CONTAINER OPERATIONS

MARITIME PORT AND CONTAINER LOGISTICS INFRASTRUCTURE AND PROCEDURES MAPPING

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1 Introduction

A port (or seaport) is a place at which the transfer of cargo and passengers to and from waterways and shores occurs (Talley, 2009). While the ports in the world are operated and managed in different ways and container processing involves a great number of parties and documents, this article will give a general and unified idea of the functionalities of maritime ports, especially in terms of international container logistics. If not specifically stated, in the following 'port' is referring to a cargo seaport rather than a passenger port. This article can be interesting for modellers of container logistics and anyone who would like to have a basic idea of maritime ports regarding the origin and development, management, organisation, and performance evaluations.

The remaining sections will be organised as follows: Section 2 introduces the multiple aspects of port development; Section 3 and Section 4 explain the maritime container shipping, in which Section 3 focuses on the infrastructure and equipment while Section 4 demonstrates the import and export process of containers in maritime ports; Section 5 will conclude this article.

2 Port Development and Management

2.1 The timeline of port development

Lots of port-related events have happened in the past decades. In Burns (2015), the past decades are divided into 4 eras: from the industrial revolution to the 1960s, 1960s-1980s led by containerisation, 1980s-1990s as the era of logistics with intensive production, complex logistics was largely going on, and 1990s-2008 marked by the globalisation of trading and finance. They also propose the 5th era after 2008 in the Post-New Economy Era. The remarkable events in the eras have been driving the evolution of port generations.

UNCTAD (1993) summarises the 3 generations of ports. Before the 1960s, ports were in the 1st generation and served merely as an isolated location to transfer cargo. During the 1960s to 1980s, ports started to integrate industrial and commercial services by extending towards hinterlands and cooperating with commercial companies, providing added value. They classified that from the 1980s on, the ports had entered the 3rd generation. Ports in this stage have been providing specialised services for global multimodal transportation of containerised cargo. Later on, in UNCTAD (1999), the 4th generation of ports is proposed as "physically separated but linked through common operators or through a common administration". The 4th generation ports are more a part of the supply chain than independent centres and focus more on flexible services and sustainability.

2.2 Port development and port industries

The port industries do not appear once a port is established. They gather and develop gradually with the improvement of the infrastructure and functions of a port. Bird (1963) proposes the "Anyport model" to demonstrate the evolution process of port infrastructure. When a port is constructed initially, the most important consideration is the geographical location. The port performs basic functions like warehousing and wholesaling with simple port facilities. The evolution usually starts with the expansion of quays due to the growth of the number of goods and the size of ships. Also, dock constructions such as jetties are more and more needed. Rail lines are also integrated into the port terminals to increase access to the hinterland and the throughput of the port. With the prosperity of port activities, port industries are attracted and included gradually. Next, the port is going towards specialisation, when specialised terminals are designed to handle different types of goods, such as coal, containers, ores, etc. Other aspects are also enhanced, especially in terms of warehousing and handling capacity, water depth and jetties. The original site of the port may also be abandoned and transferred to a new centre.

It is found that the port industry has been developed and included in ports with the diversification of port activities and functions. Generally, two types of port industry are directly relevant to the ports: 1) those who rely on the port's natural conditions and serve the shipping industry; 2) those whose business activities depends on the shipping industry of the ports. The first group can include maritime transportation, loading/unloading, warehousing and logistics, while the second group can be shipbuilders/repairers, manufacturing companies and so on. In addition, some industries are not directly connected with ports but also very important, for example, banks, insurance, consulting, travelling, and management companies. A specific case is the Port of Antwerp, in which quite a lot of heavy industries are also based in the port, e.g., oil refineries and chemical companies such as BASF, Bayer, Total. This is because the convenient access to maritime ports can greatly benefit the transportation of their raw materials and finished goods. The operations of such companies will not be elaborated while the logistics-related companies instead are to be discussed further in the following parts.

