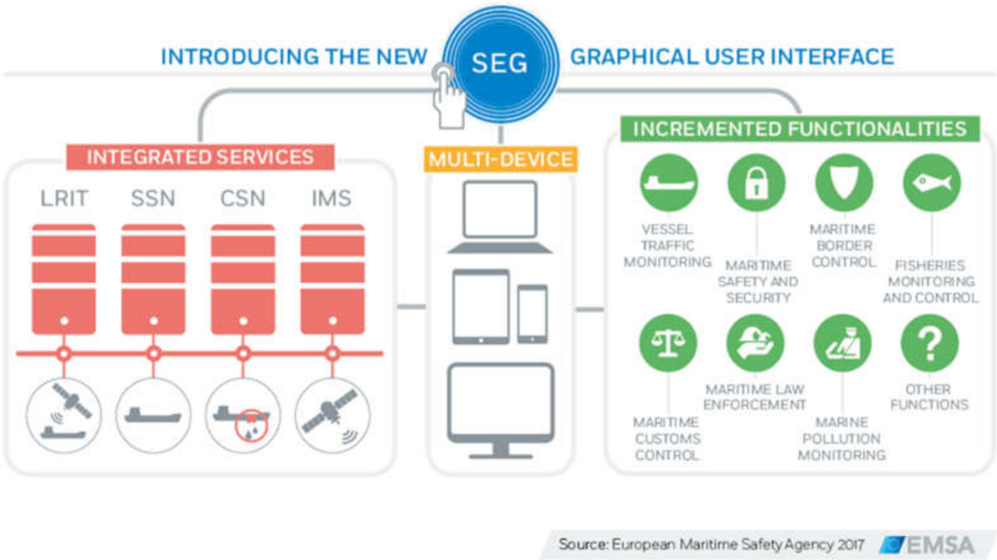

Figure 4-16 The structure of SEG

The SafeSeaNet system has a greater influence when it is integrated with the satellite-based global LRIT system and the CleanSeaNet pollution monitoring system in a single display application. EMSA provides an earth observation service with satellite-based oil spill detection through its CleanSeaNet Service and vessel tracking through its SafeSeaNet Service (Carpenter et al., 2016). Integrated Maritime Services (IMS) combine data from EU member states, EMSA, and other EU agencies to provide a comprehensive real-time maritime picture. The IMS app is a simplified version of SEG for mobile devices.

5) Use Case

Two EU-wide pilot projects are introduced. They are both tested via SafeSeaNet. The projects have meaningful effects on customs simplification and Single Window construction. It also proves SafeSeaNet as a useful tool for information exchange in the European area.

- Blue Belt pilot project

The Blue Belt pilot project, which starts in May 2011, aims to explore new ways to promote and facilitate Short Sea Shipping in the European Union by reducing the administrative burden for intra-Community trade. Around 250 ships have been selected to participate in the project. The movements of ships are monitored via the SafeSeaNet system. The ship’s master should ensure the AIS equipment is always turned on and all the relevant information is correctly filled in. Customs authorities receive a timely notification report before the ship arrives at an EU port. The report provides extra information on the voyage of the ship and previous ports of call. Consequently, customs officials use this information as input for risk assessment and prioritization of control. The ship's master and agent benefit from the faster processing of goods through customs when arriving at the port (EMSA, 2013).

- eManifest pilot project

The eManifest pilot project, from November 2018 to February 2019, aims to simplify the submission of information required by different authorities for container formalities. Through the project, a harmonized eManifest was proposed which encompasses data required in several maritime and customs formalities. As a tool for the implementation of this pilot project, EMSA developed the European Maritime Single Window (EMSW) prototype to test how the eManifest data could be reported along with other reporting formalities in a harmonized manner, submitted to the relevant authorities, and exchanged among the Member States. The EMSW has an interface with SafeSeaNet. The exchange of eManifest via SafeSeaNet is tested to assess whether it can minimize reporting obligations between EU ports. The results of the eManifest pilot project should be used as starting point for the elaboration of the future EMSW data set and related business rules. The idea of EMSW is shown in Figure 4-17.

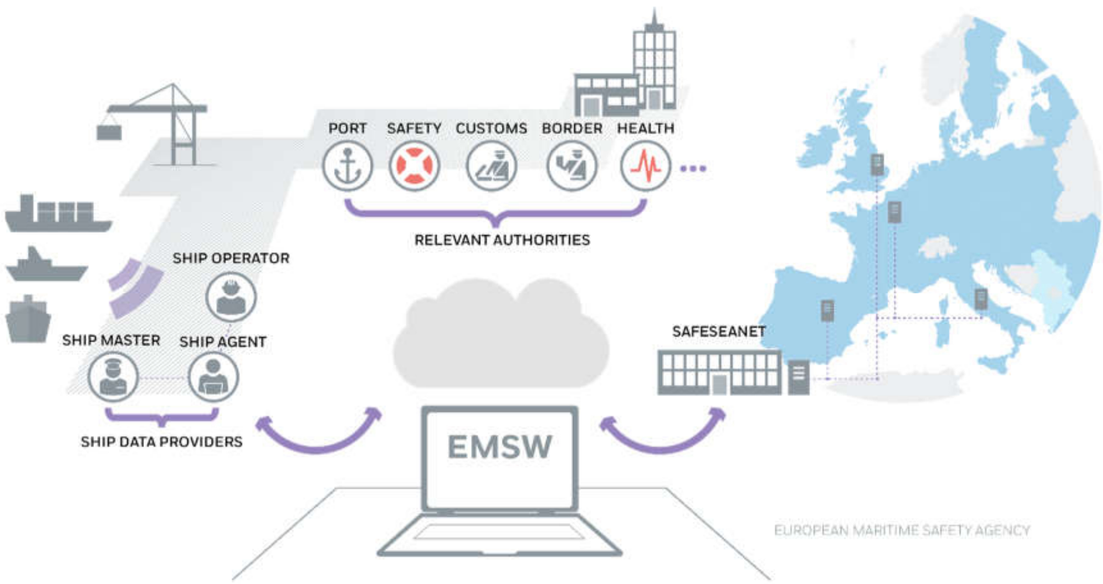

Figure 4-17 European Maritime Single Window

4.2.2.3 E-Navigation in Europe

1) VTMIS-NET

The European VTMIS-NET (Vessel Traffic Management and Information Services - NETwork) project was sponsored by DG TREN (Transport and Energy) from January 1998 to February 2000. The emphasis with this project has been on interchanging pre- and post- waterborne transport-related information to expand VTS to Vessel Traffic Monitoring & Information Systems (VTMIS). This project aimed to create pan-European methods and platforms for exchanging information based on already existing VTS systems and services, whether on a local, regional, national or EU level to be used independently. The challenge was to interlink facilities with a wide hard- and software without requiring to replace large parts of the modules.

The conclusions of this project for future development are: (1) to improve the efficiency of VTS/VTMIS by improving communication between existing systems; (2) to improve the dissemination of traffic information for traffic, transport operations, and management; (3) to provide access to vessels' data; (4) to provide access to container's data, where required for safety reasons; (5) to reduce communication/reporting; (6) to disseminate marine pollution information; and (7) to make use of traffic image, for example in SAR operations (ISSUS, 2000).

2) IMO's e-Navigation implementation

The e-Navigation in Europe follows with the IMO's e-Navigation concept and strategy. Many testbed projects have been funded by or co-funded by EU FP7, EU Horizon 2020, EU CEF, EU Interreg program, and individual governmental authorities to improve the e-Navigation in Europe. The FP7 funding ran from 2007 to 2013. Horizon 2020 is the biggest funding program for EU Research and Innovation program ever from 2014 to 2020. The Connecting Europe Facility (CEF) is a key EU funding instrument to promote growth, jobs, and competitiveness through targeted infrastructure investment at the European level. Interreg is one of the key instruments of the EU supporting cooperation across borders through project funding. These projects focus on the 5 solutions of e-Navigation as well as other extended ideas to facilitate maritime shipping. The detailed information about these projects is summarized in Table 4-9, 4-10, and 4-11.

