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Procurement Auctions in E-Commerce

Robert T. Barrett and Robert E. Pugh

The development of the Internet has led to establishing a variety of electronic marketplaces or exchanges that facilitate business-to-business (B-to-B) transactions. These Internet-based marketplaces reduce transaction costs and increase market liquidity. The vast size of the U.S. economy gives the promise of strong future growth and development of these marketplaces. The size of the U.S. economy is such that about \$10 trillion of goods and services are delivered annually to final users, which includes domestic, foreign, and capital-good customers. The inputs to the processes producing these goods and services for final

demand change hands several times before the finished goods and services reach the final customers. In fact, it is estimated that an average of three B-to-B transactions occur before the delivery of goods and services to the final users. Thus, the total for B-to-B commerce supporting the production of final demand is about \$30 trillion per year, and, for the world economy, the annual B-to-B commerce is estimated to be about \$100 trillion (Hall, 2001). Strong growth is also expected in financial B-to-B transactions, including certificates of deposits and bonds. Muni-Auction, which has conducted more than 5,500 B-to-B financial auctions for states and municipalities for about \$3.3 trillion in its first five years of operation and is increasing in volume at about a trillion dollars per year, demonstrates this growth (Grant Street Group, 2003).

Electronic marketing is proving to be highly advantageous in conducting some types of B-to-B transactions, but it has little to contribute to other types of transactions. Many types of capital equipment are custom-made

and will continue to be purchased through negotiations of design and price that are worked out over a period of weeks or months. Electronic marketing cannot contribute to completing these negotiations. For the same reasons, electronic marketing can contribute little or nothing to new product development. Components and parts that are critical to product quality and safety are usually best purchased through partnering arrangements between the buyer and seller. Again, electronic marketing has little to contribute.

In the procurement of commodity and standard parts or components, however, electronic marketing can help achieve efficiency and cost-effectiveness. In fact, some electronic marketplaces handle large volumes of procurements in industrial chemicals and metals, injection molded plastic components, printed circuit boards, fasteners, and many other noncritical inputs. Dana Corporation, one of the world's largest suppliers of components and modules to automotive manufacturers, reported the use of electronic marketing to procure more

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than \$850 million in goods and services in 2001. Among the items Dana sourced through electronic marketing were aluminum and various metals, metal pipes, tubes and fittings, plastic injection molded parts, castings, electrical wire and connectors, metal fasteners, printed circuit boards, and spring products (FreeMarkets, Inc., 2001a).

In electronic marketing in support of B-to-B transactions, auctions are increasingly being used. Most of these auctions are of the multi-unit variety. For example, a company that requests bids from suppliers for a large quantity of a commodity or standard product or service and requests that bids specify the quantity that can be provided at a specified price within the buyer's time frame, constitutes a multi-unit auction. While the ways to structure such auctions are numerous, little is known about the best way to structure them. Until recently, auction theory, which is a sub-field of economics, has restricted attention to the auctioning of a single, indivisible unit. While the research on multi-unit auctions is less well developed, it has recently become an active research area due to the impetus provided by B-to-B electronic commerce and to such problems as government auctions of radio spectrum licenses (Klemperer, 1999).

Auctions in E-Commerce

Auctions have been used from time immemorial, dating back at least to the Babylonian and Roman empires. Traditional auctions bring buyers together for the purpose of determining the price a seller will receive for a product or service. Another type of auction, frequently called a reverse auction (multi-unit procurement auctions, as discussed in this article, are invariably reverse auctions), brings sellers together for the purpose of determining the price a buyer will pay for a product or service. Auction participants are governed by a set of rules for making and processing bids and determining the transaction price or prices for the buyers and sellers. While the variants of auctions differ, only four traditional types of single-unit auctions exist:

- (1) the ascending-bid auction,
- (2) the descending-bid auction,
- (3) the first-price sealed-bid auction, and
- (4) the second-price sealed-bid auction.

