Collaborative vs. non-collaborative container-vessel scheduling

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Since the last decade, the U.S. economy has been transformed by unprecedented growth in containerized imports. Global containerized trade has grown at a compound annual rate of 11% since year 2001 to reach 88 million TEU in year 2005, and is expected to reach 130 million TEU in year 2011. To accommodate this increasing demand for overseas trade, substantial structural change has taken place in the container shipping world during the past decade. Carriers seek to expand their business and to build competitive advantages by expanding the service regions, offering customized and mixed services, and taking advantage of economies of scale and improving asset utilization by vessel-sharing. As a result, various types of collaborative agreements among carriers have been developed. One such agreement is slot chartering, by which a fixed amount of capacity per trip over a contract period is chartered to/from other carriers, with the aim of offering additional services to customers without long-term commitment through new buildings. In today’s shipping industry, about 85 percent of carriers have provided ships in some kind of vessel-sharing agreements. However, in practice, such vessel-sharing agreements have not achieved their expected efficiency. A recent industry survey revealed that about 40% of business executives are concerned with the on-time delivery of the orders at the budgeted cost. Managing the container-vessel operations to optimally balance the service frequency/routing and the shippers’ preferences has been a challenging task both in academic research and practice.

In this study, we study the performance of the following vessel operational policies in a hypothesized shipping process involving customer service issues (in terms of the customer-specified order-delivery time windows at the destination port):

- The slot-sharing policy, which requires a pre-fixed percentage ($\beta$) of vessel capacity to be exchanged between the independent carriers, where the slot sharing factor, $0<\beta<1$, is fixed (i.e., contracted through the agreement between partner carriers) over a given planning horizon. In practice, when the two partner carriers have shipping operations along the same route but different departure time schedules, slot-sharing may offer better service to time-sensitive customer orders. Such a slot-sharing policy is a known
practice in the current shipping industry and implies a *partial collaboration* between the partner carriers.

- The total-sharing policy, which aims at achieving a full collaboration between two partner carriers by total demand sharing and flexible vessel resource sharing. This policy requires the participating carriers to perform a joint optimization on their vessel departure times and customer-order assignment to the vessels. In practice, its implementation would also require the participating carriers to share the profit, the demand information, and the operating cost. Such a policy has not yet been fully practiced in the current industry and is therefore of interest to be investigated in our study.

- The non-collaborative policy, which aims at constructing vessel schedules and assigning orders to vessels to minimize an individual carrier’s operating cost without sharing any resource with external carriers. This is the traditional vessel operational policy and is used here to benchmark the effectiveness of collaborative vessel scheduling.

We develop mixed integer programming models for each of these operational policies upon the hypothesized shipping process and analyze the mathematical properties of the respective vessel scheduling problem. A set of dominance conditions that reduce the search space for the optimal feasible schedules is derived. Upon these conditions, the problem of container-vessel dispatching and order-vessel assignments problem defined under each operation policy is solved either optimally or heuristically. Empirical studies based on 2,040 randomly-generated test cases with a set of real-life parameter values from shipping industries are conducted to collect our observations on the performance of these policies. The performance comparison is made against various operational parameters, such as the level of shipping demand traffic, the vessel maximum allowable waiting time at the destination port, the tightness of customer expected receiving time windows, the vessel travel speed, the vessel loading capacity, the cargo holding cost, and the maximum order (after being released) waiting time at the origin port, etc. It is our observation from this study that as the partner carriers’ willingness to share the demand information and to share the resources in a flexible manner increases, the effectiveness of collaborative vessel scheduling increases. The effectiveness is measured by the operational cost of carriers, and is demonstrated by simulation studies.
Figure 1. Charter cost against the width of receiving time windows at the destination port.

Figure 2. Charter cost against order waiting time at the origin port.

Figure 3. Charter cost against holding cost at the destination port.