Table 4-9 e-Navigation projects funded by EU's organizations

Solution	Name	Region	Funded by
1	FAROS	European	EC FP7
1,3	CASCADE	European	EU FP7
2	STM VALIDATION	Northern Europe, the Mediterranean	EU CEF
2,4	MONALISA 1.0	Baltic Sea	-
	MONALISA 2.0	Baltic Sea & Mediterranean	EU TEN-T
	MARNIS	Norway, Italy, Portugal	EC FP7
2,4,5	EMAR	European	EU FP7
3,4	E-FREIGHT	European	EU FP7
	ESABALT	Baltic	Bonus/EU FP7
4	EUCISE2020	European	EU FP7
	ARIADNA	European	EU FP7
1,2,3,4,5	ACCSEAS	North Sea Region	EU Interreg
	EFFICIENSEA 2	Baltic Sea & Arctic Regions	EU Horizon 2020
	WINMOS	Baltic	EU TEN-T
	POLAR ICE	Arctic & Antarctic	EU FP7
	MUNIN	European	EC FP7
	EFFICIENSEA	Baltic Sea Region	Cofunded by the EU Interreg Programme
-	SKEMA	European	EU FP7
	BALTCOAST	Baltic	co-funded by EU and related to EU Horizon 2020
	FLAGSHIP	European	EU Framework
	DatAcron	European	EU Horizon 2020

Table 4-10 Information about the EU-funded e-Navigation projects

Name	Tasks and Objectives
FAROS	• to incorporate human factors into Risk-Based Design of ships.
CASCADE	• to develop new methodologies for information sharing and displaying on a ship's bridge
STM VALIDATION	• to establish standardised information sharing with open interfaces
MONALISA 1.0	• for dynamic and proactive route planning • for electronic verification of officer's certificates • to ensure the quality of hydrographic data on shipping routes and areas • for global sharing of maritime data
MONALISA 2.0	• to elaborate better standards for route exchange through a common interface and common data format by joint private-public action
MARNIS	• to provide an integrated approach to Information Management for Maritime Safety Security & Environmental Risk Management
EMAR	• to network different stakeholders • to increase automation of operational processes particularly compliance management • to facilitate the streaming of synthesised information from disparate sources to assist decision making.
E-FREIGHT	• to allow tracing goods in real time • to ensure intermodal liability • to promote clean freight transport
ESABALT	• to develop a software platform for maritime information crowdsourcing • for maritime safety, intelligent navigation, and environmental monitoring and reporting with emphasis on cross-border functionality
EUCISE2020	• to achieve pre-operational information sharing between the maritime authorities of the European States
ARIADNA	• to design a new concept and build a new series of navigation support systems • to optimize the use of maritime and inland infrastructures in order to manage traffic density • to improve safety at congested maritime and inland areas
ACCSEAS	• to use solutions based on Resilient Position, Navigation and Timing (PNT) and effective e-Navigation services • to harmonize information services through the use of the Maritime Cloud • to clarify the principle and the advantages of using e-Navigation

Table 4-11 Information about the EU-funded e-Navigation projects

Name	Tasks and Objectives
EFFICIENSEA 2	• to develop a coherent e-Navigation solution for efficient, safe and sustainable traffic at sea through improved connectivity for ships. • to pave the way for a global roll-out of e-Navigation through the development of the Maritime Cloud
WINMOS	• to develop the maritime winter navigation system and safeguard required icebreaking resources to the future requirements in EU's northernmost waters
POLAR ICE	• to develop the next generation of operational sea ice monitoring services • to support a range of activities in the Arctic and Antarctic
MUNIN	• to improve competitiveness of operation of the autonomous vessel
EFFICIENSEA	• to improve transmitting own ship's route through ship's transponder, • to improve presenting other ships' routes on ECDIS, • to improve broadcasting and presenting suggested routes from VTS to ship's ECDIS
SKEMA	• to establish a Sustainable Knowledge Platform to be used by policy makers and stakeholder groups in the European Maritime and Logistics Industry
BALTCOAST	• to develop a generic tool for assessment of integrated systems encompassing multiple impacts in a spatially heterogenreous context in coastal research and management
FLAGSHIP	• to improve safety, environmental friendliness and competitiveness of European maritime transport
DatAcron	• to addresses the requirements from the air-traffic management and maritime domains • to develop advanced tools for detecting and visualizing threats, abnormal activity • to increase the safety and efficiency of operations related to vessels and airplanes • to reduce the impact of these operations on the environment.

3) Sea Traffic Management

Sea Traffic Management (STM) is creating a new paradigm for real-time maritime information sharing and offering the digital infrastructure for future shipping. STM services include route optimization, ship-to-ship route exchange, enhanced monitoring, port call synchronization, and winter navigation. The concept of Sea Traffic Management has been developed during EU-financed research and innovation projects with several European partners within academia, government bodies, and the industry. The goals of STM are to reduce 50% of accidents, 10% of voyage costs, 30% of waiting time for berthing, 7% of fuel consumption, and 7% greenhouse gas emission by the year 2030.

The current and previous projects are summarized in Table 4-12.

Table 4-12 Projects of STM

Current Projects	Previous Projects
EfficientFlow	STM Validation
Real Time Ferries	MONALISA 2.0
STM BALT SAFE	MONALISA
STEAM	MICE

- EfficientFlow

The Baltic ports of Rauma and Gävle each implement port collaboration solutions for enabling coordinated port call planning, helping each other to optimize resource utilization. The solution also helps synchronization of the port call with the arriving ships and with hinterland operations using real-time information. All actors in the port cluster will be involved. The co-operation between the two optimized ports enables increased goods flows directly between them. The cooperation converts waiting times into increased safety and bunker savings for large ships in the narrow Swedish and Finnish archipelagos.

- STM BALT SAFE

STM BALT SAFE (2019-2021) contributes to increased safety of navigation in the Baltic Sea by providing STM-enabled maritime services to tanker traffic. Tanker ships can send and receive voyage plans with each other and with public authorities. It enhances the institutional capacity of the public sector in supporting and developing the safety of navigation services and efficiency of sustainable transport.

- STEAM

STEAM (Sea Traffic Management in the Eastern Mediterranean) is a three-year project that has started in January 2019. The primary goal of the research program is to develop the Port of Limassol to become a world-class transshipment and information hub adopting modern digital technologies brought to the maritime sector, as well as a driver for short sea shipping in the Eastern Mediterranean.

- STM Validation Project

The STM Validation Project demonstrates the STM concept in large-scale test beds in both the Nordic and Mediterranean Seas. The project encompasses 300 ships, 13 ports, 5 shore-based service centers, and 13 connected simulator centers in the European Maritime Simulator

Network. There are five activities which are (1) Port Collaboration Decision Making (Port CDM), increasing the efficiency of port calls; (2) Voyage Management, supporting individual ships by route planning, exchange, and optimization; (3) Maritime Simulator Network; (4) Maritime Service Infrastructure, validating a common infrastructure using System Wide Information Management (SeaSWIM) and using a common information environment and structure (e.g. the Maritime Cloud); and (5) Analysis & Evaluation.

- MONALISA 2.0

The project is to make real-time information available to all interested and authorized parties in the whole transport chain. Safety is improved by concrete initiatives onboard ships, e.g. indoor positioning, and onshore, e.g. mass evacuation in port.

The MONALISA project from 2010-2013, which is the forebearer of STM, demonstrated route planning and route sharing with a consortium of 7 partners. It worked with hydrographic data quality and global maritime data sharing. MICE is as MONALISA in the Ice area. Real Time Ferries project shares real-time departure and arrival times for ferries in the Baltic Sea Region to facilitate passenger and goods transport.

From the above projects, we can see that during this period, navigation and reporting information is required in real-time. The data are stored and shared by the cloud. The real-time information is used for ships' route planning and exchange and ports' coordination and development.

4.2.2.4 E-Customs

1) Introduction

The Council Resolution of 5 December 2003 on creating a simple and paperless environment for customs and trade set the framework for the e-Customs initiative. The e-Customs Decision (Decision No 70/2008/EC of the European Parliament and of the Council of 15 January 2008) is the key piece of legislation related to the e-Customs initiative that promotes a shift to an interoperable electronic customs environment. As an overall project management tool, the Multi-Annual Strategic Plan for electronic Customs (MASP-C) is an essential instrument for ensuring operational planning and implementation of all eCustoms IT projects. The MASP-C provides a complete and up-to-date overview of all future customs projects and envisaged IT requirements supported by detailed implementation planning. It reflects progress in diverse policy domains, such as the Union Customs Code (UCC), Authorized Economic Operators

Mutual Recognition, Safety and Security, and the EU Single Window environment for customs. (Taxation and Customs Union - European Commission, 2020).

The adoption and application of the UCC on 1 May 2016 complete the shift to a paperless, fully electronic, and interoperable environment in European Union. The UCC Work Program (UCC WP) was established in 2014 and updated for the first time in 2016 by EU Commission Implementing Decision. It contains a list of 17 electronic systems that must be developed for the application of the UCC. Up till now, EU Customs has already reached a very high degree of automation. For example, over 93% of customs declarations are already being processed electronically.

