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Bunker Purchasing with Contracts

Federico Farina, Peter Neergaard Jensen, Christian E. M. Plum and David Pisinger

I. Introduction

For shipping companies a very large part of the variable operating cost are for bunkers (fuel), for the vessels. For liner shipping companies in particular, the purchasing of these bunkers can be planned some months ahead. As the vessels are sailing on a fixed schedules, as opposed to tramp and other types of shipping. This regularity in the vessel schedules allows for detailed planning of the specific vessel as considered in the works of Plum and Jensen [5], Besbes and Savin [1] and Yao et al. [6]. These consider variants of a bunker optimization problem considering a single vessel. The work of Plum and Jensen [5] considers multiple tanks in the vessel and stochasticity of both prices and consumption. Yao et al. [6] does not consider stochastic elements nor tanks, but has vessel speed as an output of the model. Besbes and Savin [1] consider different refueling policies for liner vessels and has some good considerations on the modeling of stochastic bunker prices using markov processes. This is based on crude oil prices and a location dependent term, in practice an *AR(1)* model is used to describe crude prices, instead of brownian motion based methods. This is used to show that the bunkering problem in liner shipping is a stochastic capacitated inventory management problem. Besides the capacity, little modeling is done of operational constraints. A single vessel is considered, but it is mentioned that an extension could investigate multiple vessels, due to limited supply i.e. contracts.

For a more general introduction to research on maritime optimization refer to Christiansen et al. [2]. Other work on bunker costs and its impact on maritime transportation includes, Notteboom and Vernimmen [4] which considers how slow steaming and the cost structure of liner shipping networks are effected by changes in bunker costs.

The market for bunker trading is commoditized and liquid, the use of contracts for a specified amount, port and price (or discount to some price-index) is widespread. This is done to reduce both delivery and price risk and to leverage the strength of being a large player on this market. This work will extend on the mentioned literature by considering the impact of bunker contracts on the optimal bunker purchasing strategies for a liner shipping company, The Bunker Purchasing with Contracts Problem, (BPCP). It is roughly based on the work of Farina [3], which, to the best of our knowledge, is the first time this problem has been considered in the literature.

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II. Model

With an offset in the models of Plum and Jensen [5] and Farina [3], BPCP can be formulated as a Mixed Integer Program. Let $v \in V$ be the set of vessels. Let $i \in I$ be an ordered set of ports, the vessel's schedule, where duplicate ports can exist. Let t be the last considered port. Let $b \in B = \{LSFO, HSFO\}$ be the two considered bunker types. Let $m \in M = \{spot, contract\}$ be the two considered market types bunker can be purchased at. *spot* bunker is freely available, *contract* bunker must be purchased according to details given by a number of contracts $c \in C$, each with a minimum and maximum quantity that must be purchased in the period, $\underline{q}_c$ and $\overline{q}_c$. Purchases will be done at a price $p_{i,b,m}$ depending on port, bunker and market type. $o_{i,v,b,c}$ maps a purchase to a contract. The startup cost for bunkering at a port i, is $startcost_i$. Each vessel has a capacity $D_{v,b}$ for each bunker type. For each leg of the schedule, the vessel consumes $F_{i,v,b}$. The problem is then to satisfy the vessels consumption by purchasing bunkers at the minimum cost, while considering some operational constraints. The variables of the model are: the purchase of bunker for each port, vessel, bunker type and market type $l_{i,v,b,m}$. The binary variable $\delta_{i,v,b}$ which is set if a purchases of a bunker type is made in a port for some vessel. The volume of a bunker type after vessel leaves port is $h_{i,v,b}$ and the consumption of each bunker type on vessel between port i and $i+1$, $f_{i,v,b}$. The MIP model (A) can then be written:

$$\min \sum_{i \in I} \sum_{v \in V} \sum_{b \in B} \sum_{m \in M} (p_{i,b,m} \cdot l_{i,v,b,m} + \delta_{i,v,b} \cdot startcost_i)$$

Subject to

$$h_{i,v,b} = h_{i-1,v,b} + \sum_{m \in M} l_{i,v,b,m} - f_{i-1,v,b} \qquad \forall i,v,b \quad (1)$$

$$f_{i,v,b} \leq h_{i,v,b} \qquad \forall i,v,b \quad (2)$$

$$\sum_{b \in B} f_{i,v,b} = F_{i,v,HSFO} + F_{i,v,LSFO} \qquad \forall i,v \quad (3)$$

$$f_{i,v,LSFO} \geq F_{i,v,LSFO} \qquad \forall i,v \quad (4)$$

$$h_{i,v,b} \leq D_{v,b} \qquad \forall i,v,b \quad (5)$$

$$\underline{q}_c \leq \sum_{i \in I} \sum_{v \in V} \sum_{b \in B} l_{i,v,b,contract} \cdot o_{i,v,b,c} \leq \overline{q}_c \qquad \forall c \quad (6)$$

