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Direct shipping service routes with an empty container management strategy

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ABSTRACT

This paper presents an investigation of an empty container management strategy in a two-way four-echelon container supply chain for bilateral trade between two countries. The strategy reduces high maritime transportation costs and long delivery times due to transshipment. The impact of direct shipping was investigated to determine the number of empty containers to be repositioned among selected ports, number of leased containers, and route selection to satisfy the demands for empty and laden containers for exporters and importers in two regions. A hybrid solution procedure based on accelerated particle swarm optimization and heuristic is presented, and corresponding results are compared.

1. Introduction

Containerization has substantially contributed to a steady increase in global maritime trade volume because it promotes excellence in the safety and efficiency for shipments. The introduction of modern containers into freight transportation brought great advantages to the maritime supply chain, such as transmodality, that triggered drastic increases in container use. In 2015, the UNCTAD reported that seaborne trade volume reached more than 10 billion tons, and developing countries accounted for 60% and 62% of exports and imports, respectively. These statistics show the potential of a continuous increase for trade volume led by developing countries. However, the imbalance in intra-continental trade volumes has expanded from year to year. For example, Asia and North America are well-known for export- and import-dominated nations that experience a surplus and shortage of empty containers in ports and depots. Repositioning empty containers has become one of the most efficient approaches to solve this issue of imbalance.

To deal with increasing demand for seaborne trade between inter- and intra-continental routes, global shipping companies have established fixed routes and operate their vessels on a regular basis. Despite providing shipping services covering most of the major seaborne routes, direct shipment for bilateral trade is in high demand, especially for developing countries. Such evidences are found in newly established bilateral trade routes between developing countries themselves. Business Line announced that the central government of India had initiated the first direct container shipping services with Myanmar, Qatar, and Bangladesh in 2014, 2015, and 2016, respectively. These bilateral trade routes help India meet the demand of growing trade volume, substantially reduce transit times and costs, and provide better quality of services in terms of reliability. China has also started the first direct service to Myanmar

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to supply fresh agricultural products at low transportation costs. Without direct shipment agreements, when sufficient demands arise in specific regions, existing shipping services cannot guarantee affordable transportation or quick delivery. For example, because of emerging demand, new seaborne routes between India-Thailand and Dubai-UAE are now serviced weekly by global shipping companies such that a new port rotation was established according to the large demand serviced by nearby ports. In this case, the distances of the routes do not play a key role in determining whether direct shipment is recommended or not.

Because demand is a key factor used to determine the establishment of direct shipments for bilateral trade, statistics derived from the UNCTAD showed that there is a huge potential for establishing more direct shipments in future. For example, no direct service exists between Brazil and India because the trade volume for this route is relatively small compared to other routes. Rather, merchants in Brazil and India ship their containerized cargos through South Africa because each route to and from Brazil and India is directly connected to South Africa. As a consequence, in 2007, the IMF reported that international transportation costs from India to Brazil and from Brazil to India account for 34.36% and 25.81% of respective imports. However, of all the transport costs for the goods transported between India and Brazil, 9.09% are spent for shipments through South Africa. This example indicates the potential savings through direct routes when sufficiently large demands exist.

Existing literature on important topics that can be helpful in establishing direct shipment for bilateral trade include those on service route selection, ship deployment, and empty container repositioning (ECR) used to design a maritime supply chain network. ECR may be considered as part of the pricing strategy for shipping such that the flow of empty containers can be intentionally reduced by lowering the degree of demand imbalance through appropriate pricing. ECR can also be mitigated by horizontal cooperation, such as by slot or container exchange, and vertical cooperation, such as through improved visibility of container flows in the maritime supply chain. Problems of service network designs and routes may include ECR as a sub-problem because both laden and empty containers are moved over the same shipping network. Braekers et al. (2011) presented a detailed description of ECR models for strategic, tactical, and operational planning levels. Similar recent work was published by Khakbaz and Bhattacharjya (2014), who reviewed the ECR literature published between 1994 and 2013 in the fields of engineering, management, transport, and logistics. Song and Dong (2015) studied ECR problems from the supply chain perspective as well as from the modeling technique viewpoint. Usage of heuristic and meta-heuristic algorithms in the solution procedure of ECR problems is used by several studies. Dong and Song (2009) explored the effectiveness of genetic algorithms in a simulation-based optimization approach for an ECR problem of liner shipping systems. The potency of problems with specific heuristic rule-based approaches was studied by Song and Dong (2012). Long et al. (2012) used the sample average approximation method and heuristics based on a progressive hedging strategy to decrease the operational costs in an ECR problem.