The new IT Strategy has been developed within the overall framework of the European Interoperability Strategy (EIS) and the European Interoperability Framework (EIF). Meanwhile, the modernization of customs and taxation is part of the European e-Government action plan. Future work on this project is foreseen to be carried out under the initiative and leadership of the Member States with the coordination of Directorate-General Taxation and Customs Union (DG TAXUD), which is responsible for EU policies on taxation and customs and considering ways of improving its delivery model to streamline the preparation and implementation of the functional and technical specifications.

2) Grouping of Project Fiches

The overall IT Implementation plan is divided into four groups, which are further subdivided into phases based on the achieved degree of legal, business, and technical clarification and agreement. The projects listed in MASP-C are categorized according to the four groups.

- Group 1: Customs European information Systems. It contains the project fiches, procedures, and projects that have already got the common agreement on the scope and time plan so that progress can be made. It includes project fiches on bilateral international initiatives (between the EU and third countries).
- Group 2: Customs European initiatives needing further study and agreement. The projects in this group are required further discussion. It also includes project fiches on bilateral international initiatives (between the EU and third countries).
- Group 3: Customs International Information Systems. The third group concerns projects managed by international organizations in which the EU and its Member States play an active role, but are not the project organizers or owners.

- Group 4: Customs Cooperation initiatives and technological developments to facilitate Customs EIS. This group concerns initiatives for customs cooperation as well as for driving progress in the field of technology to create new functions in the planned EIS.

3) Projects

Table 4-13 summarizes the detailed information of the projects in each group.

Table 4-13 Projects in MASP-C

Group 1	UCC Customs Decisions system
	UCC BTI (Binding Tariff Information)
	UCC AEO (Authorized Economic Operators) and impacts of MRA (Mutual Recognition Agreement)
	UCC AES (Automated Export System)
	UCC Transit System including NCTS (New Computerised Transit System)
	UCC REX (Registered Exporter System)
	COPIS (Anti-Counterfeit and anti-Piracy Information System)
	EU Single Window environment for customs
	CLASS (Classification Information System)
	UCC EORI2 (Economic Operators Registration and Identification subsystem 2)
	CRMS2 (Customs Risk Management System)
	e-Commerce & CP (Customs Procedure) 42/63
	Import of Cultural Goods
	UCC ICS2 (Import Control System 2)
	UCC Surveillance 3
Group 2	UCC Notification of Arrival, Presentation Notification and Temporary Storage
	UCC GUM (Guarantee Management)
	UCC Special Procedures
	Adjustments of the existing import applications under the UCC, e.g. CCI (Centralized Clearance for Import)
	CUP-MIS (Customs Union Performance – Management Information System)
	UCC Proof of Union Status (PoUS)
	EMSWe (European Maritime Single Window environment) in relation to customs systems
Group 3	EU Implementation of UNECE eTIR (electronic International Road Transports) System
	eATA (electronic Temporary Admission) Carnet Project
	SSTL (Smart and Secure Trade Lanes)
	EU-CH EXS (Exit Summary Declaration) data exchange for indirect exports from Switzerland (On hold)
	EU-RU 'Green Corridor' pilot project (On hold)
Group 4	National Systems Implementation by IT Collaboration Projects
	CCN2 (Common Communication Network 2)
	UCC Uniform user management & digital signatures - UUM&DS (Uniform User Management & Digital Signature) (Direct Trader Access to EIS)
	High availability DG TAXUD operational capabilities
	Maintenance and updates of operational IT systems
	IT Business Continuity (Reinstated)

4.2.2.5 E-Freight

The development of e-Freight in the EU projects is sketched by 2 projects and 1 regulation in a time sequence, which are European e-freight capabilities for co-modal transport from January 2010 to June 2013, e-Freight Implementation Action from July 2015 to June 2018, and Regulation (EU) 2020/1056 of the European Parliament and of the Council of 15 July 2020 on electronic freight transport information (Text with EEA relevance).

1) European e-freight capabilities for co-modal transport from January 2010 to June 2013

E-Freight denotes the vision of paperless freight transport processes when an electronic flow of information is linked to the physical flow of goods. At that time, the e-Freight was proposed to contribute to the goals of the Freight Transport Logistics Action Plan (October 2007) and the ITS Action Plan (October 2008). The main goal of e-Freight is to facilitate regulatory processes of multimodal transport, to introduce Information Highways for co-modality to assist transport operators in establishing common end-to-end transportation processes incorporating regulations compliance and intelligent monitoring and control.

2) E-Freight Implementation Action from July 2015 to June 2018

The Action aims to foster the implementation of e-Freight to simplify and reduce the cost of exchanging information between different actors and transport modes along the chain. Four real-life trials were implemented in the Core ports in Italy, Poland, and Portugal along with three core corridors (Atlantic, Mediterranean, and Baltic/Adriatic) of the TEN-T Network.

3) Regulation (EU) 2020/1056 of the European Parliament and of the Council of 15 July 2020 on electronic freight transport information (Text with EEA relevance)

The regulation is only intended to facilitate and encourage the provision of information between economic operators and competent authorities by electronic means. Both economic operators and competent authorities need to take measures to make possible exchanges of regulatory freight transport information (eFTI) in machine-readable format via eFTI platforms. The establishment of the access points could be considered. They act only as intermediaries between the eFTI platforms and competent authorities, and can neither store nor process the eFTI data. Member States could also agree to establish joint access points for their respective competent authorities. The Action of eFTI platforms conforms with the EU e-Government Action Plan to accelerate the digital transformation of government.

As presented in the regulation, the first delegated act, which establishes and amends all the eFTI common data set and subsets concerning the respective regulatory information requirement, shall be adopted no later than 21 January 2023, including corresponding specifications on the definition and technical characteristics for each data element.

4.2.2.6 Intelligent Transport Systems (ITS)

As part of the Digital Single Market Strategy by 2050, the European Commission aims to make more use of ITS solutions to achieve more efficient management of the transport network for passengers and business. ITS will be used to improve journeys and operations on specific and combined modes of transport. The concept has been developed in road transportation for over 20 years known as road telematics, and it can be used for marine vessels as well. The European Commission also works to set the ground for the next generation of ITS solutions, through the deployment of Cooperative-ITS, paving the way for automation in the transport sector. C-ITS are systems that allow effective data exchange through wireless technologies so that vehicles can connect and interact with each other, with the road infrastructure, and with other road users. Communication between vehicles, infrastructure, and other road users is also crucial to increase the safety of future automated vehicles and their full integration in the overall transport system. The ITS in the maritime industry may focus on autonomous shipping as well as the connection with hinterland transport vehicles.

4.2.2.7 RIS, ERTMS, Motorways of Sea, and TEN-T

1) RIS (River Information Service)

Since 2009, RIS (River Information Service) experts have been involved in the harmonization of information technologies at the European level as modern traffic management systems allowing real-time data exchange between vessels and the shore. It supports inland navigation and transport management. Four key technologies are applied for RIS: Inland Electronic Chart Display and Information System (Inland ECDIS), Notices to Skippers (NtS), Inland AIS, and Electronic Reporting International (ERI).

2) Motorways of Sea

Motorways of the Sea (MoS) is the maritime pillar of the TEN-T which contributes to the achievement of a European Maritime Transport Space without barriers. It aims to introduce new intermodal maritime-based logistics chains in Europe. Three main objectives for the sea motorways projects are to concentrate freight flow on sea-based logistical routes, to increase cohesion, and to reduce road congestion through the modal shift.

3) ERTMS (European Rail Traffic Management System)

The European Rail Traffic Management System (ERTMS) is single European signaling and speed control system that ensures interoperability of the national railway systems, reducing the purchasing and maintenance costs of the signaling systems as well as increasing the speed of trains, the capacity of infrastructure, and the level of safety in rail transport. ERTMS comprises the European Train Control System (ETCS), i.e. a cab-signaling system that incorporates automatic train protection, the Global System for Mobile communications for Railways (GSM-R), and operating rules.

4) TEN-T (Trans-European Transport Network)

The Trans-European Transport Network (TEN-T) addresses the implementation and development of a Europe-wide network of railway lines, roads, inland waterways, maritime shipping routes, ports, airports, and railroad terminals. It has two network layers. The Core Network includes the most important connections, linking the most important nodes, and is to be completed by 2030 shown in Figure 4-18. The Comprehensive Network covers all European regions and is to be completed by 2050. The nine Core Network Corridors streamline and facilitate the coordinated development of the Core Network. The ERTMS and Motorways of the Sea complement the network.

