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A carrier's optimal bid generation problem in combinatorial auctions for transportation procurement

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Abstract

We consider the carrier's optimal bid generation problem in combinatorial auctions for transportation procurement. Bidders (carriers) employ vehicle routing models to identify sets of lanes (origin-destination pairs) based on the actual routes that a fleet of trucks will follow in order to maximize profit. Routes are constructed by optimally trading off repositioning costs of vehicles and the rewards associated with servicing lanes. The carrier optimization represents simultaneous generation and selection of routes and can incorporate any existing commitment. We employ both column generation and Lagrangian based techniques for solving the carrier optimization model and present numerical results.

Keywords: Transportation procurement; Carrier bid generation; Combinatorial auction; Vehicle routing; Branch and bound; Integer programming decomposition

1. Introduction

Truckload (TL) transportation accounts for a substantial portion of the annual overall billion dollar freight transportation industry in North America. A significant portion of this demand emanates from shippers e.g. manufacturers and retailers that need freight to be transported in dedicated (truckload) movements from origins to destinations. Shippers often need to acquire third party logistics carriers to meet demand since in-house transportation capacity may be insufficient. Usually, contracts for transportation services with carriers are sought through a competitive request for proposals (RFP) process. The basic unit of interest is called a lane which specifies an origin-destination pair for particular freight movement.

Carriers usually engage in some form of auction to bid on individual lanes of interest. Shippers evaluate bids on lanes individually and then awards lanes separately to carriers based on several factors e.g. price and business requirements. However, as noted by Caplice (1996), carriers are often driven by economies in scope in obtaining lanes. That is, a carrier may desire to bid on separate lanes that collectively represent a cost

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efficient service route with respect to minimizing empty miles travel and other repositioning costs. For example, a contract to move freight from Toronto to Montreal would be not be worth as much as a contract that requires movement of freight from Toronto to Montreal and then movement of freight from Montreal and back to Toronto. The first case would involve a trip back to Toronto with an empty load. In general, repositioning empty trucks comprise a substantial portion of operating expenses. In short, carriers seek a set of lanes that are synergistic with respect to repositioning costs. However, many current forms of transportation procurement do not guarantee that a carrier may get a particular cost minimizing set of lanes. A carrier may end up with an incomplete set of lanes that is worth far less than having the complete set or a carrier may incur a loss in servicing the incomplete set of won lanes due to repositioning costs. In auction parlance, the problem of not obtaining a complete set of desired items in a multi-item auction is called the exposure problem (see Bykowsky et al., 1995; Kwasnica et al., 2005). Transportation procurement auctions in most instances award lanes separately and so may be subject to the exposure problem. In general, it is desirable for auction outcomes to result in efficient allocations where bidders that value the items the most obtain them and pay accordingly the highest for the items. The exposure problem can prevent auctions from achieving high levels of efficiency since bidders may be reluctant to bid aggressively for items in fear of not obtaining a complete set of items which can make generation of revenue difficult for the auctioneer and allow others to obtain items for lower prices.

Recently, combinatorial auctions (CA) have been suggested to overcome the exposure problem in auction settings (Kwasnica et al., 2005). Combinatorial auctions are auction formats that allow bidders to place a single bid on a set of distinct items. In the context of transportation procurement carriers could place a single bid on several distinct lanes and if a bid were successful then the carrier would receive the complete set (package) else carriers would receive nothing. This would minimize the risks in obtaining only a subset of lanes that are not worth much. It would also be possible for a carrier to submit multiple packages each consisting of one or more distinct lanes. Combinatorial auctions can result in more efficient allocations in multi-unit auction settings and can be promising mechanisms to allocate lanes since carriers may have substantial synergistic preferences for certain lanes and thus will bid more aggressively for the set without fear of getting an incomplete set.

Combinatorial auctions have been suggested for truckload transportation procurement and have been successfully used in several instances. Caplice and Sheffi (2003) discuss the value of combinatorial auctions in transportation procurement and present several optimization models for shippers to assign carriers to lanes. Ledyard et al. (2002), document the experience of Sears in using CA auctions for outsourcing logistics needs and report the successful use of a multi-round CA where Sears has been savings millions of dollars annually on outsourced transportation costs by using their CA mechanism. Elmaghraby and Keskinocak (2003) present the experience of Home Depot in using a single round CA mechanism for outsourcing truckload transportation capacity to move freight between the many thousands of stores of Home Depot.

One issue not discussed extensively is on normative methods for carrier bid generation in combinatorial auction settings for transportation procurement i.e. how to determine the best set of lanes. Most CA models assume that bidders know which set of lanes to bid for. In general, the evaluation of packages from the bidding perspective is difficult since there are an exponential number of possible relevant packages for a bidder. Nevertheless, bid generation is an important issue since carriers are driven by economies of scope and thus want lanes that correspond to routes that minimize vehicle reposition costs. Thus, package of lanes should be determined optimally given general information about what lanes are available.

Song and Regan (2002) present the first carrier model that uses optimization-based approximation to determine useful packages of lanes that a carrier could bid for in the context of CA for truckload transportation procurement. This work is important in that it is the first to address the bidder evaluation complexity through optimization models in the CA literature. Since there are an exponential number of possible routes it makes sense to use a normative optimization model to find the best routes. Optimization models that can be employed such as those for vehicle routing are computationally difficult to solve. However, a route obtained by using a good approximation for an appropriate optimization will represent a vast improvement over a route generated based on naïve or non-optimization based methods.

The method employed by Song and Regan (2002) consists of two phases. A first phase determines heuristically the potential routes that will correspond to potentially useful packages of lanes that a carrier could bid for and then a second phase associates a binary variable with each route (package) generated in the first phase.