Combinatorial Auctions in Procurement[1]

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1. Introduction

Everyday, companies struggle with multiple decisions in the fight to increase their profitability. Complex decisions a company must make include, (1) how much should we order from our suppliers and when?, (2) how should we organize our supply chain and logistics?, (3) how much should we produce (4) what price should we charge or pay for goods and services?

Making the "right" pricing decision in sales or procurement is a complex task. While the types of pricing policies/methods used in the exchange of goods and services vary greatly, we can divide these mechanisms under two broad categories: posted price mechanisms and price discovery mechanisms. Under a posted price mechanism, a good is sold at a take-it-or-leave-it price determined by the seller. A posted price can be dynamic, i.e., the seller may offer different prices to different customers (customized prices) or change prices dynamically over time (intertemporal prices). In a price discovery mechanism, prices are determined via a bidding process.

A commonly used price discovery mechanism that has experienced a tremendous growth in use is an auction. In a forward auction, the seller puts out and item (or a set of items) for sale, and buyers compete in a bidding process. In a reverse (procurement) auction, a buyer puts out a request for quote (RFQ) for a service or a product(s), and prices are determined by a competition among potential sellers. Auctions implemented over the Internet have several benefits compared to traditional auctions, including lower information, transaction, and participation costs; increased convenience; ability for asynchronous bidding; and access to larger markets [9]. Hence, companies increasingly use Internet auctions to buy and sell excess inventory, first-run goods and commodities, to test prices for new consumer goods, to market one-to-one, and to fine-tune inventory levels.

Most of the B2B auctions involve the exchange of multiple products/goods. Despite this salient characteristic of B2B auctions, the research in auction theory has traditionally focused on single-unit auctions, i.e., only a single unit is to be traded via the auction or bidders only wish to acquire a single unit. In addition, while designing, implementing or studying auctions for multiple goods, a strong assumption that has been often made in the literature is that bidders experience no synergies or complementarities in values across multiple units. Two objects are said to be complements, have superadditive values, or exhibit synergies, when their value together is more than the sum of their individual values. For example, in the recent FCC spectrum auctions, bidders, comprised of US telecommunication companies, cellular telephone companies, and cable-television companies, competed to win various spectrum licenses for different geographical areas. The synergies arising from owning licenses in adjoining geographical areas create dependencies in (some) bidders' valuations for individual licenses. Similarly, in manufacturing there may be synergies, or economies of scale, in producing larger quantities, while in logistics there may be synergies associated with acquiring adjacent lanes or lanes that form a closed loop.

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While bidders experience synergies across multiple items in numerous settings, most auctions in use today are simple auctions, i.e., each unit (or bundle of units) is auctioned independently of all other units and the lowest bidder wins in each auction. A simple auction is an attractive selection mechanism because it is simple to evaluate the bids and determine the winner. However, when multiple units are auctioned and there is a strong presence of synergies in production costs, a simple auction cannot adequately allow suppliers (or buyers) to reflect their synergies in production over multiple units.

An alternative format to a simple auction is a package or combinatorial auction. In a combinatorial auction, bidders can submit all-or-nothing bids on packages of goods in the form "I will pay $X if I win goods A and B or I will pay $Y for only A and $Z for only B (where X>Y+Z)". A combinatorial auction is an effective mechanism when there exist strong complementarities over several goods, and the source of those complementarities varies for different suppliers.

In the remainder of this paper, we give an overview of combinatorial auctions and discuss a recent application of combinatorial auctions by The Home Depot in the procurement of transportation services. A teaching case study on this application is presented in [2].

2. Combinatorial auctions

The use of combinatorial auctions in industrial settings has increased of late. Sears Logistics Services and The Home Depot, Inc. are two examples of companies using combinatorial auctions for procurement of logistical services; Sears Logistics saved over $84 million running six combinatorial auctions [6]. Additional examples include Walmart Stores, Compaq Computer Co., Staples Inc., The Limited Inc. and Kmart Corporation, who implemented combinatorial auctions for procurement with the aid of Logistics.com. With the application of Logistics.com's procurement solutions, Limited Logistics Services, the supply chain arm of The Limited Inc., saved $1.24 million in shipping costs in year 2001 compared to the previous year [8].

Combinatorial auctions are auctions where bidders can name their prices on combinations of items, as opposed to individual items. Each combination of items submitted to the auctioneer is called a bundle or a package. A bid consists of a bundle and its price, and bidders are usually allowed to submit multiple bids. Due to the conditional format of the bids, combinatorial auctions lend themselves to environments where bidders have high synergies across multiple items. Despite this attractive feature, the use of combinatorial auctions has not traditionally been commonplace. The challenge facing academics and practitioners alike is how to design a combinatorial auction that will allow bidders to effectively incorporate their synergies (the mechanism design problem) without posing an unnecessary burden on the auctioneer when computing the optimal allocation (the winner determination problem). In an effort to address these issues, there is a growing body of literature on the use and design of combinatorial auctions.

A serious issue that limits the use of combinatorial auctions in real applications is the Winner Determination Problem. After all the bids are submitted, the auctioneer needs to determine the optimal selection of winning bids. The winner determination problem for combinatorial auctions is NP-complete, i.e., no algorithm is guaranteed to find the optimal solution in polynomial time [10]. Several researchers have designed fast search algorithms to solve for the exact optimal solution [16][17][3]. While solving for the optimal solution would be ideal, in most business