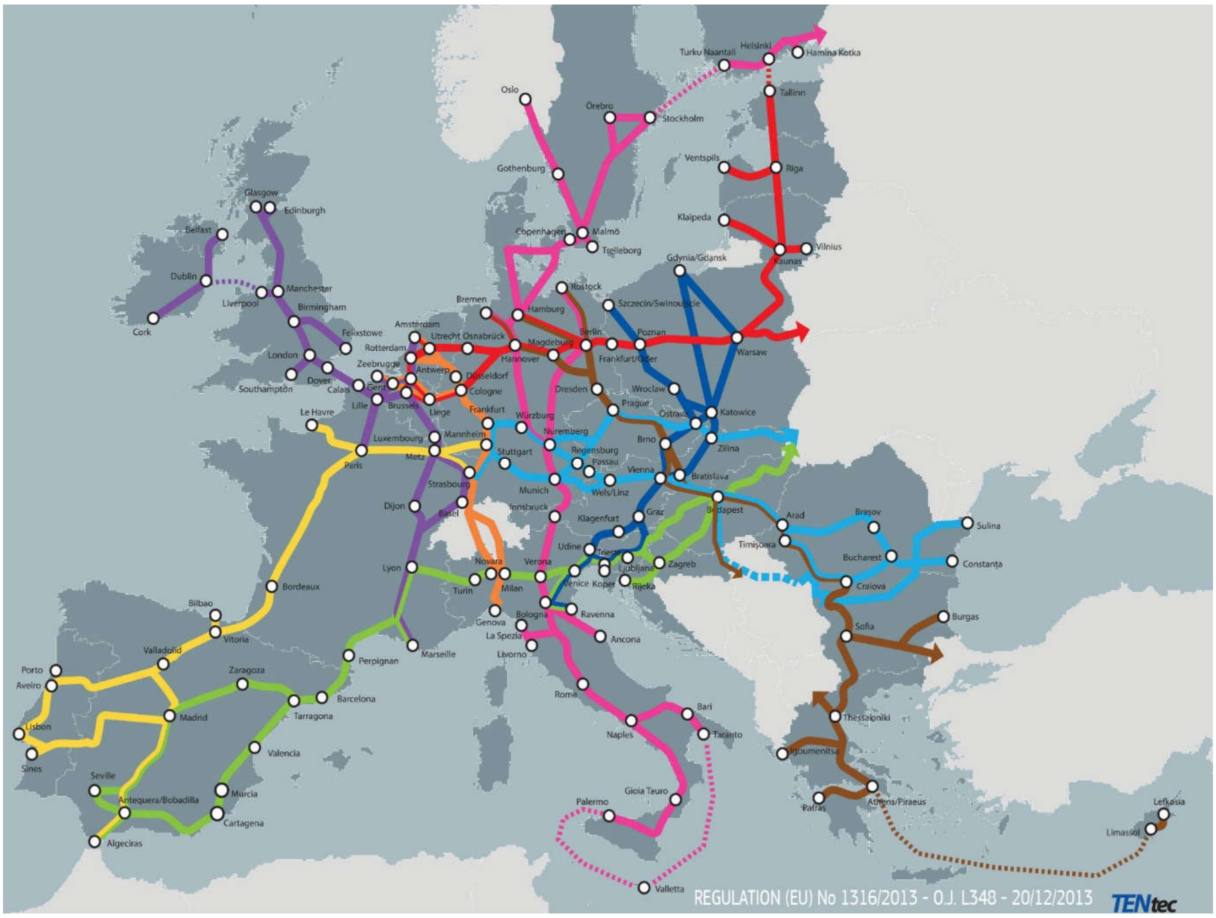

Figure 4-18 Nine Core Network Corridors (Mobility and Transport - European Commission, 2020)

4.2.3 Smart-Navigation by Korea

1) Introduction

E-navigation applications are aimed at reducing navigational accidents under the International Convention for the Safety of Life at Sea (SOLAS). It is firstly applied on SOLAS ships, which refer to a passenger ship or a non-passenger ship of 500 tons gross tonnage or more engaged on an international voyage. However, the situation of maritime safety is different from country to country, and SOLAS ships are always interfaced with non-SOLAS ships in real maritime practices. Researchers are managing to improve it as a general and recommendation method for non- SOLAS ships. The Korean SMART-Navigation project aims to include e-navigation services for both non-SOLAS and SOLAS ships especially considering the specific individual situation and conditions of the coastal states.

The smart-Navigation implements and complements the concept of IMO's e-Navigation. It provides not only IMO's GNSS-enabled e-Navigation services but also a high-speed wireless maritime network (LTE-Maritime). As e-Navigation targets at SOLAS ships, smart-Navigation services are used by both SOLAS and non-SOLAS ships (fishing vessels as well as non-fishing vessels engaging in domestic coastal areas). The services aim to prevent the potential accident causes in advance by proactively supporting them and managing areas, which are identified as being vulnerable to accidents based on utilizing the real-time relevant statistics and local situation data, from the shore-based stations. Figure 4-19 is an overview of smart-Navigation.

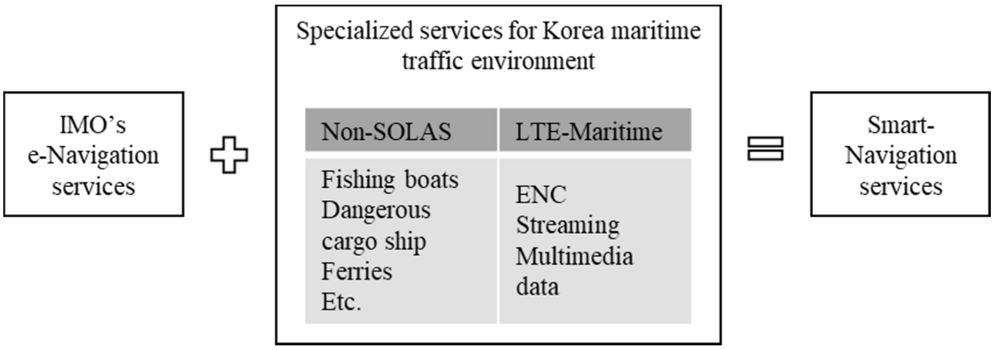

Figure 4-19 Smart-Navigation Services

2) Technology

Wireless Communication Technologies allow mobile users to access various data services anytime and anywhere, therefore, it is an opportunity as well as a challenge to develop reliable maritime communications supporting these high-speed data rates and extended coverage. Korea's smart-Navigation project introduces a long-term evolution of maritime (LTE-Maritime) to develop a maritime communication infrastructure supporting the data rates in the order of megabits per second within the communication coverage of 100km.

LTE technology is a promising solution for the wireless maritime network. The experimental results present that the LTE-Maritime could be a practical solution for ship-to-shore data communication. LTE-Maritime enables ships to communicate with onshore base stations directly and it can improve reliability. The base stations are situated at a high altitude of mountainous areas and composed of multiple radio units and digital units. Each digital unit is connected to the LTE-Maritime operation center through the wired network. Ships need to equip with the LTE-Maritime router. The onboard laptops for performance measurement are connected to the router and they measure main communication parameters. (Jo et al., 2019)

3) Services

The smart-Navigation in Korea mainly contains five services that cover 13 out of the 16 services in IMO's e-Navigation MSP. The information on the five services is presented in Table 4-14.

Table 4-14 Five Services of Smart-Navigation (Ministry of Oceans and Fisheries, Republic of Korea, 2020)

ID	Service	Target Vessels	Communication Method
SV1 (NAMAS)	SV1-Navigation Monitoring & Assistance Service	•Vulnerable vessels	LTE-Maritime VDES
SV2 (SBSMS)	SV2-Ship-borne System Monitoring Service	•Korean passenger ship(Domestic/International) •Upon request	LTE-Maritime VDES/SAT
SV3 (SORPS)	SV3-Safe & Optimal Route Planning Service	•Korean passenger ship(Domestic/International) •Upon request	LTE-Maritime VDES/SAT
SV4 (REDSS)	SV4-Real-time Electronic Navigational chart Distribution & Streaming Service	•Domestic Costal vessel	LTE-Maritime
SV5-1 (PITAS)	SV5-Pilot & Tugs Assistance Service	•Pilots and Tugs	LTE-Maritime
SV5-2 (MESIS)	SV5-2-Maritime Environment and Safety Information Service	•Upon request	LTE-Maritime VDES/SAT

Compared the five services with the 16 services in MSP, SV1/SV2/SV3 cover the VTS Information Service, Navigational Assistance Service, Traffic Organization Service, and Local Port Service; S1/S2 cover Maritime Assistance Service and Search and Rescue Service; S4 covers Nautical Chart Service; SV4/SV5-2 cover Nautical Publications Service; SV5-1 covers Pilotage service and Tug Service; and SV5-2 covers Meteorological Information Service and Real-time Hydrographic and Environmental Information Service. Besides, 3 services in MSP are not included by the 5 services of smart-Navigation, which are Vessel Shore Reporting, Telemedical Assistance Service, and Ice Navigation Service.