Terminal operator

Terminal operating companies are responsible for the loading/unloading of cargo and their relevant ship management. Some of the terminal operating companies are only present in a specific terminal of a port, the others can have branching companies in multiple ports of the world. Their major customers are shipping companies and importing/exporting companies. Generally, due to the varying handling processes of cargoes, a terminal operator only handles one type of cargo. Most of the terminal operating companies confine their service range within the port, but they have started to provide value-adding services, such as cargo reprocessing and packaging. Their costs are mainly incurred by human resources, equipment, and infrastructure renting and maintaining.

Carrier

Carriers operate deepsea vessels and provide waterway transport services, which can be categorised to liner and charter shipping companies according to whether they have fixed schedules for specific ships and shipping lines. Liners are often used to transport cargo of large variety like container and rolling goods, while charters large volume of goods, like bulk goods. The economies of scale are quite obvious for carriers in terms of the number of ships and the larger size of ships. Their costs are mainly incurred by shipping operations, fuel, staff salary, and port fees.

Transport provider

Port can be an excellent interface for intermodal transportation. The possible inland transport modes could be trains, trucks, barges and pipelines. These companies heavily rely on the condition and ownership of the connecting infrastructures. The cooperation of the transport providers and the port operators has been a long-existing problem, because there are seldom long-term contracts among them, and transport providers are often small-scaled and geographically sparse.

Transport agency

Some agency companies do not possess physical assets but can be very important entities. For example, freight forwarders and shipping agents. Their working process will be elaborated on in Section 4. Another example is the shipbroker, who buys shipping capacity from the shipowner, and resales to the import/export companies or shipping companies.

Other logistic service providers

In the ports, transportation is the core business, but warehousing and other value-added services are also necessary. These logistic service providers (LSPs) can include ship pilotage, tugboat for ship turning and towing (sometimes it is mandatory), mooring service, fuel supply, customs, ship leasing, ship rating and maritime law department.

2.3 Port governance and management

A good way to gain an insight into a port is to discover the governing authority over the port resources. Burns (2015) categorises the port governance as follows: 1) *government/state ownership and administration*; 2) *semigovernmental organisation*, meaning the port and its services are managed by a non-profit administration compared with the previous type; 3) *state/regional ownership*, an example is Port of Rotterdam, who has the Rotterdam municipality holding its major share of authority and providing support; 4) *private-owned ports*, in which the infrastructure, superstructure, labour and the other functions are all largely privitised. As is found in the port governance categories, the responsibility distribution varies. According to the privatisation levels, there

are port governance models that can be categorised as *public service ports*, *tool ports*, *landlord ports*, and *fully privatised ports*.

Public service ports are vastly operated and managed by the port authorities, which are often a part of governments or national authorities. In public service ports, the port authority owns the infrastructure and provide all the services. This governance type can yield significant benefits if decisions are made clearly and logically. However, the monopoly can on the other hand lead to corruption and the lack of market sensitivity.

For *tool ports*, the port authorities still own and manage the port, but the control of cargo handling are operated by private companies by renting the equipment. This is often a transitional form between the public service port and landlord port, as a safe step to take before diving into full privatisation.

If the ports go further to the public-private coalition, they will reach *landlord ports*. This is the most common management model (e.g., Port of Antwerp). The port authority does not participate in the operation of the port but remains as legislation and administrative sector while leasing the infrastructure and land to private entities. The "leasing from the landlord" also shows in the settle-in of private industries (e.g., shipping agencies, chemical plants, oril refinery). The private companies provide the port equipment (superstructure). In this way, their business can thus not be interfered with by the port authority.

A *fully privatised port* implies that the ownership and policymaking are completely transferred to private companies. The public entity can be a shareholder and supervise the regulatory issues. This model is often found in the UK and New Zealand.

