



Nonlinear pricing for stochastic container leasing system



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ABSTRACT

With the substantial upsurge of container traffic, the container leasing company thrives on the financial benefits and operational flexibility of leasing containers requested by shippers. In practice, container lease pricing problem is different from the consumer product pricing in consideration of the fair value of container, limited customer types and monopolistic supply market. In view of the durability of container and the diversified lease time and quantity, the pricing is a challenging task for the leasing company. This paper examines the monopolist's nonlinear pricing problems in static and dynamic environments. In particular, the leasing company designs and commits a menu of price and hire quantity/time pairs to maximize the expected profit and in turn customers choose hire quantities/time to maximize their surpluses according to their hire preferences. In a static environment, closed-form solutions are obtained for different groups of customers with multiple types subject to capacity constraint. In a dynamic environment, we address two customer types and derive closed-form solutions for the problem of customers with hire time preference. Further, we show that the effect of the capacity constraint increases with time of the planning horizon when customers have the same hire time preference; while in the case with different hire time preferences, the capacity constraint has opposite effects on the low and high type customers. Last, the case of customers with hire quantity preference is discussed. We focus on the lease with alternative given sets of hire time and use dynamic programming to derive the numerical optimal hire time sequence.

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1. Introduction

In the past two decades, global container trade has witnessed a substantial upsurge growing from 28.7 million TEU (Twenty-foot Equivalent Unit)s in 1990 to 161 million TEUs in 2013 (UNCTAD, 2014). In contrast to the thriving container trade, the leasing companies' share of world container fleet does not change much, from 43.2% of 6.4 million in 1990 to 46.2% of 34.4 million in 2013 (Drewry, 2014). The relatively stable share of leasing company in ownership partially reveals the strong demand of shipping companies whose needs are satisfied by lessors flexible services. From the lessor's perspective, the leasing company¹ could enjoy the economies of scale by the procurement of large numbers of containers, efficient utilization and access to raise capital at a competitive rate in a volatile economy. From the lessee's perspective, renting containers could serve as a financial tool with the following advantages.

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¹ For variety, we use lessor, leasing company, monopolist interchangeably without confusion.

- *Conserving capital*: Instead of purchasing containers, the shipping companies are relieved from the burden of the huge expenditure on containers. It is reasonable especially when the new container price is too high or it is difficult to raise finance for container investment such as in the recession year of 2009. This reserves lessee's limited borrowing capacity for more profitable investments, such as infrastructure depots and IT facilities.
- *Providing a better fiscal picture*: The lease is usually qualified as pre-tax expense and considered as 'off-balance-sheet financing'. The monthly payment appears on the balance sheet as expense rather than long term debt.
- *Avoiding risk*: With fixed and predictable payment on container lease, the shipper is protected from inflation.

Besides the financial benefits, the operational advantages of renting containers to supplement their own fleet are as follows.

- *Quick response to demand changes*: Some shipping lines have extremely high imbalance container flows owing to imbalance of trade volume between continents. For instance, in 2013, the container moving from Asia to North America (13.8 million TEUs) is about twice of that from North America to Asia (7.4 million TEUs). The imbalance between Asia and Europe is even bigger with ratio 14.1:6.4 (UNCTAD, 2014). The consequence of such an imbalance cargo flow is the higher cost per TEU for these routes, which is a difficult task in capacity management to the shipping companies. In addition, the trade volume and the demand of containers are high during peak seasons such as Christmas. After holidays, the demand falls back to a low level. Therefore, it is reasonable to rent containers for fluctuating seasonal demand or imbalance cargo routes.
- *High flexibility*: It is convenient for a shipper to pick up/drop off containers at the nearest depot and select the most suitable lease contracts to satisfy their needs. When the lease period expires, the lessee could return, purchase, re-lease or replace the leased containers.
- *Cost saving*: The shippers receive carefully designed services with high quality control, unique depot selection, professional repair and the disposal of used containers. The leasing service reduces costs such as overhead cost, maintenance cost, finance cost and administrative cost.

The container lease contracts can be divided into two categories: master lease and term lease. Master lease is also referred to a full service lease. Both parties agree on a master contract: the shipper has the right to pick up/drop off container at his convenience and changes the number of leased containers under the basic terms. The lessor is responsible for repositioning the empty containers and the maintenance and repair. The term lease has fixed lease duration including short and long terms, ranging from a single-trip lease up to eight years rent. Unlike a master lease, the lessee is responsible for the maintenance and repair of containers.

In the container leasing industry, pricing is a very challenging factor for a leasing company. The main characteristics of container lease are the fair value of container, stable and limited customer types and monopolistic supply market. (1) *High value of container*: A container is labeled as an industrial product and durable good. Its value is much higher than those of daily commodities but lower than those of precision equipment. The average ex-factory price for newbuild TEU and resale price for used TEU in 2013 are US\$2150 and US\$1260, respectively (Drewry, 2014). (2) *Limited customer types*: The target customers of container lease are big shipping companies with long-term contractual relationship. There are limited discrete customer types. In the changing lease market, each customer (shipper) requests large numbers of container with diverse hire time (from one month to five years) depending on his own demand. The varied lease time and quantities of different customer types in container lease meet the requirement for second-degree price discrimination mechanism (different prices for distinct quantities). In other words, the leasing company should pay attention to the characteristics of each customer in the price determination process which is the essence of the nonlinear pricing problem. By contrast, in service pricing, the target customers are individual customers who usually demand for one unit without any contractual relationship and have wide variety of customer types. (3) *Monopolistic supply market*: The container leasing industry has been dominated by a small groups of influential companies about two decades. The top 10 companies control 87.5% of the entire lease fleet. The top tier is headed by long-standing number one, Taxtainer Group. Its fleet is about 40% bigger than its nearest competitor (Drewry, 2014). This is the reason why the monopolist supply market is studied in our paper. In practice, the lease rate determined by a leasing company is usually based on the past leasing experience. Thus it is necessary to have a scientific method assisting the leasing company on the pricing determination process.

Based on the main features of container lease, the price and discount affect customers' intention to deal, hire time and quantity. The more favorable price offered to longer hire time and larger lease quantity incurs an opportunity cost, resulting in inadequate capacity of containers that affects the lessor from gaining future profit from other customers. On the other hand, higher price deters consumers' interest to rent and cause more idle capacity. There is clearly a need for identifying the hire discount and time discount in the lease system given a capacity constraint. Thus, in this paper, we investigate the static and dynamic rental revenue management problem considering several situations (short-term lease and long-term lease) in practice. The company commits a price menu with hire quantity (time) to maximize the expected profit and in turn customers choose their hire quantities/time to maximize their surpluses based on their hire preferences. In Section 3, the company allocates the capacity once in a static environment. Closed form solutions are obtained for different groups of customers subject to capacity constraint. In Section 4, the company allocates the finite capacity repeatedly in the planning horizon. For the case of customers with hire time preference in Section 4.1, closed-form solutions are derived and the effect of capacity constraint are discussed. For the case of customers with hire quantity preference in Section 4.2, we

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