Scheduling Chemical Transshipment Operations in Maritime Transportation

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Abstract

Logistics expenses represent a significant portion of supply chain costs and can be as high as 20% in the chemical industry (Karimi et al., 2002). With the increase in the chemical production capacities of many sites/regions of Asia and worldwide, there is a growing need to transport chemicals among various remotely located sites. Ocean shipping is the most important mode of transport that serves this need. The chemical shipping companies maximize their profits by integrating their global services through redistribution of regional cargos. Transshipment is a common, but crucial, business practice existing in such situations as cargo transshipments from intercontinental feeder carriers to regional carriers, from large vessels to smaller vessels to deliver cargos to shallow ports, crude lightering, and so on. With transshipment operation, shipping companies can save large sums of money by minimizing the detour of capital-intensive deep-sea carriers and thus increasing the utilization of both deep-sea and short-sea carriers. Furthermore, transshipment operation enhances service to shallow ports. Chemical ocean carriers are highly expensive and efficient port logistics operations such as efficient scheduling of cargo transshipment process are of utmost importance, as this process involves huge operating cost and demurrage cost, especially during the congested time, when many tankers arrive at the transfer location within a short period of time. Lastly, we have found no previous work addressing this important problem.

In this paper, we consider a general chemical transshipment problem, where multiple carriers perform transshipment operations at a common transfer location. The transportation system comprises a fleet of deep-sea carriers that operates as the feeder system to a fleet of regional short-sea carriers. Both types of carriers are multi-compartment tankers shipping bulk liquid chemicals. After the required quantities of transshipment cargos have been transferred from deep-sea (donor) carriers to the designated short-sea (recipient) carriers, both of them will continue on their routes and head towards the next pickup/delivery location. Our goal is to determine the optimal transshipment sequence, unloading positions and times for transshipping cargos with minimal system cost. The system cost here is the sum of demurrage costs of both deep-sea and short-sea carriers.

We develop six continuous-time mixed-integer linear programming (MILP) formulations of two types for determining the optimal sequences, positions, and timings for unloading various cargos. In the first type (type 1), a slot-based approach is used for short-sea carriers, and a pair-wise sequence-modeling approach is used for deep-sea carriers. In the second type (type 2), we switch the two approaches. All of the formulations can effectively handle general many-to-many transshipment problems involving up to three donor carriers, five recipient carriers, and sixteen transshipment cargos in reasonable solution time. However, they perform differently on different types of problems. Therefore, we solve all examples using all the formulations to illustrate and compare their effectiveness and efficiency.

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Of the two types of formulations, in general, type 2 (type 1) that uses the pair-wise sequencing approach for the recipient (donor) carriers seems to have fewer variables of the latter type and does better than type 1 (type 2), when the problem involves many recipient (donor) carriers. For the same reasons, type 1 outperforms type 2 in problems with many two-sided cargos. Among the three alternate models of each type, the ones involving the big-M relaxation (convex hull relaxation) seem to be the fastest (slowest) in spite of their inferior (superior) rMIP values. For even larger problems, we present a cargo aggregation heuristic that aggregates cargos involving the same recipient and donor ships into single cargos. This strategy reduces problem size drastically and solution times by an order of magnitude, yet gives nearly optimal (within 2.23%) solutions for the examples in this paper. This heuristic model promises to be very effective for solving large problems of practical interest. This paper also suggests that the slot-based sequencing approach is generally more efficient than the pair-wise approach in many scheduling problems.

Keywords: transshipment operations, scheduling, chemical logistics, shipping, maritime transportation

Reference:

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