2.4 Port performance indicators

As a port needs to increase its competitiveness by standing out from other ports and also focusing more and more on delicacy management strategies of itself, port performance indicators (PPIs) are increasingly used to compare and monitor ports. In that sense, the PPIs should be straightforward enough to provide direct impressions. So far, the most prominent PPI is the throughput, which reflects the maximum handling capacity by calculating the number of goods that pass through a port. However, the goods vary in size, thus the throughput is not a very objective indicator. Besides, the growth of throughput is often accompanied by a growing cost of human resources and equipment, making throughput less effective to measure the economic benefits (de Langen, 2007). Sometimes, the throughput increases due to the regional trading volume rather than the port operation excellence. Therefore, some ports in Netherlands and Belgium also use the added value created by ports to evaluate the economic contribution, but it is not a direct indicator for port operation efficiency. Other common PPIs are the private investment in ports, amount of created employment, environment-related indicators, utilisation of digitalised information exchange, etc.

Regarding the port operations, a set of cargo handling indicators are widely calculated. A group of indicators different from the throughput is the loading/unloading operation indicators, including the tonnage worked, cargo handling coefficient, turnaround time in the port, tons per gang hours, waiting time, service time, average tonnage worked per ship/handling/day, etc.

Another set of indicators is about the utilisation of the port infrastructure and equipment, including berth occupancy, cargo storage ton days in warehouse and yard, average storage time, warehouse and yard utilisation rate, equipment in good condition rate, equipment utilisation rate.

In addition, there are also indicators representing the energy consumptions, for example, operating/ancillary operation energy consumption, energy consumption by income or tonnage worked.

Finally, a set of indicators regarding the safety of workers and cargoes, mainly containing the number of accidents, cargo damage and cargo errors.

Other than the port operational indicators, there are also calculations about port capacity. This mainly refers to the handling capacity of berth, warehouse, yard, port equipment, and workers, as well as the transport capacity of road, rail, waterway, pipeline. Additionally, the economic activity analysis of port is also often assessed, which are generally the contribution to gross domestic product (GDP), market share, rate of profit, return of investment, debt ratio, assets growth rate and operational costs. The costs of managing and operating a port can be further composed of fuel, spare parts, tyres, specialised tools, human resources, equipment depreciation, equipment repair, equipment renting, waterway maintenance.

3 Container Terminal Infrastructure and Machinery

This section introduces the components of container seaports. In short, a port is physically composed of waterside and landside. The landside consists of the terminal, storage facility, hinterland traffic area and supportive facilities, and the waterside consists of the approach channel, anchorage, and harbour basin (aka. harbour or basin).

3.1 Container terminal layout

Berth

The location for vessels for mooring, loading, and unloading containers.

Frontier (aprons)

The area between berth and yard, in which container cranes and their rails are located.

Container yard (CY)

The location to store containers. Especially, sometimes the part of CY near the frontier is used as a buffer area to temporarily store inbound and outbound containers, while the backward area is the main area to store containers, which is categorized to specialized areas for different types of containers (full, empty, reefer, dangerous cargo, out of gauge). On the ground, grid lines are drawn to indicate the slots for containers, by which containers are located at specified places.

Container freight station (CFS)

CFS could be sited at the outer parts or outside the terminal so that it is near the road or railway and convenient to handle bulk cargo. Usually, there is some light machinery in CFS to process less-than-container-load cargos.

Control tower

The centre of the port, functions as the controller, coordinator and commander of port operations, especially loading, unloading, and yard management. It also collects and processes the information from the terminals in a port.

Gatehouse (GHS)

The boundary of container terminal and a business department for container import/export. It acts as the entrance and exit and is also responsible for issues such as documentation and container and machinery handover.

Maintenance shop

The location to maintain and repair machinery and containers.

Container washing station

The location to clean and wash containers.

Terminal building

Administrative zone.

