Improving operating efficiency by integrating decisions on ship routing, berthing time assignment with transshipment option

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INTRODUCTION

The opening up of countries such as China and Eastern European nations has intensified the need for international trade. As a result, the requirement for sea transportation has been growing fast due to the cost-effectiveness of sea transportation. Hong Kong, as one of the world's major ports, handles a tremendous amount of cargos annually. Shipping companies in Hong Kong that offer short-distance feeder services seek to coordinate their ship routing and berthing operations, so as to reduce the operating costs and improve the efficiency. However, the coordination between ship routing and berth operations increases the complexity of the operations substantially. Because those shipping companies often operate multiple cargo terminals in different locations, their terminals often serve as consolidation facilities where containers can be unloaded from one feeder vessel and reloaded onto another one. This transshipment operation option further increases the complexity of shipping companies' decision making processes.

The motivation of this proposed decision support system is through a discussion with a company which operates a fleet of feeder vessels shuttling among various terminals in Hong Kong and Pearl River Delta. The company needs to ship containers from their origins to their destinations via these vessels. Some of the terminals concerned are company-owned cargo loading/unloading areas, while others are public container terminals. The company-owned terminals are often connected to land transportation, and they can serve as the origins or destinations of containers as specified by the customers. They can also be used as container consolidation facilities so that containers can be unloaded from one feeder vessel and reloaded onto another vessel. Because the large public container terminals only accept orders of certain minimal cargo volume, it is quite common for the shipping company to consolidate their containers by first unloading them from various vessels and then reloading them onto a single vessel, and have that single vessel carry them to a public terminal. Those containers that are heading toward those public container terminals are to be further transferred to ocean-going vessels. The feeder vessels are of different capacities, and the daily volume of containers to be handled varies day by day.

LITERATURE REVIEW

Many research models have been developed to tackle various kinds of ship routing and scheduling problems (Christiansen *et al.* 2004). However, most of these models have focused only on the optimization of travel distance and/or minimization of fleet size, without taking into consideration the capacity, availability, and transshipment capability of terminals. This group of studies originated from the pioneering work of Dantzig and Fulkerson (1954), who considered the problem of minimizing the required number of tankers to perform a given set of delivery schedules. In the last decade, more research has been devoted to studying the planning of fleet sizes and the scheduling of ships, Cho and Perakis (1996).

There is also a considerable amount of research on the allocation of berths at container terminals to minimize the waiting time of ships or to maximize the utilization of berths. In the above studies, the authors assume that the berths are discrete resources along a quayside and that each ship occupies a discrete number of berth locations. However, in some studies, the quayside of the berth is treated as a continuous resource, Lim (1998).

Recently, Pang *et al.* (2009) considered a ship routing problem with time clash avoidance constraints at the pickup and drop-off points. However, their model implicitly assumes that a cargo terminal is either the origin or the final destination of a container. To the best of our knowledge, no study has been conducted on integrating ship scheduling and berthing time assignment decisions which consider also the transshipment option.

METHODOLOGY

In our proposed decision support system, we consider a set of vessels, where each vessel has a given origin (e.g., a cargo terminal) and a given destination (e.g., another terminal). We assume that the origin and destination of each vessel are at different locations. We have a set of commodities (container batches), where each container batch also has a given pickup terminal and a given drop-off terminal. We need to arrange the vessels to pick up the containers from their origins and transport them to their destinations. We consider an integrated model where some terminals are public terminals in which each berthing time window is assigned to a specific vessel through advanced booking. Besides the public terminals, we also consider some terminals are company-owned terminals that can be served as consolidation facilities. These terminals allow the vessel to perform the transshipment operations during the opening hours; a container batch may be dropped off by one vessel and picked up by another vessel at any location, and has that single vessel carries the container batches to a public terminal. The objective of our proposed decision support system is to minimize the total operating cost of the system. The total cost includes the travel cost of the vessels, the loading and unloading costs of the container batches at the terminals, here, the loading and unloading costs are not constant which determined by how many times a container batch is consolidated at the terminals. The total cost also includes the cost of operating the vessels, which is calculated by the time that the vessels are in operation to perform all the pickup and delivery tasks for all the container batches.

COMPUTATIONAL EXPERIMENTS

We investigate the potential cost-saving attainable by our integrated ship routing and berthing time assignment model presented. To do so, we first generate random test data for small-size problems. Next, we obtain near-optimal solutions to the integrated ship routing and berthing time assignment problem using these data via commercial software package (i.e., ILOG CPLEX) by setting a maximum limit on the running time. These solutions are then compared against the solutions obtained by the traditional solution method, which the decision on the routing and the berthing time assignment of the vessels are made separately. This traditional approach may lead to serious congestion of the vessels at some terminals, as many vessels may be assigned to berth at the same terminal to perform the loading/unloading of the container batches at the same time period, some of these vessels are then needed to wait at the sea until the berth is available to service them. In such case, the operating cost will be higher when compared with the integrated model that we proposed, because the operating time of the vessels becomes longer as they have to wait at the sea until the berth is available. Besides, the transshipment operation is not possible as the routing and berthing time of the vessels are determined individually, such that the arrival time of the vessels at a terminal is not coordinated. In fact, the pickup and drop-off operations of a container batch is assigned to a single vessel only, when the routing of the vessels are determined separately, which means the container batch will only be loaded to a vessel which this vessel will then transport the batch to it's drop-off location and unload the batch, so there is no consideration on the consolidation option, which will lead to longer total travel distances of the vessels. It is because a vessel is responsible for both the pickup of a container batch at it's origin and drop-off of that container batch at it's destination, the vessel has to travel to more terminals to perform the loading/unloading of the container batches. In contrast, if transshipment option is possible, the vessel may pickup some containers batch at their origins, and transport and unloads some of them at a consolidation facility before transporting the remaining batches to their destinations. In such case, the distance travelled by the vessel is shorter in general.

CONCLUSIONS

We have proposed an integrated decision support model for making ship routing and berthing time assignment decisions collectively which allow transshipment option in some of the terminals. Preliminary computational experiments have demonstrated that saving in traveling and operating costs can be obtained using such an integrated model when compare with the traditional decision approach. We anticipate that the saving can be substantial when the integrated model is applied to large scale scenarios.

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