In the ascending-bid auction, or English auction, the object for sale is bid upon in an open forum resulting in the bidder offering the highest price having the obligation to

purchase the item for that price. The English auction is an open system requiring that all bidders be made aware of all bids offered. The descending-bid auction, or Dutch auction, works in an opposite manner from the ascending-bid auction. The auction begins with a high price and the price is lowered in steps, usually at set time intervals. The first bidder who agrees to accept the current price wins the object and pays that price. The first-price sealed-bid auction requires each bidder to independently submit a single bid without knowing the others' bids; the object is sold to the bidder who makes the highest bid. The second-price sealed-bid auction, or Vickery auction, requires each bidder to independently submit a single bid without seeing the others' bids; the object is sold to the bidder who makes the highest bid at the price bid by the second highest bidder (Klemperer, 1999). The rules for these four basic types of auctions have to be generalized to accommodate multi-unit auctions since in multi-unit auctions bidders bid on different numbers of units and may pay different prices per unit. The variety of ways in which these rules can be generalized is wide.

In addition to the four traditional types of auctions are forward and reverse auctions. These terms distinguish whether multiple buyers or sellers are involved

in an auction. The forward auction is the classic situation in which multiple buyers compete to purchase items from a single seller. Forward auctions are well suited to selling art or other unique items and to liquidating inventory. In the reverse auction, multiple sellers or suppliers compete to satisfy a buyer's needs. For example, if a firm were purchasing a fleet of vehicles, the firm would post specifications and a request for price quotes on the auction site. Suppliers would then compete through bids for the buyer's business (Mitchell, 2000).

The development of the Internet has led to electronic marketplaces, or exchanges, that create market liquidity and reduce transaction costs. Market liquidity, in this context, is created by the power of the Internet to bring together a critical mass of buyers and sellers who communicate almost instantaneously. These marketplaces focus on specific industries or markets or on specific functions or business processes. For example, GM, Ford, and Daimler-Chrysler have joined together to create an automotive industry portal for auctions and other automotive procurement activities. These firms recognize this industry portal will be of little value for parts and components that require a significant degree of supplier involvement in the design, such as fuel filters that are custom-designed for each fuel

system. However, for commodity materials, parts, and components, such as steel, plastic parts, castings, and nuts and bolts, the auction can achieve savings (Fleischer, 2000). Altra-Energy (www.altraenergy.com) provides a global marketplace for trading, scheduling, and transporting in the energy industry. Marketplaces for functional business processes include CarrierPoint (www.carrierpoint.com), providing shippers and carriers with the means to communicate and conduct business with each other in real time, and ReturnExchange (www.thereturnexchange.com), providing retailers with solutions to returns problems while maximizing revenue from returned merchandise.

Auction-determined prices as well as posted, fixed prices are used in e-commerce, but auctions are increasingly being used by more companies on both company web sites and electronic marketplaces operated by third parties. The use of auctions for exchanging goods such as antiques, artwork, agricultural products, and gold has a long history. With the advance of the Internet, the use of auctions for the sale of goods and services among and between companies and individuals has increased dramatically. For example, A-Plus Auctions (www.aplusauctions.com) holds on-line auctions of antiques, art glass, and estate liquidations. PriceLine (www.PriceLine.com) sells

mortgages, cars, and airline tickets by allowing shoppers to bid their price and terms for an item after which the web service tries to find a willing seller at that bid. The web sites AuctionNet (www.AuctionNet.com) and BidFind (www.vsn.net) list hundreds of web sites that conduct auctions.

For many, the term Internet-based auction brings to mind eBay, the well-known company operating an on-line person-to-person, or P-to-P, community of traders on the Internet bringing together sellers and buyers in an interactive auction format. The eBay community trades personal items such as collectibles, antiques, coins, computers, stamps, and toys. EBay, Inc., has created and operates the world's largest P-to-P Internet-based trading community. Although P-to-P trading was its initial focus, eBay has become more and more involved with established businesses. EBay provides an entertaining and efficient auction format to buy and sell items in more than 1,000 categories. The service provided permits sellers to list items for sale, buyers to bid on items, and all users to browse through the items listed. EBay, Inc., was founded in 1996 and has been among the more successful of the Internet-based e-commerce firms. EBay continues to grow rapidly and, in mid-2002, had a total of 46.1 million registered users, representing a 55 percent increase over the previous year (eBay, Inc., 2002).

Recently, eBay expanded into fixed-price listings to accommodate some on-line users who are not comfortable with the dynamic auction format. Now, about one-third of the new listings carry a fixed price. Jerry Adler of *Newsweek* reported that as many 200,000 businesses now exist entirely on eBay (Adler, 2002). A search of the eBay Stores' directory finds that major retailers such as Dell Financial Services, Ritz Camera, KitchenAid, Sears, Sharper Image, and IBM now have on-line storefronts hosted by eBay. The eBay business model is interesting in that the company provides the technology to allow individuals to connect with one another, but eBay is not involved in the pricing, which is set by the sellers and buyers, nor is it involved in settling the transactions and delivering the items (Fryer, 2001, and Roth, 2001).

