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A dynamic pricing strategy for a 3PL provider with heterogeneous customers

Jian Zhang [a,1], Barrie R. Nault [b], Yiliu Tu [a,*]

[a] Department of Mechanical and Manufacturing Engineering, University of Calgary, 2500 University Drive NW, Calgary, Alberta, Canada T2N1N4
[b] Haskayne School of Business, Scurfield Hall, University of Calgary, 2500 University Dr. NW, Calgary, Alberta, Canada T2N1N4

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ABSTRACT

We study the pricing problem for a third-party-logistics (3PL) provider that provides ware-housing and transportation services. When customers arrive at the 3PL provider, they specify the delivery dates for their freight, and before the specified delivery dates, their freight is stocked in the 3PL provider's warehouse. We propose a dynamic pricing strategy (DPS) and develop a stochastic-nonlinear-programming (SNLP) model which computes the optimal freight rates for different delivery dates incorporating the 3PL provider's current holding cost and available transportation capacity for each route. As customers are heterogeneous in their valuations and price sensitivities for delivery dates, and the distributions of the customers' delivery date preferences are unknown to the 3PL provider, we modify the standard multinomial logit (MNL) function to predict customer choices. Through a simulation experiment, we show that the proposed MNL function can be a good replacement for the mixed MNL function when the mixed MNL function is not applicable. Through simulation we also compare the proposed DPS with a static pricing strategy. We show that with our DPS both the 3PL provider and its customers are better off, and the 3PL provider has different investment incentives for increasing transportation capacity. Our results can be also applied in similar settings that feature holding costs, limited production capacity and delivery-date-sensitive customers.

1. Introduction

In recent years, the third-party-logistics (3PL) industry has grown swiftly with E-commerce. According to *US census bureau*, E-commerce based manufacturing shipments have grown from US $996 billion to US$2283 billion during the seven years from 2004 to 2010. The growth of E-commerce increases the intensity of competition in many industries, and increasingly companies are encouraged to embrace the one-stop logistics services provided by 3PLs so that they can increase their supply chains' efficiency and concentrate on their core competencies (Vaidyanathan, 2005). For example, many online sellers prefer to stock their products at a 3PL distribution center so that they can reduce processing time for shipment after customers place orders. 3PLs have evolved to provide a full set of integrated logistics activities such as transportation, warehousing, freight consolidation and distribution, rate negotiation and logistics information systems (Rabinovich et al., 1999; Sink and Langley, 1997). Moreover, E-commerce has induced 3PLs to increase their investment in central warehouses. According to the North American Industry Classification System (NAICS), 3PLs with warehousing and storage services belong to the *Warehousing and Storage* industry (NAICS Code: 493). The data from the *Bureau of Labor Statistics* (BLS) in US shows that, from January 2001 to October 2012, the number of employees in Warehousing and Storage increased by 31% while in its NAICS super sector, Transportation and Warehousing, the increase was only 4.3%. The data from the *Bureau of Economic Analysis* (BEA) in the US also shows that, from 2001 to 2011, the GDP added from Warehousing and Storage industry increased by 80.1% while the Transportation and Warehousing sector GDP only increased by 48.0%. In 2010, about 85% of 3PLs reported providing warehousing services (Capgemini, 2010). These changes in the 3PL industry have increased the efficiency of traditional supply chains, and consequently drawn the attention of the academic community to the problems faced by 3PLs that provide warehousing and transportation services.

We study the pricing problem for 3PLs that provide these comprehensive services including warehousing and less-than-truckload (LTL) transportation. This work is motivated by a local 3PL whose customers include local manufacturers, wholesalers and retailers. Customers negotiate with the 3PL on the price and delivery date for shipments, and then stock their freight at the

* Corresponding author. Tel.: +1 403 220 4142; fax: +1 403 282 8406.
E-mail addresses: jiazhang@ucalgary.ca (J. Zhang), nault@ucalgary.ca (B.R. Nault), paultu@ucalgary.ca (Y. Tu).
[1] Present address: COSMO Stochastic Mine Planing Laboratory, McGill University, Canada.

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3PL's warehouse until the freight is delivered. The 3PL transports the customers' shipments by trucks. The 3PL's transportation network includes multiple lanes each of which connects to a city in a neighboring state/province. For each lane, there are a certain number of trucks running between the destination city and the home city. The 3PL operates its transportation lanes with its business partners, usually other 3PLs located in the destination cities. When the 3PL operates a lane with a partner, it shares the trucks running on that lane and the warehouses at both ends of the lane. The trucks usually belong to independent transporters, and for each lane, the 3PL signs long-term contracts with these transporters. If the 3PL temporarily increases the number of trucks for a lane, the temporarily added trucks will charge higher transportation costs than the long-term contracted trucks. Thus, for any lane, the daily transportation capacity, which is determined by the number of long-term contracted trucks, is fixed, and if the freight scheduled to be transported in a day is more than the 3PL's daily transportation capacity, the 3PL incurs a penalty as a consequence of hiring temporary capacity. With the daily arrival of hundreds of shipping orders from different customers with different quantities and delivery date preferences, it is difficult for the 3PL to satisfy all the customers' first-best delivery date requirements with the limited transportation capacity.

