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Bid price optimization for truckload carriers in simultaneous transportation procurement auctions

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ABSTRACT

We study simultaneous transportation procurement auctions from a truckload carrier's perspective. We formulate a stochastic bid price optimization model aimed at maximizing the carrier's expected profit. The model accounts for synergies among lanes and competing carriers' bid patterns. We develop an iterative coordinate search algorithm to find high-quality solutions. The benefits of employing the bid price optimization technology are demonstrated through computational experiments involving a simulated marketplace.

1. Introduction

In this paper, we design and analyze bidding strategies for a truckload (TL) carrier participating in multiple independent simultaneous single-lane transportation procurement auctions. Our focus is on developing bidding algorithms for a carrier that account for synergies among lanes and that anticipate the bidding behavior of competitors.

Outsourcing of transport operations is a widely used practice in supply chain management. When outsourcing transport operations, firms interested in shipping goods (i.e., shippers) procure the services of firms specializing in transportation (i.e., carriers). Due to its relatively low cost of entry, the trucking industry consists of companies of varying size and geographic coverage. While some trucking companies operate only a handful of trucks, others operate thousands of trucks. While some operate in a specific region, others operate across multiple regions. As a result, a shipper typically has multiple trucking companies to choose from, and seeks to identify one or more that offer reliability and low prices.

Shippers typically sign service contracts with carriers that remain in effect for a year or more to protect against volatility in future prices, capacity availability, and service quality. The carriers agree to these contracts when the shipper offers sufficient freight volume, acceptable regularity, and service compatibility. For establishing these long-term contracts, shippers use Request for Proposals (RFPs) (Sheffi, 2004; Foster and Strasser, 1991) to identify and select the carrier(s) for their freight lanes. The RFP process can span several weeks, since many lanes, sizeable freight volumes, and large amounts of money may be involved.

Even when a shipper has long-term contracts with carriers in place, fluctuations in shipment volume may cause the shipper to seek services of other carriers for short periods of time. As a result, in addition to having long-term contracts with

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carriers, shippers often also engage carriers for short periods of time, even for one-off shipments. These short-term engagements are established using a much simpler process than the RFP. A shipper may simply request quotes from a few carriers by phone and employ the carrier that offers the lowest quote.

Advances in information and communication technologies, especially the wide-spread availability and use of the Internet, facilitate quick, convenient, and cost-effective negotiations and transactions between shippers and carriers. This is especially well-suited for establishing short-term engagements, and has lead to public freight exchanges, such as www.teleroute.com, that act as a spot market which enables shippers to satisfy immediate and short term transportation needs resulting from fluctuations in shipment volume in a cost effective way. Carriers (including non-asset-based 3PL service providers) use these public freight exchanges to complement contracted customer lanes, or to subcontract lanes if they anticipate insufficient capacity on those lanes. In such a market place, shipments needing to be transported are listed, and interested carriers contact them with offers. The shipper then decides which carrier will serve the shipment. See Nandiraju and Regan (2005) for a review of transportation marketplaces and their characteristics.

Whenever a shipper seeks the lowest cost carrier by requesting proposals or quotations, he is effectively running an auction (Krishna, 2009). Since multiple lanes may be auctioned, it is, in fact, a simultaneous multiple-unit auction. The term *auction* usually refers to the case that involves a seller and several buyers. On the other hand, a procurement auction, or *reverse auction*, involves a buyer (shipper) and several sellers (carriers); prices are bid down instead of up. In reverse auctions, sellers have production or service costs, while in forward auctions, buyers have a valuation of the object or service to be purchased. Most of the auctions studied in literature are forward auctions. Fortunately, the models and intuition derived for forward auctions can mostly be easily reversed and applied to reverse auctions (Rothkopf, 1994).

A carrier participating in procurement auctions has to take several factors into account when deciding on a bid for a given lane, namely: (1) the type of auction mechanism employed, (2) the carrier's own cost structure, and (3) the competitors' bidding strategies. The carrier's price must be high enough to make serving the lane profitable, but low enough to beat the competitors' prices.

The revenue associated with an auctioned lane is determined by the auction mechanism employed by the shipper. In a first-price sealed-bid auction, the revenue is equal to the winning carrier's bid. In a second-price sealed-bid auction, the revenue is equal to the second lowest bid, which is unknown to the winning carrier when he places his own bid. In sealed-bid auctions, a carrier cannot change his bid once it is placed, so the carrier must estimate the competitors' bids and carefully decide on his own bid. In descending procurement auctions, the bidders are allowed to decrease their bids, so a carrier can start by placing a high bid and revise it when competitors' bids are revealed.

In order to assess the profitability of serving a lane at a given price, a carrier must estimate the incremental cost of serving that lane. A TL carrier's operating costs are determined by his vehicle routing and fleet management technology and the interaction between the lanes to be served by that carrier. The set of lanes a carrier participating in a transportation procurement auction ends up serving is uncertain due to the participation of other carriers in the auction. The probability that a carrier wins a certain lane depends on the carrier's bid and the competitors' bids. In simultaneous transportation procurement auctions, the carriers are thus susceptible to the so called "exposure problem." That is, a carrier may fail to win one of the lanes which has strong synergies with the lanes he does win, leading to an unprofitable outcome for the carrier. In such a setting, it is critical that the carrier anticipates his competitors' bids and uses this information when deciding on his own bids.

In this paper, we introduce and investigate the value of a stochastic bid price optimization model for a carrier participating in simultaneous, independent, single-round, sealed-bid, first-price auctions of lanes aimed at maximizing the carrier's expected profit. The model accounts for synergies among the lanes (those being auctioned and those that are part of the carriers existing long-term contracts) and anticipates competing carriers' bids (based on historical bid patterns of the competitors). We develop an iterative coordinate search algorithm to efficiently find high-quality solutions to the stochastic bid price optimization model and demonstrate its efficacy through computational experiments involving a simulated marketplace.

In this study, we incorporate the competitors' bidding strategies by anticipating the lowest competitor bid on each lane using probability distributions based on past bid statistics. In other words, we model the lowest competitor bid on each lane as a random variable with a particular probability distribution and compute the parameters of the distribution based on historically observed bids. We have experimented with uniform, normal, and empirical probability distributions to investigate the trade-offs between using a computationally simpler but less accurate distribution model versus a more accurate but computationally more complicated one.

The contributions of the research presented in this paper can be summarized as follows:

- We are the first to study simultaneous truckload procurement auctions from a carrier's perspective. The existing literature studying transportation procurement auctions from a carrier's perspective has focused on combinatorial or sequential auction settings.
- We formulate a stochastic bid price optimization problem aimed at maximizing a carrier's expected profit that accounts for synergies among lanes as well as anticipates competitors' bids, and we develop an effective iterative coordinate search algorithm for its solution.