Development of Auction Theory

Although auctions have long been used in determining the prices at which goods will be bought and sold, they have only entered the research literature since in the 1950's and 1960's. The research has been primarily in two disciplines, economics and operations research/management sciences (OR/MS), with only limited interaction between these two lines of research. While our research is

more closely aligned with the OR/MS approach, it is useful to briefly examine both lines of research.

In the economics literature, auction theory is regarded as a sub-field, with some of the earliest papers by Vickery in the early 1960's (Vickery, 1961 and 1962). Klemperer more recently compiled a comprehensive review of the economics research identifying 217 pieces of research literature (Klemperer, 1999), and, even more recently, he updated his auction theory bibliography with an additional 22 references (Klemperer, 2003). While Klemperer focuses primarily on the economics literature, he includes a number of references from the OR/MS literature.

The economics literature has restricted most attention to the sale of single, indivisible units. As Klemperer noted: "[t]he literature in the sale of multiple units is much less well-developed, except for the case where bidders demand only a single unit each." The multiple unit auction in which bidders demand multiple units is, however, "the most active field of current research" (Klemperer, 1999). By current research, Klemperer is referring to auctions such as the first auction of the European rights for the new "third generation" mobile-phone services held in 2000. Klemperer worked for nearly two and one-half years for the

government of the United Kingdom to develop this auction, which lasted seven weeks and netted bids totaling \$34 billion, the most ever raised by an auction (Klemperer, 2003). Auctions of this type involve dealing with collusion, complementarity, and other complexities that do not arise in multi-unit procurement auctions for commodity items. Collusion refers to the exchanging information and price setting during the bidding process by bidders. Complementarity arises when items or objects have different values to bidders depending on whether they win or fail to win complementary items or objects, which may, in turn, cause other bidders to stop bidding earlier than otherwise (Klemperer, 2003). While collusion and complementarity are important issues in auctions such as auctioning rights to mobile-phone service areas, they have little relevance for multi-unit procurement auctions of commodities because of the restricted bidding periods allowed in such procurement auctions and because of the homogeneous nature of the items being auctioned.

In the OR/MS literature, auction theory research has focused more narrowly on the competitive bidding aspects of auctions. Probably the earliest of the OR/MS auction-related papers is Goldstein's application of linear programming to minimize the cost of a

multi-unit procurement of a set of related items (Goldstein, 1952). While Goldstein's procurement is not an auction in the usual sense, it is of interest because it is an early example of structuring the bidding process to promote competitive bids from suppliers. In 1979, Stark and Rothkopf developed a comprehensive bibliography of almost 500 titles on competitive bidding. The research studies cited are a mixture including *ad hoc* advice to bidders, analyses of historical data on bidding, and bidding in specific industries. For example, 30 percent of the studies cited are related to the construction and natural resource exploration (oil, gas, and minerals) industries. Only about 11 percent of the studies were published in mainstream economics or OR/MS journals (Stark and Rothkopf, 1979). In 1994, Rothkopf and Harstad updated the competitive bidding bibliography with more than 120 studies, about 90 of which were published in the 1979-1994 period. About half of these studies appeared in the mainstream economics and OR/MS literature. As the authors of this update indicate

most bidding theory papers discuss a single isolated auction of a single indivisible asset. The most common exception is papers discussing an isolated sale ... of a fixed number of identical

assets to bidders ... typically called 'multi-unit' auctions (Rothkopf & Harstad, 1994).

Not surprisingly, since 1994 was early in the development of Internet-based transactions, none of these papers deal with Internet-based multi-unit procurement auctions.

The more recent OR/MS literature also was reviewed by examining *Decision Sciences*, *Interfaces*, *Management Science*, and *Operations Research* for the period from 1994. This search located six articles related to auctions conducted on-line; however, only one of these dealt with multi-unit procurement auctions. That article described an on-line auction in which Sears, Roebuck, and Company procured trucking services, and the auction was multi-unit in that it allowed carriers to make bids on trucking services for multiple lanes. This process saved Sears more than \$80 million in annual transportation costs (Leyland, et al., 2002).