We develop a dynamic pricing strategy (DPS) that links the price for each shipping order with the 3PL's capacity usage and inventory holding cost. In our DPS, different delivery dates are priced differently. Similar practices can often be found for firms offering standard orders and rush orders with different prices. However, this simple price differentiation in practice usually cannot promise an exact delivery date. Rather, at best each type of order is promised an expected leadtime or a maximum leadtime that is computed based on theory of priority queues. Because no exact delivery date is promised, this pricing strategy can only be applied in a business environment where customers have delivery date flexibility rather than strict requirements for just-in-time (JIT) delivery. For the 3PLs, the pricing problem is more complex when considering the 3PL's transportation capacity, inventory cost and the customers' delivery date requirements that are increasingly strict and unpredictable. Thus, a well-designed DPS has the potential to increase the profit of the 3PL and its customers, which consequently increases the profit of the entire supply chain.

We compute the optimal price for each delivery-date option through stochastic nonlinear programming (SNLP). In our SNLP model, we use a multinomial logit (MNL) function-based method to estimate customers' choices of delivery dates, and the maximum-likelihood estimation (MLE) is employed for regressing the MNL function. The MNL function has been extensively used in marketing science to predict customers' choices from multiple substitutable alternatives. The MNL function and MLE-based method is applicable to our problem for two reasons. First, because customers can obtain different value by choosing to deliver their freight on different delivery dates, we can treat the multiple options of delivery dates as alternatives differentiated in ‘quality’. Second, because 3PLs usually receive hundreds of orders from local customers each day, large enough samples can be collected for regression.

In a MNL function, the term “taste coefficients” is often used to describe the weights a consumer puts on different dimensions of an alternative, and a consumer's taste coefficients determine its utility from choosing different alternatives (Train, 2003). We use taste coefficients to describe the weights that determine the choices of the 3PL's customers although the customers are usually firms. One difficulty in using a standard MNL function is the assumption that customers are homogeneous in their taste coefficients. In our problem customers are heterogeneous in their taste coefficients. That is, individual customers may put different valuations on delivery dates and prices when they choose from delivery date options based on their individual requirements. A mixed logit function is often employed to solve a discrete choice problem when customers' taste coefficients are heterogeneous. In a mixed logit function, the probability of choosing an alternative is computed by integrating the standard logit probability over the density of the taste coefficients. Thus, the employment of a mixed logit function requires the distributions of all taste coefficients to be known. However, because in our problem, the factors that affect customer choices are outside the information available to the 3PLs, the distributions of customers' taste coefficients are unknown. Hence, we develop a new variant of a MNL function for our problem where customers have heterogeneous taste coefficients with unknown distributions.

Our pricing model can also be employed in other manufacturing or service-providing settings which have similar features as the 3PL studied in this work. For example, a make-to-order company produces goods or parts for its customers that are heterogeneous in their delivery date preferences, and developing a DPS incorporating its inventory and production status can increase its profit and optimize the allocation of its resources to inventory and production capacities.

1.1. Background literature

DPS and its impact on a supply chain have attracted increasing interest in recent literature. For example, Jia and Zhang (2013) and Zhu (2015) studied the cooperation of a manufacturer and a retailer both employing DPS. We study the DPS that enables a 3PL to coordinate its transportation schedule with its customers' production schedule, which is a marketing-based solution for *supply chain scheduling* as first defined by Hall and Potts (2003). Chen (2010) provides a review of research studying supply chain scheduling between manufacturers and distributors. However, little research in supply chain scheduling studies cooperation between manufacturers and 3PLs that provide comprehensive warehousing and LTL transportation services. Moreover, in review articles by Maloni and Carter (2006), Selviaridis and Spring (2007) and Marasco (2008), there is no work that covers 3PL pricing. Lukassen and Wallenburg (2010) reviewed research related to pricing strategies for 3PL services but only in the context of the pricing of logistics services where the 3PL and its client are involved in a long-term contract. Carter et al. (1995) studied how the pricing in LTL transportation industry affects the manufacturers' lot-sizing decision but not scheduling. Ülkü and Bookbinder (2012a) studied dynamic pricing for a manufacturer which provides delivery with guaranteed delivery dates and Ülkü and Bookbinder (2012) extend the pricing method for a 3PL which provides both transportation and warehousing services. In their DPS, the price for each order depends on the order's time of arrival, but customers do not have multiple delivery date options to choose from. Similar DPS is can be also found in Feng et al. (2011) which studies a GI/M/1 system.

By adopting our DPS to maximize profit while incorporating its holding cost and transportation capacity, the 3PL induces some flexible customers to choose other delivery dates if there is not enough capacity on their first-best delivery dates. Thus, the DPS is actually a priority dispatching strategy when the 3PL's transportation capacity is limited. Priority pricing relates to the literature on pricing/queuing models defined by Hall et al. (2009), literature that originates from the research on priority pricing in a queuing system. To the best of our knowledge, Kleinrock (1967) was the first to study priority queues in which the priorities are associated with prices paid by customers. However, he focuses on the customers' behavior rather than on the priority pricing scheme. Well-cited research on priority pricing in priority queues can be