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# Simultaneous optimization of schedule coordination and cargo allocation for liner container shipping networks

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ABSTRACT

A liner container shipping carrier usually collects immediately-delivered goods that are produced by manufacturers in world factories, and transports the products to worldwide market destination by offering weekly shipping service. In practice, the carrier has to consider extra demurrage cost of containerized cargos incurred from waiting for weekly shipping service at ports. In this paper, we develop a mathematic programming model to maximize the carrier's profitability by simultaneously optimizing the ship route scheduling and interrelated cargo allocation scheme. The nonlinear optimization model is transformed into an equivalent mixed-integer linear program, and its applicability is demonstrated by a case study.



## 1. Introduction

It is well-known that world factories in Asia, especially China, have manufactured a large amount of goods in every workday. More than million-ton productions will be containerized and delivered into worldwide consumptive markets in Europe and America by shipping services. Among all the sea cargos, 52% in dollar terms are containerized. The containerized trade volumes expanded in 2012 reach 155 million Twenty-foot Equivalent Units (TEUs) (UNCTAD, 2013). In every workday, the manufacturers will sum up the freshly-generated productions and directly transfer them to a long-term contract carrier in order to reduce warehousing cost. However, the liner container shipping carrier always provides a few ship routes with weekly-frequency long-haul shipping services. The carrier thus will collect containerized cargos and store them at his own warehouses or rented spots at port. No matter whether his own or rented warehouses are used, extra demurrage cost will be incurred for the carrier, since some containerized cargos have to wait for the weekly shipping services at ports. In order to reduce the demurrage cost incurred by an extra waiting time of containerized cargos, the liner container shipping carrier will hope to optimize his service plan in terms of schedule coordination and cargo allocation among several ship routes.

Schedule coordination and cargo allocation will simultaneously affect the profitability of the carrier. On the one hand, the waiting time and resultant demurrage cost of the containerized cargos can be directly reduced by optimizing the schedules of the ship routes so that in some measure the total demurrage cost for the container shipments can be controlled and even minimized. It is not difficult to imagine that, the carrier will give the priority to the port at which the largest amount of

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containerized cargos is loaded, when there is only one ship route to be coordinated. Evidently, the ship route schedule coordination problem will be more complicated but more useful for reducing the demurrage cost incurred by the long waiting time of cargos, if there are several ship routes available for coordinating by the carrier. On the other hand, when the carrier coordinates the schedules of the operated ship routes, the cargo allocation, that is, how to allocate the containers from one port to another among all possible ship routes that visit these two ports, should be taken into account simultaneously (Song and Dong, 2012). Inevitably, the schedule coordination of operating ship routes will alter the departure time of the ship from the ports of call as well as cargo waiting time. In general, cargo allocation for each origin–destination (O–D) cargo demand depends on the departure time of the ship from the ports of call and ship capacity. Therefore, in order to maximize the carrier's profit, it requires optimizing schedule coordination of different shipping routes and cargo allocation simultaneously by taking into account the cargo waiting time and incurred demurrage cost at the port. The illustrative example will show the importance of the schedule coordination and corresponding cargo allocation scheme to reduce demurrage cost.

### 1.1. A two-alternative example

Consider the container shipping services in Fig. 1. The figure has a simple shipping network of two ship routes visiting two ports: Shanghai (SHA) port and Rotterdam (RTD) port. These two ship routes provide identical services, except for the departure schedule. Each ship route has a weekly frequency. The port rotation for each ship route is SHA–RTD–SHA. The time spent at each port and the transport time of each voyage leg are assumed to be fixed and given: port time at SHA is 2 days, SHA to RTM is 19 days, port time at RTM is 1 day, and RTM to SHA is 20 days. Each ship route has a service capacity of 10,000 TEUs. Once the departure time of 1st port of call is given, we can easily determine the arrival and departure times at each port of call of the ship routes. For example, if a ship leaves SHA on Monday, it will arrive at RTM on Saturday (19 days later) and leaves RTM on Sunday.

Assume that there is a constant daily production at Shanghai port during Monday to Friday. Each container has capacity of one TEU. In this example, the cargo production manufactured in Shanghai is assumed to be 4000 TEUs/day. As a result, the weekly production is summed to 20,000 TEUs. The weekly cargo production will be containerized and transported from Shanghai to Rotterdam by the two liner container shipping services. The daily manufactured containerized cargos will be immediately delivered to the carrier and wait for the shipment. The problem for the carrier is how to coordinate the schedules of two ship routes and how to allocate the cargos on each ship route with the objective of minimizing the demurrage cost (or maximizing the profit).

It is assumed that the containerized cargos will arrive at Shanghai port at least 1 day ahead of ship departure in order to guarantee sufficient handling time at the port. We use two scenarios to show how ship route schedules and cargo allocation scheme affect the waiting time (i.e., extra demurrage cost) of containerized cargos. In the first scenario, both ship routes will depart from Shanghai port on the same day (end of that day). The waiting time for the cargos produced in every workday is given in Table 1 according to the different departure times of ship routes. From Table 1, we can see that the shortest average waiting time for all produced cargos is 3 days. That is, if both ship routes depart from Shanghai port on Saturday (end of Saturday), on average, the containers to be shipped will wait for 3 days. In this respect, we can find that the schedule coordination of shipping departure time is important for reducing cargo demurrage cost. Note that the cargos can be allocated to any ship route because both routes provide the same shipping service, including shipping schedule, and both shipping services are fully loaded.

Another scenario is that one ship route departs from Shanghai on Thursday and another one leaves on Saturday. Since both ship routes offer the same shipping services with the exception of schedules, we assume that ship routes 1 and 2 will depart at the first port of call Shanghai on Thursday and Saturday, respectively. The outcomes of schedule coordination and cargo allocation are summarized in Table 2. It can be seen that the cargos produced on Monday and Tuesday will be transported by ship route 1; the cargos produced on Wednesday will be divided into two equal parts that are transported by two ship routes, respectively due to the service capacity constraint by ship route 1; the cargos manufactured on other workdays will be naturally served by ship route 2. Consequently, in this scenario, the average waiting time for the containers is only 2 days. This reveals that a reasonable schedule coordination would save demurrage cost. Meanwhile, in order to make a

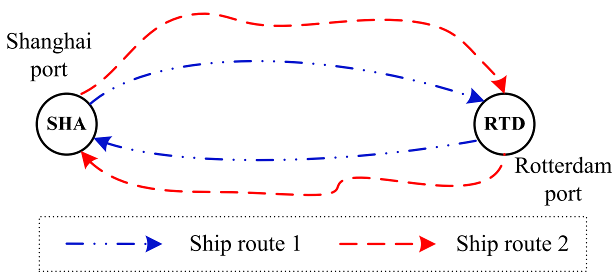


**Fig. 1.** An illustrative example.