In recent research, Jap has identified some of the differences between Internet-based procurement (or marketplace) auctions and auctions from the economics and OR/MS literature (or theoretical auctions). Marketplace auctions differ in that they allow bidders in different geographic locations to participate fully and provide immediate bidder feedback. In addition, suppliers in

marketplace auctions bid in a computer-controlled environment, and suppliers are typically anonymous among competing suppliers. From this, Jap concludes that the findings and theories from the pre-Internet era literature may not generalize to Internet-based procurement auctions. Thus, these Internet-based auctions "appear to be a fundamentally different phenomenon" from auctions of the past. However, this difference is not intended to imply that overlaps, similarities, and insights from pre-Internet auctions are irrelevant to procurement auctions. "The critical point is to realize that the dynamics and use of on-line industrial sourcing auctions are very different from those of the past" (Jap, 2002).

Procurement Auctions

As the Internet has developed, companies have realized that it provides a powerful tool for the procurement of goods and services to support production activities. More specifically, it has been recognized that commodity-type goods and services are highly suitable for Internet-based procurement, and auctions have increasingly come to be used to assist buyers and sellers in negotiating transaction prices in such procurements. Firms have found that competitive procurements by Internet have allowed them to leverage their

purchasing power, attract the interest of a larger group of suppliers, and, in general, streamline their procurement processes. Industries that adopted Internet-based technology at an early stage include chemical, pharmaceutical, manufacturing, transportation, and insurance; and they benefitted significantly. Future growth seems assured, and Forrester Research projects that procurement via Internet-based auctions will increase at a compound rate of nearly 100 percent per year during the early years of the 21st century (Mitchell, 2000).

Most companies that use Internet-based procurement methods also use traditional negotiation methods for some of their purchasing needs. The manufacture of lithium batteries at Eveready illustrates the distinction between commodity-type purchases and critical component purchases. The lithium battery product line is used primarily in cameras and flash units. The company purchases a number of commodities such as chemicals and metals to support the production of these batteries. For Eveready's lithium batteries, the circuit breaker is a critical component for the safety and quality of the product because lithium batteries can produce a huge amount of power that can cause fires if a short circuit occurs. The circuit breaker is a small disk at the top of the battery cylinder that stops an

excess current flow that could start a fire. The circuit breaker disk is inexpensive, costing only about a nickel, but it is a critical component. Eveready proceeds carefully in selecting a supplier for circuit breakers, studying a supplier's proposal, conducting extensive laboratory tests on samples of the circuit breaker, and evaluating the supplier's reputation. If the supplier passes these tests and can beat the price offered by existing suppliers, Eveready will consider an agreement with the new supplier. This partnering approach is common in the procurement of critical components, and competitive bidding processes are of no help in this process. However, in the support of the production of lithium batteries, Eveready buys a number of standard industrial commodities, such as the lithium itself. These commodity-type products are purchased from a number of qualified buyers, and, because these products are standard and their market prices fluctuate, auctions using Internet technology are very useful in arranging such purchases at cost effective prices (Hall, 2001).

A basic question companies face is, should they engage in on-line procurement auctions for some of their sourcing? Jap has identified three conditions regarded as critical to successfully engaging in on-line procurement auctions. These

conditions were developed from her experience with on-line auctions in a variety of product categories in conjunction with her field interviews and other research. The conditions relate to product characteristics, sourcing strategies, and supply base characteristics.

- Products for which purchase price constitutes the largest component of value are well suited for on-line auctions. Examples of such products include computer parts and supplies, software, plastic and metal parts, fuel, construction services, and hotel services.
- Sourcing strategy is a second consideration in that on-line procurements must be integrated into a company's ongoing sourcing strategy. Frequently, on-line sourcing auctions represent a strategy component intended to cut costs from the sourcing process, whereas other components of an overall strategy may focus on collaborative relationships with suppliers.
- The third essential component for promoting successful use of on-line procurement is the existence of spare capacity in the supply base and a competitive environment among suppliers that is

often associated with spare capacity (Jap, 2002).