4) Activities

The project is divided into 3 activities, which consist of 13 Work Packages, as shown in Table 4-15. The first activity is to implement the e-Navigation service, the second is to extend the technology and service based on the TLE-Maritime as well as integrating the navigation systems, and the third is to develop the maritime data standards concerning the LTE-technology and to harmonize them with international standards.

Table 4-15 3 Activities and 13 WP of Smart-Navigation (Ministry of Oceans and Fisheries, Republic of Korea, 2020)

Activity 1	Developing core technologies for e-Navigation service	Enabling comprehensive situational awareness & responding service	WP1	SV1-Navigation Monitoring & Assistance Service (NAMAS)
		Developing e-Navigation services enhancing Korean maritime traffic safety	WP2	SV2-Ship-borne System Monitoring Service(SBSMS)
			WP3	SV3-Safe & Optimal Route Planning Service (SORPS)
			WP4	SV4-Real-time Electronic Navigational chart Distribution & Streaming Service (REDSS)
		Developing e-Navigation services for SOLAS vessels	WP5	SV5-Pilot & Tugs Assistance Service (PITAS)
			WP6	SV5-2-Maritime Environment and Safety Information Service (MESIS)
Activity 2	Developing e-Navigation operating system & Digital maritime communication		WP7	Integrated e-Navigation system
			WP8	Establishing high speed wireless maritime network(LTE-Maritime)
			WP9	Establishing digital maritime wireless communication (VDES/D-HF)
Activity 3	Harmonization with e-Navigation international standards		WP10	Developing Maritime data standards(S-10X)
			WP11	Developing Maritime Connectivity Platform
			WP12	Developing maritime wireless communication technology
			WP13	S-mode

4.2.4 Influences of Digitalization on Maritime Shipping

1) Influence on Ship-related Operations

Digitalization improves onboard systems, ship reporting, routing and scheduling, and activities of people onboard.

- Onboard Systems

Sensors onboard collect various data about vessels' status and the marine environment, and the data is used to monitor and analyze the vessel operation, thus improving the vessel management, such as energy management and smart maintenance. The systems onboard may be integrated on a digital platform and then evolve into a ship digital twin so that the monitor is more visualized and intelligent with technologies like IoT, CPS, GIS, etc. The bridge systems are connected with other vessels and stations on land to provide safer and more efficient navigation services. The systems are provided with real-time and reliable data.

- Ship Reporting

The statistic and dynamic information for ship reporting are regulated by IMO. Digitalization enables the digital, automatic, and timely transfer of information. The aim will be to measure the required information automatically and diminish the manual typing of information which means all data can be collected by sensors especially concerning the dynamic data. Furthermore, the information in the reporting can be shared and forwarded to other authorities with a digital interface for other regulatory, commercial, or logistical needs.

The digital logbook is used to replace paper-based logbooks to record key navigation, engine watch, port calls, and other operational activities onboard vessels of all sizes. Typical marine electronic logbooks are deck logbook, dynamic positioning logbook, engine logbook, oil record logbook, operational log, and radio logbook. The information can be recorded on different electronic devices and data are stored and computerized in the cloud. Information can be searched, managed, and shared more easily.

- Ship routing and scheduling

Digital technologies, like ECDIS, AIS, LRIT, etc., make a lot of benefits for ship routing and scheduling to improve the safety of maritime shipping. Ship routing can immediately action based on real-time data provided by ECDIS to lead to more reliable voyage planning and efficient fuel consumption. By digitalizing ship routing, the safety of a ship can be improved by considering various navigation factors. Completed digitalization of ship routing would enable a more centralized voyage planning process and open new ways for predictive shipping. Finally, it will develop into semi- and fully- autonomous ships.

- For Ship Operators

Digitalization releases and facilitates part of the ship operations for the captain and crews, and the updated human-oriented system design improves operability for them to use the systems onboard. The information is more comprehensive and reliable to ensure safe navigation, and thus to guarantee the safety of people on board. Software and applications help to simplify the recording work and the analysis of data. The land stations also provide maritime services for them.

2) Influence on Multimodal Transport

Digitalization helps to develop holistic solutions for door-to-door transportation, integrating with the hinterland transport networks and optimizing the interconnectivity between transport modes. Advanced logistic chain management systems and operational tools enable fast sea and land information interchange. It is possible to fully integrate short-sea shipping and inland waterways into the logistics chain and decrease the congestion of road transportation. Further development of common definitions, rules, and common interoperable management framework architecture improves the cooperation between the partners in the logistics chain.

3) Influence on Administration

The regulatory processes have already been simplified by the EDI, PCS, and Single Window systems. Furthermore, more and more certificates are enacted in their digital versions which are supported by the legislation and regulation. The containerized cargo documents are simplified to one document and shared among different transport modes. These actions speed up the time and cost of administration procedures. Technology like blockchain can enhance reliability and security.

4.2.5 Developing Trends

1) Autonomous Shipping

Autonomous shipping is coming around the corner in the support of digital technology development. Autonomous ships are equipped with an autonomous ship control system and an automated collision avoidance system. Before fully autonomous operations are remote-controlled vessels. The key enabling technologies including sensors and system integration. This brings challenges to ship navigation and communications.

Previously, the shore-based station plans and monitors ship routes. For the remote-controlled vessel, it can also maneuver ships. The operation is based on CPS. Autonomous shipping will change a lot of the operation for navigation, ship-to-shore communication, etc. They are still in the experimental phase. The first version of EU operational guidelines on trials of Maritime Autonomous Surface Ships has just been distributed in October 2020. The technologies and the influence of autonomous shipping for maritime business and logistics are still in trials and under development.

2) Intelligent Multimodal Transport

The integration between sea-side maritime shipping and land-side hinterland transport is influenced not only by the infrastructure connections but also the documentary and information integration. A large amount of work has been done for the infrastructure construction. When the transportation networks are finished or developed to a certain degree, the way to improve the integration should focus on the information integration for the shared documents and information. The systems for each transportation mode can be integrated or improved by building interfaces for them. Data and information can be stored in the cloud, thus it is easily accessible and used for computing for business or logistical demands. The security and access limitations of the data and information should also be considered when it involves business privacy. Future multimodal transport will be more dynamic, efficient, and environmental friendly by making decisions on real-time information and scientific computing.

4.3 Smart Port

4.3.1 Introduction

Ports have undergone several generations along with the development of technologies that apply to port operations, from isolated ports to expanded ports, to container ports, to integrated ports, and now it is time to develop Smart Ports, as shown in Figure 4-20 (Molavi et al., 2020). The Smart Port, which connects all parts of the port terminal operations, warehousing, logistics, yards, and port transportation through the wireless network, provides all kinds of information for daily supervision, replacing related government departments and port shipping enterprises (Li, 2018).

The concept of the Smart Port is related to smart logistics, smart city, and Industry 4.0. The idea of smart logistics has emerged in the context of Industry 4.0. In the context of Industry 4.0 and smart logistics, supply chains have undergone significant changes, which are also accompanied by global economic growth and development. This has created a need for a new configuration and supply chain design and also the emergence of sustainability challenges to synchronize the development of the port. Since the port is the point of interaction between transport modes and supply chain actors, its criticality becomes more explicit, and the new configuration of supply chains and global logistics focuses on the port. Ports are not only the physical notes of interaction between land and sea but also nodal points with facilities and personnel that can facilitate the development of global supply chains. There is a need to establish an integration relationship between ports and supply chains. The new Smart Port is focused on improving the competitiveness of the port and facilitating collaboration between different port stakeholders to achieve horizontal and vertical integration of all supply chains (Douaioui, 2018).

