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Bunkering decisions for a shipping liner in an uncertain environment with service contract

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ABSTRACT

As bunker fuel cost constitutes a major portion of the shipping liners' operating cost, it is imperative for them to minimize the bunkering cost to remain competitive. Service contract with a fuel supplier is a strategy they venture on to reduce this cost. Typically, liner operators enter into a contract with fuel suppliers where the contract is specified by a fixed fuel price and amount, to mitigate the fluctuating spot prices and uncertain fuel consumption between the ports. In this paper, we study such bunkering service contracts with known parameters and determine the liner's optimal bunkering strategy. We propose to use bunker up to level policy for refueling, where the up to level is dynamic based on the observed spot price and determine the bunkering decisions (where to bunker and how much to bunker) at the ports. A dynamic programming model is formulated to minimize the total bunkering cost. Due to the inherent complexity in determining the gradient of the cost-to-go function, we estimate it by Monte Carlo simulation. Numerical experiments suggest that all the contract parameters must be considered together in determination of the optimal bunkering strategy. Contracting an amount lesser than the average consumption for the entire voyage, at a contract price lesser than the average spot price is found to be beneficial. The insights derived from this study can be helpful in designing these types of service contracts.

1. Introduction

As ocean shipping is relatively cheaper compared to the other modes of shipping like air freight, the seaborne trade has increased by 67 percent in terms of weight since 1980 (Christiansen, 2007). The demand for liner shipping service has increased significantly during recent decades. The liners generally follow the same cyclical route comprised of a fixed number of ports. With the global macro environment becoming increasingly more challenging for consumer-related industries and the expansion of the super post-panamax fleets, shipping liners need to be more cost-effective and efficient in order to maintain their competitive advantage. To be cost-effective they need to reduce the total cost of operations. Since bunkering fuel cost constitutes about three quarters of the operational cost of a container ship (Ronen, 2011), reducing the total bunkering fuel cost can bring in substantial cost saving. The price of bunkering fuel remains uncertain as the price of crude oil fluctuates. Fig. 1 shows the bunker fuel price (IFO380) at four different ports – Fujairah, Houston, Rotterdam and Singapore from January 2013 to November 2013. The general trend for bunker fuel price is fluctuating and uncertain. The fuel price can vary significantly at different ports, even on the same day. During this period, the price was lowest at Rotterdam from January to June, but jumped to the highest in August, again falling back to the lowest from September to November.

As fuel consumption largely depends on the cruising speed (Ronen, 1982, 2011), operators sometimes use slow steaming techniques to reduce the cost; but slow steaming increases the total travelling time and can hamper the schedule of the liner service. Speed selection is, thus, very important and needs to be decided based on the objective of the operator. The operator also needs to decide where to bunker and how much to bunker as prices vary dramatically at different ports. Service contract with a bunkering fuel supplier can be a strategy to reduce the fuel cost under these uncertain conditions. Service contracts are, generally, specified by the price, quantity and port of bunkering. Contracts help in reducing both the price risk (volatility of spot prices) as well as the supply risk. By entering into a contract, the liner gets guaranteed supply of fuel and also gets a discount on price by leveraging on the large quantity committed (Plun, Jensen, & Pisinger, 2014). Since contracts are designed for a longer time period, these parameters should be decided beforehand. In marine industry, there are several types of service contracts available (BP Marine, 2012). The most common type of contract specifies the total amount of fuel to be refilled during a certain period of time from the supplier at a pre-determined fixed price. Sometimes, the price of the fuel is not fixed in advance; but may fluctuate within a range that is agreed upon by the supplier and the liner operator. Typically, when the total

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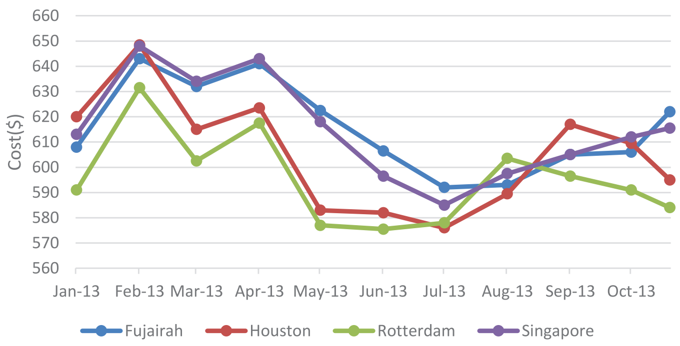

Fig. 1. Fuel prices at different ports (IFO380) (January 2013–November 2013) (*Source*: Bunkerworld.com).

amount of fuel required exceeds the contracted amount, the liner has to buy the extra amount at spot price, though the supply of the extra amount is not guaranteed, whereas a service contract ensures guaranteed supply of contracted amount of fuel. If the liner does not fulfill its commitment of buying the contracted amount of fuel from the supplier within the stipulated period, it has to pay damage charges on the unconsumed amount to the supplier. These types of contracts are also found in airline industry (e.g. AVCARD contract fuel program). Therefore, it is important to study marine service contracts and understand their role in designing an effective bunkering strategy. In this paper, we model service contracts with known parameters and determine bunkering decisions, i.e. the ports to bunker and bunkering quantities at each port, which minimize the total bunkering cost. The study also helps to understand the impact of the contract parameters on the bunkering decisions and the total bunkering cost. The insights from this study can be quite useful in designing a service contract but that is outside the scope of this study.