Firms interested in Internet-based procurement in support of their production activities have two choices. First, a firm may choose to create its own system, and, for large firms, this option is viable. Philips, the Dutch global electronics manufacturer, undertook the development of its own worldwide e-procurement system in early 2000. This system, which took nearly two years to implement, is expected to produce savings of eight percent annually in the Philips \$5 billion purchasing budget and to save 100 man-years annually for the firm in Europe alone (Goodwin, 2000). Second, as an alternative to establishing its own Internet-based procurement system, a company may rely on a third party to provide the support to conduct procurements. Quaker Oats contracted with FreeMarkets, Inc., to develop an Internet-based auction system for procuring transportation services and glycerin and other raw materials. Quaker Oats announced that it was achieving annual savings of \$8.5 million with this procurement system (King, 2000). United Technologies Corporation has also used FreeMarkets as a third party provider in support of its supply chain management initiatives, including auctions. Kent Britton, United's vice president of supply management, indicated that

we have placed more than \$2 billion in annual contracts into the marketplace through execution of over 3,000 online negotiations, identifying savings in the range of 20 percent (FreeMarkets, Inc., 2003 a).

Another firm that has developed its own Internet procurement technology is Sun Microsystems. The firm's CEO, Scott McNealy, feels that the Internet is rendering fixed prices obsolete. Sun Microsystems markets its products using auction sites much like eBay, and "we've been very pleased with the results," (McNealy, 2001). The firm is reaching new customers, as evidenced by a third of the sales through Internet auctions being to customers that had never bought from the company before. McNealy's philosophy on marketing by Internet is that the

market sets the price and frees our sales force to focus on the benefits of our product line. We want them out there selling the advantages of our hardware and software architectures, our strategy, and our business practices (McNealy, 2001).

Sun Microsystems has also applied Internet technology to

advantage on the purchasing side. In a recent year, the firm made \$1 billion in procurements via Internet auctions and estimated its savings at 20 percent. McNealy believes the development of a "variety of marketplace models—auctions, reverse auctions, demand aggregation, and buyer's forums—will emerge to handle transactions of all kinds," and that "Internet exchanges will make the supply chain more efficient, speeding up production and delivery, and driving costs down" (McNealy, 2001).

It is revealing to examine FreeMarkets, Inc.'s, approach to developing Internet-based procurement systems for other firms as FreeMarkets is one of the largest firms dedicated to developing on-line procurement systems. FreeMarkets operates as a combination consulting firm and service provider for Internet-based procurements. As a consultant, FreeMarkets helps identify and attract new suppliers for its clients to expand a client's pool of potential suppliers. FreeMarkets also assists clients in developing a detailed, complete requests for price quotes. Finally, FreeMarkets conducts procurement auctions for its clients. These auctions are typically 10 to 20 minutes in length with each bidder seeing all bids, but not the identities of bidders (Hall, 2001).

FreeMarkets supports the captive procurement operations of many large companies

such as Eaton, United Technologies, Quaker Oats, and Owens Corning. An example of a FreeMarkets procurement auction in which a client seeks suppliers for a shipment of plastic automotive moldings illustrates the effectiveness of auctions. The bidding began at \$738,000 and descended to \$585,000 during the 20-minute regular bidding period. Because of interest by suppliers in extending the auction, it continued for 13 overtime minutes. The final bid price was \$518,000. The client had most recently paid \$745,00 for the same shipment of moldings (Hall, 2001). In working with Eaton Corporation, FreeMarkets operated private auctions with suppliers helping Eaton to save three to 30 percent of procurement costs. Stanley Mickens, Eaton's vice president for purchasing, indicated that the software and services provided by FreeMarkets

are enabling us to reach out and find the best suppliers, not only in Ohio or the Midwest but globally. They're shrinking the world of procurement (Weinberg, 2001).

Eaton Corporation's relationship with FreeMarkets has continued to expand, and recently Pavan Pattada, Eaton's global manager of e-commerce, indicated that this relationship is "an integral

part of our efforts to lower our costs and reduce our supply risk." He added that working with FreeMarkets, Eaton

can gain a better understanding of its global spending, and ultimately maximize our opportunities to generate savings and efficiencies that positively impact our bottom line (FreeMarkets, Inc. 2003b).

FreeMarkets' customers are making better purchasing decisions including lower prices and time savings for buyers. These improvements are apparent in FreeMarkets' work with Westinghouse Electric's power generation division in Orlando, Florida. This division, which makes industrial turbines and generators, is headed by Kevin Burns, a Westinghouse vice president and the general manager of the power generation division. Through the auctions conducted by FreeMarkets, the firm spent about 30 percent less than previously for a variety of parts and hardware items. Burns says that

two-thirds of the savings came from competitive pricing on bids and one-third from Westinghouse Power Generation's own operational efficiencies gained by spending less time

researching suppliers and conducting negotiations (Wilder, 1997).