$$l_{i,v,b,m} \leq \delta_{i,v,b} \cdot D_{v,b} \qquad \forall i,v,b,m (7)$$

The constraint (1) ensures flow conservation at each port, vessel and bunker type. Constraints (2) ensures that more bunker than available is not used between port i and $i+1$. Constraints (3) and (4) maintains the consumption of bunker, allowing LSFO to substitute HSFO, but not opposite. The bunker capacity of the vessels are enforced by constraints (5). The minimal and maximal quantity required by the contracts are ensured by double sided constraints (6) and the decision variables $\delta_{i,v,b}$ are set by constraints (7).

Initialization and termination criteria for start and end bunker volumes must also be set:

$$h_{0,v,b} = h_{v,b}^{init} \quad \forall v, \forall b \tag{8}$$

$$h_{t,v,b} = h_{v,b}^{term} \quad \forall v, \forall b \tag{9}$$

III. Algorithm

The fleet of a global liner shipping company can consists of hundreds of vessels, with many of these having overlapping schedules visiting the same hub ports. This gives that the full problem can be of a very large size which makes it interesting to consider a decomposition of model (A), to solve these large problem instances.

The arc flow model given by (1) - (9) is Dantzig - Wolfe decomposed on the variables $l_{i,v,b,m}$. Let R_v be the set of all feasible bunkering patterns for a vessel v, satisfying constraints (1) - (9), except (6), this set has an exponential number of elements. Each pattern $r \in R_v$ is denoted as a set of bunkerings, let $E_r = \sum_{i \in I} \sum_{b \in B} \sum_{m \in M} (p_{i,b,m} \cdot l_{i,v,b,m} + \delta_{i,v,b} \cdot startcost_i)$ be the cost for pattern $r \in R_v$. Let λ_r be a binary variable, set iff the bunkering pattern r is used. The BPCP can then be formulated as:

$$\min \sum_{v \in V} \sum_{r \in R_v} \lambda_r \cdot E_r \tag{10}$$

Subject to

$$\underline{q}_c \leq \sum_{v \in V} \sum_{r \in R_v} \lambda_r \cdot o_{r,c} \leq \overline{q}_c \qquad \forall c \tag{11}$$

$$\sum_{r \in R_v} \lambda_r = 1 \qquad \forall v \tag{12}$$

The objective minimizes the costs of purchased bunker and startup costs. Constraints (11) ensures that all contracts are fulfilled. Convexity constraints (12) ensures that exactly one bunker pattern is chosen for each vessel.

A. Pricing Problem

Let $\underline{\pi_c} \leq 0$ and $\overline{\pi_c} \geq 0$ be the dual variables for the upper and lower contract constraints (11) and let $\theta_v \in \mathbb{R}$ be dual variables for the convexity constraints (12). Then the pricing problem becomes:

$$\text{Min: } E_r + \sum_{c \in C} (\underline{\pi_c} - \overline{\pi_c}) - \theta_v \tag{13}$$

Subject to constraints (1) - (9), except (6).

This pricing problem is a Mixed Integer Program, considering a single vessel. This size of problem can efficiently be solved by a standard solver as CPLEX, as done in Plum and Jensen [5]. Negative Reduced cost columns λ_r will then be added to the master problem, also solved as MIP with Cplex.

IV. Further work

The proposed model and algorithm must be implemented and tested. Numerous additional operational constraints can be included in the modeling as reserve requirements, multiple bunker tanks, mixing penalties and others mentioned in related literature for single vessel bunkering problems.

V. References

References

[1] Omar Besbes and Sergei Savin. Going bunkers: The joint route selection and refueling problem. *Manufacturing and Service Operations Management*, 11(4):694–711.

[2] Marielle Christiansen, Kjetil Fagerholt, and David Ronen. Ship routing and scheduling: status and perspectives. *Transportation Science*, 38(1): 1–18, 2004.

[3] Federico Farina. Bunker optimization with contracts. Master's thesis, Universita Di Bologna, 2012.

[4] T.E. Notteboom and B. Vernimmen. The effect of high fuel costs on liner service configuration in container shipping. *Journal of Transport Geography*, 17(5):325–337, September 2009.

[5] Christian E. M. Plum and Peter Neergaard Jensen. Minimization of bunker costs. Master's thesis, 2007.

[6] Zhishuang Yao, Szu Hui Ng, and Loo Hay Lee. A study on bunker fuel management for the shipping liner services. *Computers & Operations Research*, 39(5):1160 – 1172, 2012.