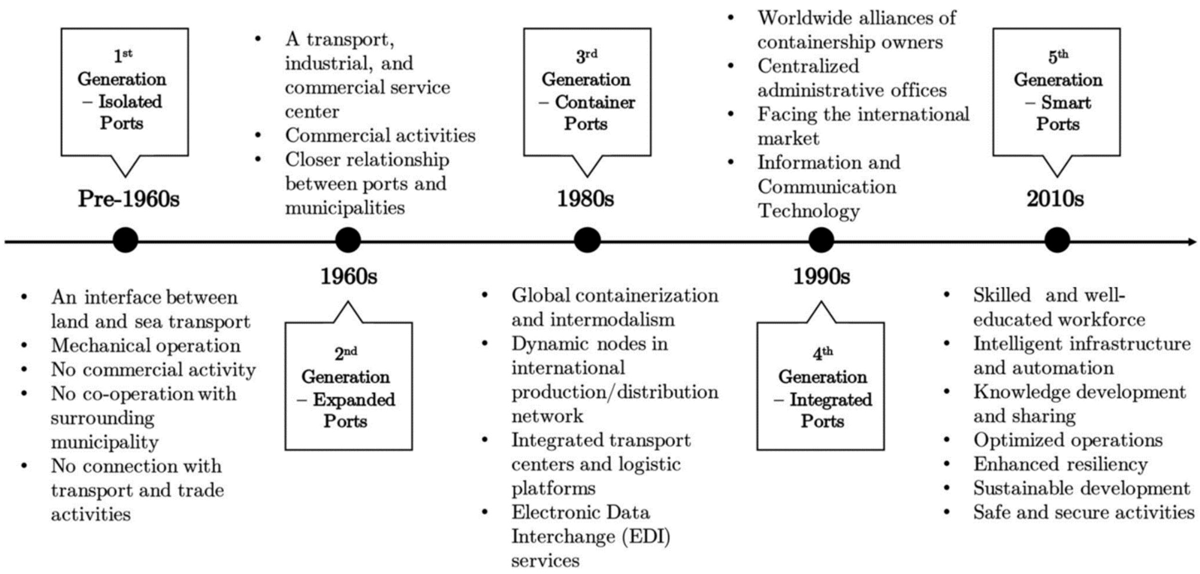

Figure 4-20 Port development throughout history (Molavi et al., 2020)

Two pillars, supporting the transformation to Smart Port, are (1) the interconnection of the entire port logistics chain and (2) the automation of port operations and equipment, as shown in Figure 4-21. The interconnection of the entire port logistics chain promotes coordination between transport operators, improves communication between key actors, and develops innovative business models that improve maritime and port operations. The systems to improve the interconnection are intelligent information systems, data centers, and cybersecurity. Automation is realized by the combination of software, hardware, and mechanics. The revolutionary of automation reduces unnecessary labor and ensures speed, reliability, fluidity, and traceability of container's operations. It minimizes resource wastes and increases the technical efficiency in ports. The components that contribute to port automation are smart ships, smart containers, and automated operations (Douaioui, 2018).

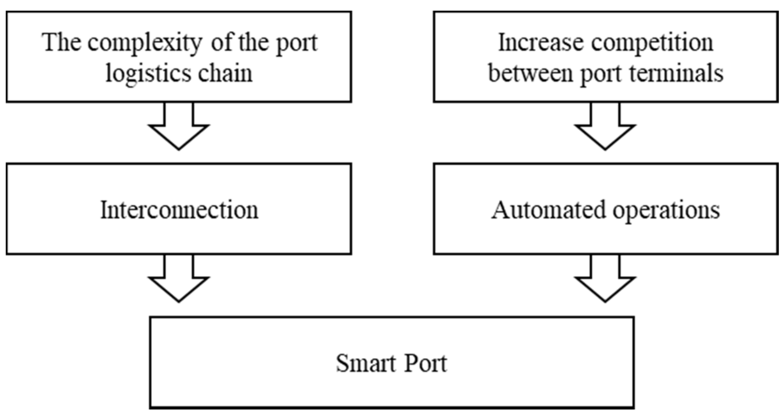

Figure 4-21 Pillars of Smart Port (Douaioui et al., 2018)

A Smart Port contains four main activity domains, which are operations, environment, energy, and safety and security. The four domains have subdomains respectively shown in Table 4-16. These domains are also the performance indexes for evaluating the Smart Port.

Table 4-16 Classification of Smart Port activity domains and subdomains (Molavi et al., 2020)

Domain	Subdomain	Description
Operations	Productivity	• Productivity about berth, infrastructure, land, use of maximum capacity, lines calling, and level of intermodality • Automated stack, path, rail, lift, trucks, and quay • Integrated information systems and software • Various avaliable handware
	Automation	
	Intelligent infrastructure	
Environment	Environmental management systems	• Environemnt management systems based on ISO 14001 • Air emission control • Noise pollution reduction • Actions plans to handle, recycle, recept, and reduce waster to standard amounts • Wasterwater assessment and reduction • Reduce water consumption
	Emissions and pollutions control	
	Waste management	
	Water management	
Energy	Efficient energy consumption	• Reduce energy consumption by containers, fleet, lighting, terminal equipment, and offices and companies • Use renewable energy such as solar power, wind, biomass, wave and tidal energy • Efficient use of solar and electric transportation • Monitor and optimize energy consumption
	Producing and use of renewables	
	Energy management	
Safety and security	Safety management system	• To administer safety principles based on IMO's International Safety Management Code • To identify threats and to provide assurance based on IMO's International Ship and Port Facility Security Code • To connect hardware and software for data gathering, visualization, analysis, and optimization
	Security management systems	
	Integrated monitoring and optimization systems	

Smart Port is beneficial for environment-friendly operations, adhering to the green development trend of ports. Therefore, a green port and a smart port are systematic concepts of development and are not independent of each other (Chen et al., 2019).

4.3.2 Technologies and Applications

1) Technologies

The main information technologies that are applied to develop Smart Port is IoT system, Big Data, Cloud Computing, sensors, RFID, and wireless communication technologies. These technologies are used to connect the physical infrastructures, monitor the operations, and instruct the movements of containers.

Sensors are effective tools to measure the physical characteristics of objects and convert them into digital information that can be read by other devices. As information is collected and accumulated by sensors, the data is transferred by communication technologies to the cloud for further management. A network of smart sensors and actuators, wireless devices, and data centers make up the key infrastructure of the Smart Port. There are various sensors, such as inertial sensors, ultrasonic sensors, eddy current sensors, radar, lidar, imaging sensors, and RFID readers and tags.

With the rise of the IoT and the availability of sensor networks, information that gathers from the natural and man-made elements of the seaport has rapidly increased. Such an amount of data is useless without a system that enables meaningful information visualization. A web platform as an Internet or mobile application is needed to manage and visualize the sensor data for seaport monitoring and management. The platform can provide access to current and historical data and can do the data analysis. It should be open to the operators who are involved in the maritime business and logistics for exploring the usage of the data. (Fernández et al., 2016).

In the cloud IoT system, the raw data streams flow between smart bricks and fog systems, the information streams transfer between fog and cloud systems, and finally, the information services are provided from cloud systems to service application systems. The information is used to provide several information services like internal monitoring services, public monitoring services, and navigation and logistics services. Apart from common attributes for applications such as vendor, version, and operator, the new data processing systems need additional attributes as they are operating in the cloud (Schirmer et al, 2016).

Besides the technologies above, for the existed ICTs, it is necessary to interlinking if the port administration wants more efficient traffic management. These systems are recommended to connect the logistic chains to allow a smooth information change and to optimize the port processes. The logistics process can be digitalized by using the available data and the secure data exchange from the systems. (Gasparotti et al., 2019)

2) Applications

The applications in a smart port support ship and port management, port terminal operations, hinterland transportation, and regulatory processes.

- Intelligent Ship Management

The connections based on IoT and AIS information between ships and port provide real-time monitoring of ships, effective management of ships in the port, and help customs to monitor the ship import and export declarations and the procedures of arriving and departing (Belfkih et al., 2017). The port calls are more flexible as the ships can get the freshest information about the port terminals' free positions, and then arrange the voyages to avoid long waiting times. Furthermore, there may be time predictions for every ongoing activity based on the systems' computing function, consequently, the port can provide reserved berthing services for ships. The berthing, mooring, piloting, and tug services can also be automated in the Smart Port in the future.

- Automated Port Terminal Operations

When ships arrive at the terminals, the quay cranes work automatically to load and unload the containers. AGVs that are controlled by computer systems transport the containers from the quayside to storage yards. Then yard cranes stack containers automatically as well. All the port terminal operations are completed without human interference, but they can be more correct and safer.