With many new technologies, such as on-line procurement auctions, that have a potential to significantly change organizational processes, it is difficult to evaluate savings gained from applying the technology. This difficulty is especially true in the early stages of applying and integrating technology into ongoing organizations. A general, pervasive agreement is that this technology (procurement auctions) can produce supply chain savings and that a number of companies have reported significant savings. Some researchers, however, have begun to analyze the question of savings. Emiliani and Stec, in particular, have found that on-line auctions do not deliver immediate savings and that savings are often less than initially anticipated. Not surprisingly, they found savings difficult to measure and drew a distinction between gross and net savings. They also identified factors, such as the costs of developing new procedures, training, and software development, that can reduce anticipated savings, especially in the early stages of adopting the technology. A significant point that they make is that on-line auctions do not teach buyers and suppliers how to jointly

solve problems, a process that must be done in any procurement operation (Emiliani & Stec, 2002). Identifying net savings is an area that will continue to be examined as on-line auctions are increasingly used in procurement.

Structuring Auctions to Reduce Costs

It is apparent that Internet-based auctions can assist in the competitive procurement of the inputs to the production of goods and services. Such procurement auctions are often called reverse auctions because the sellers or suppliers are making the bids whereas the buyers make the bids in the more traditional or forward auctions. In such procurements of commodity-type items or services it is frequently necessary to make purchases from a number of suppliers to satisfy total demand. These activities occur when large quantities must be purchased and/or when many of the potential suppliers are small. For example, in procuring regional truck-freight services to support a firm's activities specified on a weekly basis and covering a quarterly period, it may be necessary to use a number of trucking lines. In addition to its necessity, using multiple suppliers is frequently advantageous from the cost perspective (Pugh, 1990).

In procurement auctions, the primary objectives of the

buyer are to minimize transaction costs and to minimize the price paid to the set of suppliers selected. Regarding the first of these cost objectives, it has been noted that

reverse auctions are now a daily occurrence where not only price but shipping, taxes, insurance, and delivery costs are factored into the deal (Mitchell, 2000).

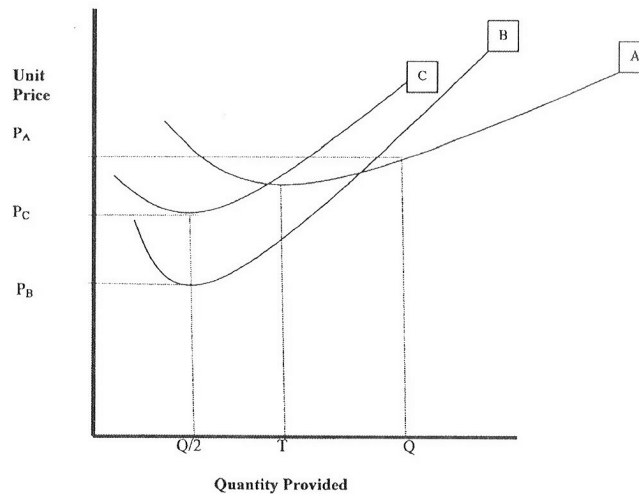
In addition, the buyer's cost function may include the interest costs of funds used to buy in advance of demand, which is a principal component of inventory holding costs. Regarding the second of these dimensions, the buyer must divide the procurement into parts of various sizes so that potential suppliers have an opportunity to bid on parts of the procurement that the suppliers can handle efficiently and, hence, offer at a good price. This latter objective helps to create value across the supply chain, encouraging efficiencies of the suppliers.

While the idea of minimizing supply chain cost within the buyer's organization is clear, the structuring of a procurement so as to solicit competitive bids from suppliers needs closer examination. The rationale for structuring procurements to reduce buyer cost depends on the quantity/

price relationships governing the economic behavior of suppliers. Each potential supplier in a competitive procurement has a cost curve that governs the unit price at which the supplier can provide a specified quantity of a good or service during a specified time period, although the supplier often will not have perfect information on his cost curve. A graph of these cost curves may be thought of as having quantities, Q , of the good or service to be provided on the horizontal axis and the unit price, P , on the vertical axis. Figure 1 shows some illustrative cost curves. These curves are typically concave upward, although not always so. The typical concave upward patterns arise because, for a supplier, some quantity (Q) generally exists that the supplier can deliver at the lowest unit price in a specified period. If Q is significantly increased or decreased, then the unit price will usually increase. From Supplier A's cost curve, in Figure 1, it is seen that the goods and services may have very different cost curves depending on firm size, efficiency, production commitments, and other factors.