3.2 Container terminal machinery

Container

The container is a standardised reusable transportation unit. To be able to withstand the shipping operations, their design is well-planned and standardised. While it is pointless to elaborate on all the technical specifications, it is necessary to mention that the most common size of standard containers is 20ft and 40ft, whose dimensions are shown in Table 3.1. Also, 20ft containers are largely used as a standard measurement unit for containers – TEU (Twenty-foot Equivalent Unit). For example, a 40ft container equals 2 TEU. The following are the common types of shipping containers:

- dry cargo container: this is the most common container. The dry cargo container is airtight and can transport almost all kinds of goods as long as the size/weight fits, except e.g. frozen cargo, liquid;
- bulk container: a type of airtight container with openable loading hatches on the top, which could be made of glass or steel. It is normally used to transport bulk cargos such as grains, feedstuff;
- reefer container: a type of container to transport chilled or frozen cargo with refrigeration equipment. Reefer containers have higher costs than other containers due to the power supply management facility, dedicated storage area, risks of failure of temperature maintenance and the resulting cargo damage, etc.;
- open-top container: a type of container with the top covered by canvas or tarpaulin rather than steel. This is mainly for the convenience to load oversized goods from the top like timber;
- platform-based container: a type of container composed only with corner post and floor but without sides, ends and roof. The floor is thicker and stronger to load over-weighted goods, which also makes the net weight heavier than the normal containers;
- pen container: a type of container specially designed to transport animals with a metal net installed on the sides for ventilation;
- tank container: a type of container to transport liquid cargo, e.g., beers, foods, medicine, chemicals. It is a tank fixed in a protective container-shaped framework. The goods can be loaded from the top and unloaded from the top or bottom;

Table 3.1 – Common container size and dimensions

Size	Length		Width		Height	
	(m)	(ft in)	(m)	(ft in)	(m)	(ft in)
40ft	12.192	40’	2.438	8’	2.896	9’6”
					2.591	8’6”
					2.438	8’
					< 2.438	< 8’
20ft	6.058	19’10.5”	2.438	8’	2.591	8’6”
					2.438	8’
					< 2.438	< 8’

- car container: a type of container to transport cars with a similar exterior to the common containers, which can be converted to two layers to load more cars.

Container crane

A container crane can refer to a general type of machine that is used to lift and move heavy materials. For container transportation, this mainly refers to the ship-to-shore crane in the terminals. Also, there is a hoisting machine in the container yards called transfer cranes. This will be mentioned afterwards.

The cranes are shown as in Figure 1. A ship-to-shore crane could have a height of over 70 m and a weight of over 700 t. When it is loading, a container is lifted from the trailer parking under the crane, then moved horizontally by a trolley on the crane, and lowered to the place on the ship according to the stowage plan. The cranes can also move along the terminal by railway so as to target the position of the ships.

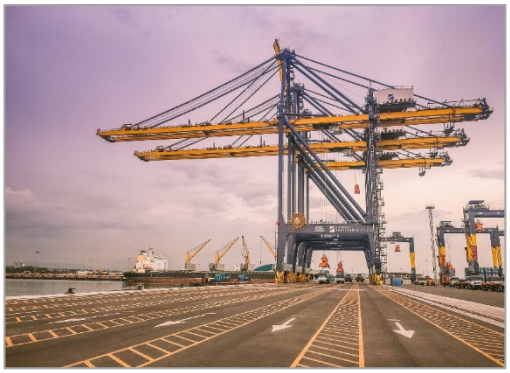

Figure 1 – Ship-to-shore crane (source: Pixabay)

Chassis

Chassis is the platform pulled by a trailer carrying the container without engine power. It is also the main intermediary transportation means for containers between the terminal and the yards. A recent development on that is automated guided vehicle (AGV), which carries containers in a smart port without an operator or driver on it.

Figure 2 – Straddle carrier
(Photo by Port of Tacoma on Foter.com)

Some container yards also utilise a chassis system as their yard operation method. A container yard with a chassis system means that all the containers are stored in the yard without being unloaded from the chassis, so it would be fast and convenient for a trailer to come and pull a container away without needing any additional machines. However, the chassis system has a lower land utilisation rate because it does not allow containers to stack, and it needs to reserve enough corridor space for trailers.