In addition to examining ECR, several researchers have studied the performance of an overall maritime supply chain. Shintani et al. (2007) constructed a design problem for a container liner shipping network that addresses repositioning and leasing of empty containers. They used a genetic algorithm (GA) for implementing a solution method for the problem. Moon et al. (2010) studied the ECR problem by considering the simultaneous effects of leasing and purchasing. They also used a GA to reduce computation times and obtain near-optimal solutions. Meng and Wang (2011) demonstrated the potential cost savings by incorporating ECR considerations into the design process of a liner shipping service network operating in the medium term. They used the CPLEX to find the optimal solutions for medium-sized problem. Maraš et al. (2013) investigated the efficiency of MIP heuristics with the commercial MIP-solver, CPLEX, for the task of optimizing transport routes for barge container ships to maximize profits. Moon et al. (2013) used an ECR problem to find the impact of the repositioning costs of foldable containers on the use of standard containers. They proposed two heuristics to find the optimal allocation and compared the results with the LINGO. Li et al. (2014) dealt with empty container reuse problem for green supply chain management in the maritime industry. They claimed that empty container reuse strategy requires supply chain collaboration, which adds economic value to a shipping supply chain for overall profit maximization. Zheng et al. (2015) studied the empty container allocation problem by considering the coordination among shipping liners and proposed a two-stage optimization method to find the optimal allocation. Although, the authors neglected the capacity constraints. Sun et al. (2015) proposed an integrated model for multiple factories and a distribution center with a due-date-based cut-off rule (DBC). In their model, the production processing time was considered in accordance with different types of transportation mode such as inland and maritime. The DBC was used to achieve computational efficiency for their exact algorithm used to solve large instances. By presenting a two-stage optimization method, Zheng et al. (2016) formulated an ECR problem to determine the perceived container leasing prices for different container types, such as standard and foldable, at different ports. Schepler et al. (2017) used restrict-and-fixed heuristics to minimize weighted turnaround times in a multi-terminal and multi-modal maritime port.

Theofanis and Boile (2009) examined and analyzed empty container logistics at the global, inter-regional, regional, and local levels. They discussed key factors affecting empty container logistics management and the strategies implemented by ocean carriers and other stakeholders to manage a container fleet better. Caris et al. (2011) presented an analysis and a comparison of alternative types of container-bundling networks in the ports in the Antwerp area. They developed a discrete event simulation model that is used to examine the effects of the alternative ways to organize container barge transport. Lin and Tsai (2014) studied the ship routing and freight assignment problem under daily frequency operation for a shipping liner and claimed that the liner service quality and reliability can be improved with the model they proposed. In daily frequency operation, a liner dispatches their largest ships to pick up and deliver goods at mega hubs where demands are highest; meanwhile they send feeder ships to handle the demands at smaller ports. It was determined that ship size is one of the essential components for designing an efficient shipping-service network (Ng, 2017; Monemi and Gelareh, 2017; Wang and Meng, 2017). Recently, Lin and Chang (2018) applied a more general model for ship routing and freight assignment to a real world case, called the *Northern Sea Route*, which attracted much attention for ice-free ports. In a similar study, Santini et al. (2018) used a pick-up and delivery method in a container-liner shipping feeder network. In addition, the models of Kelle et al. (2007) and Kheljani et al. (2009) of total supply chain costs for which both the retailer and supplier are taken into account simultaneously. We adopted these ideas about simultaneous cost savings from direct shipments and applied them to the