Container Shipping Supply Chain

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Container shipping supply chain (CSSC) consists of several key stakeholders such as the shipper, freight forwarder, shipping line, port/terminal operator, inland carrier, and intermodal terminal/depot operator, who are working together to transport containerized cargo by different transport vehicles (e.g., vessels, trains, and trucks) and handle the containers by various types of handling equipment and facilities (e.g., terminals, cranes, trailers, wagons, lifters, and depots) from origin to destination along the entire end-to-end supply chain.

container shipping supply chain | transport logistics | maritime transport | port management | container logistics

1. Introduction to CSSC

Container transport is regarded as the world's truly global supply chain due to the fact that a single cargo-laden container can be moved by different transport vehicles (e.g., vessels, trains, and trucks) and handled by various types of handling equipment and facilities (e.g., terminals, cranes, trailers, wagons, lifters, and depots) from origin to destination along the entire end-to-end supply chain. The importance of the container shipping sector is supported by the facts that over 70% of world trade by value is carried by the seaborne transport mode, and over 50% of world seaborne trade by value is carried by container ships according to the 2018 annual review of maritime transport by The United Nations Conference on Trade and Development. The container shipping supply chain (CSSC) consists of several key stakeholders such as the shipper, freight forwarder, shipping line, port/terminal operator, inland carrier, and intermodal terminal/depot operator.

According to the main business operations of these stakeholders, the CSSC may be classified into five value-adding segments [1][2]: Shipment arrangement; Container management; Seaborne transport; Port and terminal management; Inland transport & depot management. From the logistics management perspective, the five value-adding segments may be interpreted as: freight logistics, container logistics, vessel logistics, port/terminal logistics, and inland transport logistics. Specifically, freight logistics focuses on the arrangement of the storage, routing and scheduling of cargos and containerized shipments. Container logistics focuses on the planning and control of the container fleet to meet customer requirements and better utilize the container fleet. Vessel logistics focuses on the planning and control of the containership fleet to provide reliable shipping services to shippers by maximizing profit or minimizing the logistics costs. Port and terminal logistics focuses on the provision of efficient services to vessels, trains and external trucks when handling and storing containers at port. Inland transport logistics focuses on the planning and control of inland vehicle fleets (mainly trucks and trains) and facilities (depots, railheads and intermodal terminals) to transport, store and maintain containers in the inland region [3].

2. Freight Logistics

In the CSSC context, freight logistics concerns the efficient and effective flow and storage of containerized cargo from exporter’s warehouse to importer’s warehouse by using the most appropriate transport mode for each segment of the journey in the end-to-end CSSC. Clearly, it is appropriate to take the shipper’s or freight forwarders’ viewpoint when managing freight logistics since they are the cargo owners. The common planning activities and processes in freight logistics include: selecting transport modes and carriers; negotiating delivery terms and freight rates; contracting with ocean carriers; arranging relevant documents and customs clearance; consolidation and decomposition; arranging inland pickup and delivery; container shipment routing and scheduling; container storage and transhipping.

As the end-to-end CSSC usually involves both seaborne transport and inland transport, the CSSC tends to use multiple transport modes. This gives rise to the phenomenon of intermodal or multimodal transport, which tries to take advantage of the inherent economic benefits or the unique characteristics of each transport mode. For example, the maritime transport mode has the advantage of low cost over long inter-continental distance, whereas the road transport mode has the advantage of high accessibility for the “first mile” or “last mile” delivery. Specifically, intermodal transport can be defined as the movement of goods in a single loading unit through two or more successive modes of transport without handling the goods themselves in changing the mode of transportation. An interesting development of intermodal transport is synchro-modal transport, which adds the feature of real-time switching among various available transport modes during the journey in a flexible manner.

At the global scale, there are many CSSCs and they interact because they share common resources such as ports, vessels, handling equipment, human resources and facilities. Therefore, shipment assignment and routing exist at three planning levels: individual level, multiple level and industry-wide level. The individual level focuses on the routing of a specific shipment within a shipping network, which may be solved by the shortest path method. The multiple level focuses on the assignment of a set of shipments over the shipping network; and the industry-wide level considers the different identities and behaviors of the shipments and the different behaviors and attitudes of the stakeholders in CSSCs across the container industry.