Figure 3 – Container forklift
(Photo by Parto Domani on Foter)

Straddle carrier

Straddle carriers can move containers between cranes, yards, CFS and chassis. Straddle carriers can lift, move and stack containers without the help of other machinery, saving time and space for these operations. On the downside, they are considered to have a high failure rate and repair cost, and the stacking level is limited.

Container forklift

The container forklift is a common vehicle to shortly move and stack containers in the yard. Some of the container forklifts can stack up to 7-9 layers. Usually, it undertakes auxiliary works and handles empty containers.

Transfer crane

Transfer cranes unload and reload containers between chassis (truck and train) and yards. They are reliable and their operations can be easily controlled and automated by computers. Transfer cranes can be further categorised into rubber-tired gantry cranes (RTG) and rail-mounted gantry cranes (RMG).

Reach stacker (front-handling mobile crane)

The reach stacker is auxiliary machinery for stacking and short-range transportation. Due to the flexibility to operate containers in multiple rows at a time and the higher stacking level, it is becoming increasingly popular.

Figure 4 – Transfer crane (source: Pixabay)

Figure 5 – Reach stacker (source: Pixabay)

4 Container Maritime Transport

4.1 Container export process

A simple process for container export is shown in Appendix 2, which involves a shipper (owner of cargo), forwarder, carrier (or its shipping agent), trucking company, port operator and custom. Banks are not included although they are an important party, because it will complicate the diagram while doing little to explain the logistic procedures. In Appendix 2, it is assumed that the container is stuffed and unstuffed at the shipper's site and the cargo is not required to be inspected by a permit-issuing authority (PIA). The documents shown in Appendix 2 are the important and process-decisive documents but do not stand for the complete group of needed files.

4.1.1 Pricing

When a shipper receives an order from a buyer, he will have the need for shipment. However, the maritime shipment has complicated processes and lots of documents to prepare, for which the shipper does not always know well about the maritime transport process. A freight forwarder can be an intermediate agency to provide service for shippers, carriers, and customs. Sometimes, a forwarder can have its agencies at ports all over the world to ensure the full coverage of shipments. To respond to the enquiry, the forwarder should calculate the price according to the goods to be shipped. The pricing could be different for full container load (FCL) and less than container load (LCL).

Full container load

The total maritime freight charges include inland transport costs, port charges, ocean freight, and document and handling charges, in which ocean freight (O/F) is the sum of basic ocean freight (BO/F) and surcharges. Inland transport costs and port charges can be calculated according to the incoterms agreed between the shipper and buyer. The calculation of BO/F varies in the charging policies, mainly by the number of containers to be shipped, either dependent (freight for class, FCS) or independent (freight of all kinds, FAK) on the class of the cargo.

Less than container load

The pricing is generally the same with FCL. However, if the cargo to be shipped cannot fill a container, the shipper can either request a pick-up service at his factory or warehouse or deliver the cargo to CFS so that the forwarder can consolidate according to the destination of the cargo. Sometimes, if the destinations are not the same, the container could be further unstuffed and re-consolidated. This will vary the total freight charges.

4.1.2 Booking

According to the information on the cargo to be shipped, the shipper and the forwarder sign the Shipper's Letter of Instruction (SLI), in which the following information is confirmed and included: port of loading (POL), port of destination (POD), shipper, consignee, goods description, weight, measure, and price. Special instructions are also to be specified here, for example loading terms (door-to-door, CFS, CY), cargo prepared time, clearance party, fumigation, bill of lading (B/L) instructions (original B/L, Telex release (TLX) or seaway bill), etc. Then the forwarder makes the booking request by sending a booking note (B/N) to the carrier. If the carrier accepts, booking confirmation is sent back with specifications on the time and location to pick up empty containers and return full containers.

4.1.3 Stuff cargo and declaration

The declaration can happen either after, during or before stuffing cargo to save time for transporting and exchanging nonconforming products. The basic process is preparing documents, audit, tax payments, random inspections, and release, but we do not elaborate it here as it is less relevant to physical logistics.