- Intelligent Hinterland Transportation

The traffic flows in ports are mirrored to the web platform. Hinterland transportation carriers can get real-time information about containers and the port traffic situations, and then arrange their journeys to pick up containers. IoT systems can be used for inter-organizational processes. The systems of maritime transportation may be integrated with the hinterland transportation networks, thus door-to-door transportation can be achieved efficiently as a holistic solution.

- Intelligent Port Management

To manage the traffic flow in port, to manage the infrastructure for maintenance, etc. for power consumption in the port area. Technologies are used to reduce power consumption in ports by implementing a usage-dependent light control, such as modeling dimmable lights.

- Integrated Information Platform

An integrated information platform, which can be considered as PCS or other Single Window System, that will provide the real-time regulatory information or other monitoring information for all the actors such as freight forwarders, shipping companies, shipping agents, hinterland transportation companies, customs, port authorities, etc. As the cross-border trade involves a lot of regulatory procedures among many actors, and the physical flow requires approval notifications, a platform that publishes the regulatory status to all the actors is helpful to simplify the data transfer and sharing, and thus any actor that gets the information can arrange or prepare its logistics activities in time or in advance. This is also a character of the interconnection of different actors in Smart Port.

4.3.3 Cases

- Port of Hamburg

The Port of Hamburg situates in the city and space in the harbor is limited. To overcome the geographic limitation and attract more business, the Hamburg Port Authority (HPA) launched the smartPORT initiative in 2012 to improve the efficiency of port operations and enhance the port's competitiveness. The initiative consists of two sub-initiatives smartPORT Logistics (SPL) and smartPORT Energy (SPE) as shown in Table 4-17. The SPL project strives for optimizing the logistic processes in the harbor mainly by adopting smart technologies, and the SPE project aims at reaching sustainability goals. The goals are to establish an intelligent infrastructure and to optimize the flow of information to manage trade flows efficiently.

For several years of development of the projects, the HPA has completed 10 service tasks for constructing the Smart Port. 7 tasks are under the SPL project and the rest 3 follow the SPE project shown in the table below. The projects implement smart technologies like sensors into roads, bridges, and railway points. The IoT systems generate data that can be aggregated and used for improving traffic management or for predictive maintenance. By using a large number of small sensors and computers, the physical world and the information world are getting directly interlinked (Saxe, 2018).

Table 4-17 Developed services of the Hamburg smartPORT initiative

Project	Services	Description
Smart Port Logistics (SPL)	Navigation in real-time	• To improve traffic flow in and out of the port • The HPA provides personalized navigation for the drivers, as well as the information in and around the port. • The drives have access to parking and infrastructure information, closures of the moveable bridges, etc.
	Parking for professionals	• To use the smartPORT logistics app for truck parking
	Intelligent railway point	• The frequently used points on the harbor railway are fitted with sensors that transmit the data to a central IT system in real-time • The maintenance work or repairs can be identified at an early stage to avoid downtime
	Virtual deport	• It is used to optimize the movement of the empty container between packing companies • The cloud-based system informs operators which containers are to be delivered back to the depot and then the packing company requests for the containers directly.
	Port monitor	• A variety of information is centrally gathered such as vessel positions, water level data, berths, etc. that is always accessible to the actors who need it
	The mobile sensor	• A mobile GPS sensor wirelessly forwards data to the IT system for intelligent fleet management • Sensors are also used for other measurements, such as temperature, wind speed and direction, air pollution, and the flow of the Elbe
	Smart maintenance	• The infrastructure is monitored using mobile end devices, such as tablets or smartphones • The devices send measurements of roads, bridges, and tracks automatically to the downstream IT systems to make the maintenance processes more effective and efficient and to improve the quality of notifications
Smart Port Energy (SPE)	Shore power from renewable energy	• a landside cruise liner power supply sourced from re-newable energies
	E-Mobility in the port	• to use e-Mobility to passenger and freight traffic in the harbor area
	Renewable energies	• Reviewing wind and solar power and even bioenergy

- Le Havre Smart Port City

In France, the Port of Le Harve has embarked on the Smart Port City project to coordinate maritime and city operations. 5G is the main technology to implement this project to explore wireless connectivity.

To provide a digital service, the port has developed a digital bathymetric database to replace printed marine charts, thus enabling the real-time cross-referencing of digital data with electronic marine charts. The data stored on a shared server is accessible to port authorities and pilotage services and is useable on digital tablets to enable more accurate ship movements and channel maintenance.

- Port of Shanghai

In Port of Shanghai, the Yangshan Phase 4 is a fully automated terminal. The Shanghai International Port Group (SIPG) aims to handle 3.2 million TEU at the terminal which is still considered under its maximum handling capacity. The port also implements 5G technology to facilitate automated operations like driverless container trucks.

- Port of Rotterdam

The Port of Rotterdam focuses on Smart Energy & Industry, Smart Logistics, and Futureproof Port Infrastructure. The main technologies to achieve the goal are sensors and IoT platforms. It will have an experiment on smart ships to call at the port and to handle the autonomous ship by the automated container terminals. Meanwhile, the port plans to invest 5G and Artificial Intelligence (AI) to develop the Smart Port goal. AI is used to predict the ship's arrival time and thus reduce the waiting time based on an application that receives data from the port authority database and AIS. The application is used for standardized data exchange on port calls for maritime actors to plan and monitor their operations and implement changes.

- Port of Singapore

In 2015, the Maritime and Port Authority of Singapore made a plan for the Next Generation Port (NGP) 2030 for Singapore. The core of the NGP 2030 is to develop an intelligent port to manage the future marine traffic in the port and the increasing ship sizes. The new generation of technologies, such as AGV, automated yard and quay cranes, big data, and sensor-integrated smart systems, are utilized to increase efficiency and productivity, intensify land-use facilities in the port, improve safety and security, and raise the level of sustainability. The major component of the NGP 2030 is the next generation Tuas Terminal, with a capacity to handle 65 million TEUs as the largest single mega container terminal in the world. To enhance the berth capacity, a two-tiered container terminal and the use of an Automated Storage and Retrieval System for containers are explored. For land-use facilities, one of the new concepts is to develop a platform above part of the container port on which port-related and industrial developments, such as container freight stations, logistics hubs, and other facilities, can be taken to intensify the land-use. Consequently, the port will be more community-oriented and accessible to the public. More R&Ds are included in NGP, such as the autonomous platforms that can be deployed in the air, on the water surface, or underwater, Unmanned Surface Vessels, a new generation Vessel Traffic Management System, and the use of clean energy (Maritime and Port Authority of Singapore, 2015).

4.3.4 Developing Trends

The future port is developed into a knowledge hub for innovative industrial, service companies, universities, and non-academic research facilities. The Port Traffic Center integrates the traffic information from all water-, rail- and road-bound carriers and controls all forms of transportation to guarantee optimum traffic flows in the port. Port Authorities takes on the role of freight and logistics integration and creates the port value-adding network efficiently. They should focus on improving hinterland connections by drawing up joint investment programs for the necessary infrastructure improvements. Moreover, they can facilitate the application of technology and enable better insight into traffic flows, helping enterprises to further optimize their supply chains and make them more flexible.

Developed ports, which are already digitalized physical operations into automation, may shift its business to become a service provider and focus on the connection of all stakeholders who contribute to seaport operations. As Smart Ports represent the last development stage in the digitalization of port activities, it brings out new services that replace traditional practices.

Smart Port is going to be one critical part of achieving Industry 4.0 in the production industry and the Smart City objective in some countries. Environment protection is also a necessary issue for consideration in the future, so the Smart Port will be integrated with the concept of Green Port.

The technologies, besides sensors and IoT, CPS, Blockchain Technology, AI, 5G, etc. are all had the potential to be applied to the construction of a future Smart Port implementation. For example, the CPS enables the self-configuration level of function; Blockchain may change the platform for regulatory processes; AI can be used for predictive activities based on a large amount of data.

4.3.5 Obstacles

Though a lot of developments have already been achieved to the port digitalization, the concept of Smart Port is still on experiment and trials. The new business services are under exploitation as some applications show few interests for the industry side. However, it is an inevitable trend for the port future development.

In the port digitalization era, data are explosive and information may be overload. It is necessary to work on data mining and computing to make them usable for logistical and business services. The visualization techniques used for communication should also be enhanced. As Smart Port is initiated by the port and then provides the platform to other actors, it may become a close space to which only a small group has access. More transparency is needed and it is important to build a sense of community so that everyone can participate actively with the Smart Port.