From the modelling perspective, the shipment assignment and routing problems can be addressed by a top-down approach or bottom-up approach. The top-down approach often applies mathematical programming methods to optimize the shipment assignment and routing in a given transport network, where the organizational identities of shippers and shipping lines are often ignored. The bottom-up approach tries to capture the individual entities’ behaviors and decision-making activities, which often applies the agent-based modelling method or multi-agent system. This is more natural and closer to the realistic global shipping system because individual shipping companies are independent and competing in practice. In the literature, agent-based modelling (ABM), complex adaptive systems (CAS), and multi-agent systems (AMS) have been used in the container transport sector. Such agent technologies are more suitable to model the container shipping supply chains because many heterogenous and autonomous agents (stakeholders) are involved in CSSC. Even for the same type of agent, e.g., shipping lines, there are a large number of independent companies which coexist and compete in the global container transport business. These companies adopt different operational strategies and behave differently in terms of service network provision, ship fleet deployment, container fleet management, and freight pricing and contracting. Such heterogeneity and complex interactions, including both competition and cooperation between the involved entities, make the bottom-up agent-based modelling approaches more appropriate.

The focal companies of freight logistics in CSSC are shippers and freight forwarders. They are the cargo owners that initiate the container transport demands.

3. Container Logistics

Container logistics concerns the efficient and effective management of container flows and storage in transport networks to meet customer demands and maximize the utilization of the container fleet. According to Drewry Shipping Consultant, the world container fleet exceeded 37 million twenty-equivalent units (TEUs) in 2018, which were owned mainly by shipping lines and container lessors roughly at a 50:50 split. As an equipment asset, containers have two states in the logistics processes, i.e., laden container (with cargo inside container) and empty container (without cargo inside container). Laden containers are often regarded as shipments with their routing largely specified by shippers or freight forwarders, while empty containers are moving equipment for reuse, whose storage and flows are largely determined by shipping companies. Broadly, container logistics includes the following planning problems: Container fleet sizing; Container leasing and off-leasing; Laden container canvassing, routing and dispatching; Empty container repositioning (ECR).

Container fleet sizing concerns the number and types of container in the fleet that will be used and reused in a transport system. A larger fleet size may decrease the need for empty container repositioning but will incur higher capital and inventory costs. Container leasing is a contractual relationship between a container lessor and a shipping company regarding a temporary lease of a set of containers. Moreover, because both laden containers and empty containers share the capacitated resources in the same transport networks (e.g., vessels, trains and trucks), container logistics should coordinate laden container canvassing, routing and dispatching together with ECR. Empty container repositioning refers to managing the flows and storage of empty containers in transport networks, which is the primary planning task of container logistics. ECR is fundamentally driven by the imbalance of laden container movements. Clearly, the management of laden containers, e.g., by pricing the freight rate appropriately, may mitigate the degree of trade imbalance.

From the logistics channel perspective, the solution measures to the ECR problems may be classified into four categories: organizational measures, intra-channel measures, inter-channel measures, and technological measures . From the modelling perspective, the existing solution models may be classified into two broad research streams: network flow models, and inventory-control models [4]. The focal companies of container logistics are shipping lines and container lessors as these are the container owners.

4. Vessel Logistics

.Vessel logistics concerns the management of shipping service supply and relevant information flows to meet shippers' transport demands efficiently and effectively. The vessel fleet is the most capital-intensive asset for a shipping company in providing container transport services. The main planning problems associated with vessel logistics in CSSC can be classified into strategic, tactical and operational planning levels in Table 1.

Table 1. Planning problems associated with vessel logistics in CSSC.

Planning Level	Planning Activities
Strategic level planning	Trade lane and market coverage selection and expansion; Horizontal integration & strategic alliance; Shipping line competition; Vertical integration; Long-term contracting strategy; Ship design; Fuel and energy system selection; Ship fleet size and mix; Ship chartering
Tactical planning level	Shipping network design and redesign; Fleet deployment & redeployment; Ship routing and adjustment; Ship scheduling and timetabling; Ship speed & service frequency planning; Ship laying-up; Ship recycling; Inventory routing; Shipment routing; Container fleet management
Operational planning level	Spot-market pricing; Empty container repositioning; Ship speed optimization; Slow steaming; Ship rescheduling; Ship repositioning; Environmental/weather routing; Disruption event management; Container stowage planning; Ship bunkering; Ship loading/unloading

The focal company for vessel logistics is the shipping line (or ocean carrier). Shipping is a rather conservative and risk-averse industry, partially due to the nature of capital intensiveness and the high level of uncertainty. The regularity of container shipping services implies that the vessels are required to stick to the published timetable regardless of whether the vessels are under-utilized. The global coverage of the CSSC implies the involvement of a large number of different players that makes the relationships between these players complicated and varying over time.