For FCL, usually, trailers are arranged to pick up empty containers from an Empty Depot (where empty containers are stored) and transport the full containers to the terminal, during which the containers are loaded and sealed at the factory or warehouse of the shipper. The operations should be done before a few deadlines, or some costs can be incurred. For example, a late fee should be paid for the late return of containers; if containers need to change vessel, the movement and storage during the waiting period will be charged. While for LCL, the cargo should normally be sent to CFS for consolidation.

4.1.4 Bill of lading

After containers are loaded to the vessel, the master bill of lading (MBL) will be issued by the carrier to the forwarder or the shipper (according to the party in the 'consignee' field in the MBL). MBL is the proof of the ownership of cargo, by which the corresponding containers can be picked up at POD by the 'consignee' written on the MBL. However, for LCL, the usual case is that both shipper and the consignee specified in the MBL are the same forwarder because carriers are not going to handle the consolidation of containers and are not well aware of the contents in the containers. If MBL is issued to the forwarder, a house bill of lading (HBL) is then to be issued to the shipper by the forwarder, which however cannot be the real proof of ownership. Instead, the forwarder owns the actual control of the containers and the goods, and the consignee can pick up the cargo with the HBL from the forwarder.

The previously mentioned B/L with the consignee specified is called straight B/L, and the container can only be picked up by the specified party. But as B/L is issued when containers are loaded to the vessel, at the time point when the name is specified on the B/L., the ownership of cargo is transferred Therefore, sometimes, the order B/L is issued for the shipper rather than the consignee to remain the owner of the cargo before the payment arrives. The 'consignee' field is 'To order' instead of a specified name. Order B/L can be transferred by endorsement (and thus the ownership of goods). Very occasionally, blank B/L (also called bearer or open B/L) is issued, with the 'consignee' field left as blank, indicating that anyone who holds the blank B/L can pick up the containers from the carrier.

4.2 Container import process

The import process is much simpler than export. When the ship arrives at the POD, the port operator will request the manifest (M/F) and bay plan of the ship. A terminal operation plan will be made accordingly, and the containers are stored in the CY. For FCL, in which the consignee holds the MBL, he may contact the agency of the shipping company and obtain an EIR and Delivery Order (D/O). MBL and D/O are on the list of needed documents for clearance in the next step. After the cargo is released, the consignee may contact the transport company to pick up, unstuff and return the container.

If the consignee is not located in the customs territory of the POD, customs transit can happen to get clearance at the customs other than the customs of the POD. The broker can apply for the customs transit. Then the imported containers will be sent to the local customs, and the logistic parties will go through the rest of the procedures similarly. The customs transit can also be applied for export containers in a similar way.

In the case of LCL, when the forwarder is the actual consignee, the forwarder presents the MBL to the customs to get multiple D/O's. Then the cargo owners can exchange their D/O's with their HBLs with the forwarder and pick up their cargo at the port warehouse.

5 Conclusion

In this article, the general pattern of port operation is described. Especially about the history of ports, governance and port organisations. To provide the reader with an initial impression of the stakeholders in ports, the composition of the operating costs of port and the port-related organisations are also mentioned. And for ports, the port performance indicators are introduced.

To stress the maritime container shipping process, the relevant machinery and the common container terminal layout is explained. Because a port is a complex system with numerous participants involved, a separate section is written to demonstrate how containers are imported and exported in the general sense.

However, the up-to-date research on port development is not mentioned in this article, but this article can provide a good knowledge base for the basic understanding of multiple aspects regarding port operation and management.