The work of integration and interconnection of different transport modes and organizations is not easy even though it can gain benefits as a whole. Firstly, there are different data standards, so it is a huge amount of work to standardize the document into one and used by all; second, the information systems are already built by each actor, it takes time to integrate the old one into the platform so that providing a middleware as interfaces between the systems is a method to solve these problems; thirdly, the applications should be available to all the actors without a large number of technology investments, thus web or mobile applications are favorable and easy to implement; fourthly, the web security should be considers that the database and platform will not be attacked by hackers and the information is safely stored and exchanges; fifthly, it is also important to light up the interests of the authorities and the whole industry to develop the Smart Port, driving by governmental policies and investment, and active participating by the industry companies on both physical constructions, software developments, and new business model explorations.

4.4 Summary

The concepts mentioned above have various influences on the maritime industry, especially considering the main actors, e.g. shipping lines, port authorities, and hinterland transport companies. A SWOT analysis is conducted to clarify the strengths, weaknesses, opportunities, and threats of these concepts to the maritime actors.

1) Strengths

The concepts of e-Navigation, e-Maritime, and smart-Navigation enable a more comprehensive and immediate track of vessels and containers, complemented by the environment and weather information, shipping lines improve the safety and security of vessel movements. Single Window systems speed up the regulatory procedures, and Smart Ports enhance the efficiency of terminal operations. These shorten the time vessels' waiting and berthing time and increase the rate of vessel circulation. The Single Window concept brings a large amount of convenience to the business process in cross-border trade, thus attract more trades to the nations.

2) Weaknesses

Single Window is mainly proposed for inter-organizational procedures. The regulatory process in maritime logistics may involve a large number of governmental authorities. Some authorities have already invested in their systems and are conservative to the new Single Window concept. Meanwhile, the policies and legislations differ from country to country. The standards are not unified in this industry. E-Navigation covers only the SOLAS ships. For other vessels, it may be not worthy to invest in the system. To realize the automated navigation requires investments in the corresponding ashore stations as well. Inadequate cybersecurity is also an important issue.

3) Opportunities

Shipping lines and ports can develop more services for an integrated supply chain management of international trade. The concepts of Single Window and Smart Port bring an opportunity for ports as network hubs to the hinterland. The physical flow and information flow along the maritime chain may be synchronized, transparent, and open to different users. Vessel shipping and port operations are developed into automation.

4) Threats

Though there are a lot of benefits that the developed concepts may bring, the implementation of the concepts may require several times' trials. The new technology and applications are not mature now. It has risks to invest in these concepts because they are still under exploration. The maritime actors, who successfully implement the new technologies to meet the business needs, may have a leading influence on the industry. There is also an imbalance development in different regions, such as a tendency towards a digital gap between ports in developed and undeveloped countries.

5 Findings, Conclusions, and Recommendations

Digitization and digitalization have gradually transformed the maritime industry for over 60 years. Technologies are developing continuously, and applications are designed to meet the business requirements. This work has researched how digitization and digitalization influence the maritime industry from the perspectives of effects on information flow, business, and logistics operations, based on the methodology of literature review and case study. Literature about maritime digitalization is categorized and summarized according to influences on the different business processes. For each ICT and developed concept, there are cases from the industry. The three sub-questions about the ICTs, the influences of the ICTs, and the developing trends and strategies in the maritime digitalization process are answered and analyzed in Chapters 3 and 4.

This work aims at providing an analysis of the digitalization process in the maritime industry, considering the established, developing, and future ICTs and applications. It finds out that digitalization has influenced all the commercial, regulatory, logistical, and financial processes in the global business and supply chain. As a traditional and important transportation mode of global business, the maritime industry has been through several changes and ushered in a vision for future development under digitalization. By identifying the changes and trends, it is useful for international organizations, governments, and authorities to make decisions for future strategies; it facilitates the maritime actors to have a glimpse of the digitalization process to catch opportunities and challenges; it also provides IT companies with tips on demands of the applications in the maritime industry.

The influences of digitization and digitalization on the maritime industry on information flow, business, and logistics operations are concluded as below.

1) Influence on maritime industry's business

The logistics service providers build e-commerce and mobile-commerce channels that make transportation into standard service products. For example, the shipping companies and global freight forwarders provide transportation products with estimated schedules and prices online. It simplifies the methods for shippers/consignors to search and order suitable transportation services and reduces costs and time for communication and making transportation contracts. The information of the orders will be tracked and available throughout the maritime logistics chain online. Furthermore, the service providers compile the digital information of each order into EDI documents that can be used for cross-border regulatory processes. Digitalization has pushed the process of document standardization and the integration of different authorities and systems. Meanwhile, the payment has also been accomplished online. It is said that blockchain technology may enable online payment without a third party which is required by online transfer at present. The smart contract based on blockchain technology is proposed to govern the business transaction.

2) Influence on maritime industry's logistics operations

Digital technologies have largely improved the logistics operations in maritime shipping from ocean shipping to port operations to hinterland transportation.

Firstly, the influences on ocean shipping are presented by the implementation of e-Navigation, remote controlling, and autonomous shipping. The IMO's e-Navigation largely enhance the safety of maritime shipping for tracking the ships' route, sending notifications about the dangers, and instructing the navigation. 16 services are identified as a VTS MSP for reference. International standards (S-Mode and S-100) are set up, which are for ECDIS and the development of digital products and services for hydrographic, maritime, and GIS communities. The e-Navigation is applied around the world. In Europe, the extended strategy like e-Maritime contains the e-Navigation implementation. The smart-Navigation in Korea extends the service for non-SOLAS vessels. When the ICTs develop to a certain degree, vessels can be controlled by the ashore stations for navigation. Autonomous shipping is also proposed as a future developing trend. The autonomous ships have already been taken into action or are waiting to be tested. The common use of autonomous shipping for business is not mature yet.

Secondly, the port operations are improved by digitalization. The main development is the semi- or full- automated port terminals that improve the efficiency of terminal operations. Containers are tracked in ports and transported by AGVs from the quayside to the yards. The operations are controlled by computer systems. The information about vessels, e.g., where and which berth they will arrive or depart, about the traffic flow in or around ports, whether there is congestion, and about other notifications is provided by the port platform via the website or mobile application that is easy to access. The overall development drives the port into an integrated information hub.

Thirdly, hinterland transportation is also enhanced by digitalization. Real-time information sharing makes benefits for transport coordination. Hinterland transportation can arrange the activity based on the port's transparency information platform. When the network of maritime shipping and hinterland transport are interconnected, it brings a lot of potential development to provide a holistic solution for door-to-door transportation.

3) Influence on maritime industry's information flow

The concept of a Single Window improves the information flow in cross-border trade both for regulatory and logistical affairs. Firstly, the Single Window uses standardized documents, and in an ideal situation, the required documents are simplified and reduced into one single document that is available for all processes. Secondly, it integrates or provides interfaces for different systems, avoids repeated submitting of the same information, and reduces the possibility of manual mistakes. Thirdly, it simplifies the procedures that involve inter-organizational relationships.

Different ICTs have separate influences on information flow. Big Data and Cloud Computing enable the collection of a large amount of data and analyze and use the massive data for business and logistics purposes. The cloud products can be provided as software that is available for anyone who can get access to the internet. Blockchain is considered to transform the industry's information flow in the future. It is used to track every point of the document transaction or container's movement with reliability. The Blockchain BoL has already gained a lot of attractions and been taken into use. The related applications are still under development. All of these digital technologies are making the information flow more transparent, simplified, and straightforward, and it is presented by a platform and shared by different actors.

The technologies such as 5G, CPS, AI, etc. are still at the beginning phase of applying to the maritime shipping industry. They will largely support autonomous shipping and automated port operations. Maritime Autonomous Surface Ships are under experiment but operational guidelines have already been distributed by regional or national authorities. More collaborations are expected among multimodal transportation as well as the regulatory authorities. The concepts in the digitalization process are related to each other, for example, the Smart Port is connected with Smart City and Green Port; Port Single Window, Customs Single Window, and National Single Window may be cooperative as well as competitive. Consequently, it is important to have an overview of the digitalization process, concerning the standards for documents and technologies and the interoperability of information systems.

This research aims to analyze the influence of digital technologies from an overview vision. However, more detailed evaluations of each technology are not included. Meanwhile, the case studies for the developed concepts are worthy to be further learned for making suggestions for different authorities on development. This work has not fully presented the relations of each technology with the developed concepts. As new technologies like blockchain and smart contracts have a potential influence on maritime business and logistics, it is also important to study the influences of these specific techniques and their applications on the business, logistics, and information flow. The future study may concern about the mentioned topics above.

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