Researchers have shown immense interest in maritime transportation during the recent decades as the importance of ocean shipping has increased many folds. The initial work in the area of tanker routing and scheduling was by Flood (1954). Later Jameson (2008) and Christiansen, Fagerholt, and Ronen (2004) also considered ship routing and scheduling. Ronen (1983) provided a review of literatures related to ship routing and scheduling problems. Later Ronen (1993) also reviewed the available literature on ship scheduling and routing during the last decade. It was found that ship routing and scheduling problems have become increasing relevant and important for the ship operators. However, Christiansen, Fagerholt, Nygreen, and Ronen (2007) found out that relatively little research has been done regarding optimizing the ship speed and bunkering cost. A string of papers appeared following the oil crisis in 1970s for optimizing ship speed and routing decisions. Ronen (1982) analyzed three closed-form analytical models to determine the optimal speed of a single vessel with a single engine operating under different types of legs, namely income generating, positioning and mixed. As this work focused mainly on trampers and industrial shipping, it did not consider service frequency. Subsequently, Brown, Graves, and Ronen (1987) presented a model to optimize the fuel consumption of ship with multiple engines. Perakis and Papdakis (1987a) proposed a non-linear optimization model to explicitly determine the fleet deployment and associated speed with the objective of minimizing the total fleet cost including the lay-up costs for the unutilized ships. Perakis and Papdakis (1987b) extended this model to incorporate uncertain cost components. Notteboom and Vernimmen (2009) presented a descriptive model to determine the bunker fuel costs at various speeds for different ship sizes on the Europe-Far East route.

Recently, Fagerholt, Laporte, and Norstad (2010) considered bunker fuel optimization problem for a fixed given route with discrete arrival time and determined the ship speed by shortest path method. Ronen (2011) studied the effect of fuel price on containership speed and fleet size. He developed a cost model to analyze the trade-off between speed reduction and increasing the fleet size. Yao, Ng, and Lee (2012) developed an empirical formula to express the relationship between ship speed and fuel consumption and developed an optimization model to minimize the bunker fuel cost for deterministic fuel prices.

The bunkering problem we study here can also be viewed as an inventory management problem. The fuel consumption between two ports resembles the demand for the fuel and refueling decision can be treated as the ordering decisions to the suppliers. If the fuel is not sufficient to cover the fuel consumption to the next port, a huge penalty cost is imposed, similar to the lost sale cost in inventory management problem. The up to level for the bunkering problem is dynamic and dependent on the cost of the product (fuel). We now discuss the literature related to inventory management which is relevant to our problem. Kalymon (1971) extended the classical inventory problem by allowing product prices to follow a Markov process. Song and Zipkin (1993) considered an infinite-time inventory model where demand rate varies with an underlying ‘state-of-the-world’ variable. ‘State-of-the-world’ defines that if the world is in state *i*, the demand follows Poisson process with rate λ_i. The fuel price model considered in our research is based on the work by Hamilton (1989). He presented a tractable approach to model ‘regime’ changes in a Markovian setting. Besbes and Savin (2009) used this approach to develop the fuel price model. They presented a profit maximization problem for routing and refueling decisions for tramper and liner services. Neel and Gooding (1997) discussed the impact of service contracts and price discount within the shipping liner conferences, but did not consider contract with fuel suppliers. Though service contracts are relevant in today’s shipping industry and many oil companies, like BP, are offering service contracts to the liners; it has never been considered by the researcher in maritime transportation.

The rest of the paper is organized as follows: Section 2 describes the bunkering fuel management problem with service contracts and the objectives of the study as well as the assumptions made. Section 3 develops a dynamic programming model for the total bunkering cost. Section 4 provides the solution of the dynamic programming model. Numerical results are presented in Section 5 and finally Section 6 discusses conclusions and possible extensions.

2. Problem description

We consider a bunker fuel cost optimization problem where the operator of the liner has a service contract with a supplier for a fixed amount of fuel at a pre-determined fixed price. The supplier has refueling stations at several ports of call and the liner can refuel at any of these stations at the same fixed price. The spot fuel price at a port is not known in advance and the fuel consumption between two ports is also not fixed and depends on several factors like weather, route etc. We use a bunker up to level policy (or base stock policy) for refueling i.e. the liner bunkers (refuels) an amount to raise the fuel inventory to the bunker up to level (or base stock level), irrespective of the current inventory. After consuming the entire contracted amount, the liner can buy any extra amount at the spot price prevailing at that port. The liner also has the option of not using its contract and refuels at the spot price. But if the liner does not fulfill its commitment and consumes less than the committed amount, it has to pay a damage charge to the supplier for unconsumed amount. These types of contracts are often found in the marine fuel industry (e.g. BP Marine, 2012). The damage charge is imposed on the unconsumed amount at a fixed rate, and is specified in the contract. This rate is, sometimes, calculated as a multiple of the fixed contract price. This damage charge forces the operator to fulfill its commitment of refueling the agreed amount. Without this charge, the service contract would be more advantageous to the operator as it would not have any compulsion to execute the contract and would buy fuel from the market if spot price is less than the contract price. Therefore, when spot price is low, the