5. Port and Terminal Logistics

Ports are gateways for cargo and passenger transported by seagoing ships. A port may consist of several terminals, which specialize in handling certain types of commodity. Container ports and container terminals are often used interchangeably, designed as an interface to transfer containers between ships and other transport modes. From the import perspective, containers arrive at a container terminal at a large volume that are unloaded from a ship and then are transported to hinterland shippers via different transport modes (e.g., trucks, trains, barges) at a small volume. The container terminal is also equipped with various facilities for the maintenance and storage of containers. Therefore, port and terminal logistics can be defined as the efficient and effective service provision to associated stakeholders such as shipping lines, road hauliers, rail operators, freight forwarders and shippers.

Clearly, the main goal of port/terminal logistics is to improve the efficiency and productivity of port operations. A few survey papers have reviewed the literature on the application of operations research modelling in port logistics processes including ship planning process, storage and stacking logistics, quayside transport, and landside transport. The main planning problems associated with container port/terminal logistics may be categorized into a two-dimensional matrix according to the planning horizon and the logistics process in **Table 2**[3]. Some planning issues cut across multiple logistics processes or even the entire port area.

Table 2. Planning problems associated with container port/terminal logistics.

	Quayside	**Yardside**	**Landside**	**Across Processes**
Strategic	Berth layout Quay crane selection	Yard layout Yard equipment	Gate layout Rail terminal layout	Port competition, Port cooperation, Integration, Multi-modal interfaces, Terminal layout, IT systems
Tactical	Berth allocation Quay crane assignment	Storage planning Resource assignment	Vehicle booking system Rail service planning	
Operational	Quay crane scheduling Loading/unloading	Yard crane scheduling Container relocation	External truck handling Wagon shunting	

	Workforce scheduling Internal truck scheduling	Workforce scheduling Internal truck scheduling	Workforce scheduling Equipment scheduling

Methodologically, the commonly applied methods in port/terminal logistics include analytical methods (such as mathematical programming; game theory), heuristics or meta-heuristic methods, simulation methods, and multi-agent approaches. The focal organizations of port and terminal logistics are terminal operators and port authorities.

6. Inland Transport Logistics

Inland transport logistics concerns the management of inland vehicle and depot logistics. It focuses on the planning and control of inland vehicle fleets (mainly trucks and trains) and facilities (depots and equipment) to transport and store containers in the inland region. Inland transport vehicle includes trucks, trains and barges. Trains and barges often run with fixed regular routes and schedules, whereas trucks are flexible in terms of route and time. Inland depots represent intermodal terminals, dry ports and empty depots, which provide logistics services such as handling inland vehicles, container storage, maintenance, consolidation, and unpacking.

Hinterland container transport has received much attention due to its indispensable role in both the export and import sides of the global CSSC, and the increasing concerns about road congestion, emission and pollution, and traffic safety. Both laden and empty containers are moving, stored and maintained in the hinterland transport network consisting of ports, depots, and customer warehouses using various transport vehicle and handling equipment. The main planning problems associated with inland transport logistics in CSSC can be summarized in Table 3.

Table 3. Planning problems associated with inland transport logistics in CSSC.

Logistics Sectors	Planning Activities
Truck operations	Truck fleet management; Truck pooling and sharing; Container drayage; Vehicle booking system; Empty vehicle repositioning; Empty container repositioning; Truck routing and scheduling; Disruptive event management.

Rail & barge service	Rail/barge route design; Service timetable design; Wagon shunting; Barge vessel stowage planning; Rail-car fleet management; Empty rail-car repositioning; Container loading and unloading; Transport mode choice; Carrier selection.
Inland depot	Depot/dry port location; Inland container transport network design; Depot layout; Container storage; Container repair and maintenance; Container substitution; Demurrage and detention; Loading and unloading; Consolidation and unpacking.

The focal companies for inland container transport are inland carriers and depot operators.

References

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