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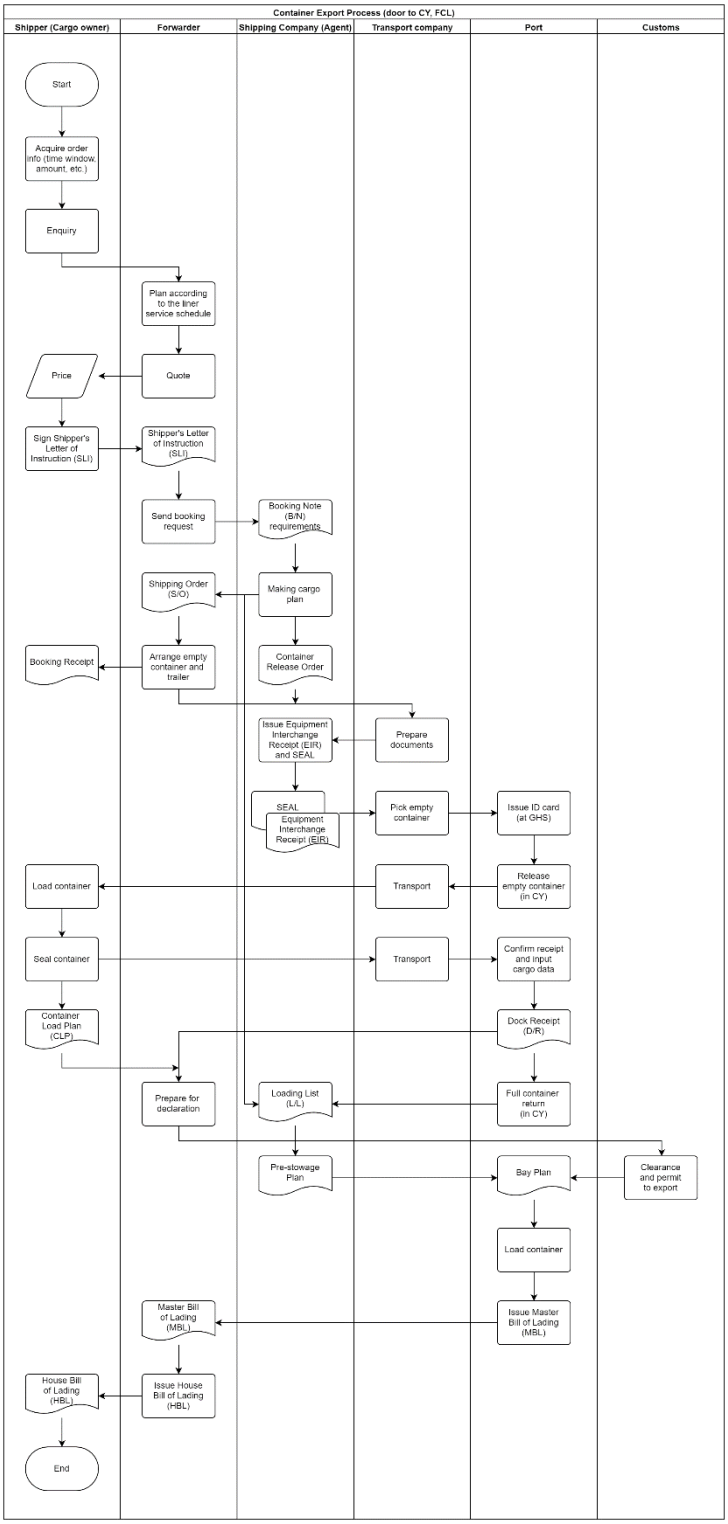
Appendix 1. Abbreviations for Maritime Shipping

Abbreviation	Full name
AGV	Automated guided vehicle
B/L	Bill of lading
B/N	Booking note
BO/F	Basic ocean freight
CFS	Container freight station
CY	Container yard
D/O	Delivery order
FAK	Freight for all kinds
FCL	Full container load
FCS	Freight for class
GHS	Gatehouse
HBL	House bill of lading
LCL	Less than container load
M/F	Manifest
MBL	Master bill of lading
O/F	Ocean freight
PIA	Permit issuing authority
POD	Port of destination
POL	Port of loading
RMG	Rail-mounted gantry crane
RTG	Rubber-tired gantry crane
SLI	Shipper's letter of instruction
TEU	Twenty-foot equivalent unit
TLX	Telex release

Appendix 2. Diagram of Container Export and Import Process

CONTAINER EXPORT PROCESS



CONTAINER IMPORT PROCESS