As an illustrative example, if Suppliers, A, B, and C, have cost curves as shown in Figure 1 and a buyer seeks to buy Q units of a good or service from these firms at the best possible price, if the buyer requests bids on a quantity Q , then Supplier A will bid a unit

Figure 1
Illustrative Cost Curves



price of P_A for a total price of $Q \times P_A$. This bid will be lower than the bids made by Suppliers B and C, assuming that all suppliers bid in accord with their cost curves. If, however, the buyer divides the procurement into two equal parts of size $Q/2$ and specifies that each supplier can bid on one part or on both, then the results will be different. Now Supplier B will bid a unit price of P_B for $Q/2$ units and Supplier C will bid a unit price of P_C for $Q/2$ units; and while each supplier may make other bids, the buyer will select these two bids with a total cost of $Q/2 \times P_B + Q/2 \times P_C$ to satisfy his or her requirements. The total price of the procurement structured in the second way is clearly lower than the first since the average of unit prices P_B and P_C is less than the unit price

P_A , assuming all suppliers bid according to their cost curves.

A more realistic procurement problem would have a large number of potential suppliers, and the procurement would be divided into a number of parts of various sizes. Structuring the procurement in this way provides each potential supplier an opportunity to bid on a combination of parts that the supplier's firm can handle efficiently and offer at a competitive price. To structure procurements in this way, a buyer must solicit bids that provide information about the supplier's cost curves. This information enables the buyer to purchase quantities from suppliers that each supplier can handle efficiently and at low cost, thereby reducing overall procurement cost. This contributes to the primary goal

of supply chain management to minimize costs (i.e., maximize efficiencies) across the supply chain.

A buyer may structure a procurement and its reverse auction bidding process using two basic approaches.

The first is termed "supplier-structured bids" because of the strong role suppliers play in the bidding process. To initiate a supplier-structured bid auction the buyer indicates the total quantity of the good or service needed and the time period for delivery. The price information in bids may take different forms depending on instructions from the buyer and the suppliers' cost curves. In its simplest form, bids may specify that the supplier agrees to deliver items at a specified unit price for some specified minimum and

maximum size order. Such bids imply that the supplier has a constant unit price or uniform cost curve, or nearly so, over the range of order sizes specified. Given a set of such bids, the buyer can select a least-cost set of suppliers by choosing the set of lowest unit cost bids that meet the demand. The buyer may want to restrict the number of suppliers because of the costs of placing and administering orders.

Another form that bids may take provides a quantity-and-price schedule allowing for a unit price discount for large quantities or for unit price increase for large quantities. From the suppliers' standpoint, quantity discounts are motivated by the savings in marketing and production expenses for large orders. Unit price increases for larger quantities are necessary when unit production costs increase due to labor overtime premiums and other costs related to exceeding normal production levels. In both of these types of quantity-and-price bids (quantity-discount bids and quantity-increase bids), the suppliers' bids reflect their cost curves and the unit cost of production and distribution at various levels of output. From the buyer's perspective, the quantities to be purchased are selected from the bids that reflect the suppliers' most efficient performance and lowest production cost and results in minimizing the cost of buying the product or service.

Under the second approach to structuring bids, referred to as "buyer-structured bids," the buyer takes a stronger role. The buyer begins by dividing the total procurement into a number of *tasks*, in which the division into tasks is based on any appropriate rationale such as task size, task location, or other criteria. The buyer then invites the potential suppliers to bid on jobs, in which a *job* is defined as any combination of one or more tasks. Usually a supplier is allowed to define and bid on as many jobs as he or she chooses. The buyer may impose other rules on the bidding. It may be specified that a job can consist of, at most, a limited number of tasks, say four. Further, if a supplier bids on a job, then he or she must submit a bid separately on each of the tasks making up the job. From the bids received, the buyer selects the set of bids that satisfy the procurement at the lowest cost.

These two approaches to structuring bids define a continuum. In practice, bidding is often structured by a combination of these supplier- and buyer-structured approaches. The most appropriate approach evolves from the buyer's understanding of the market for the item being purchased including the number of potential suppliers, number of likely bidders, the size of the supplier firms, and the degree of competitiveness among the supplier firms.

An example illustrates the basic idea of structuring procurements. If it is assumed that a buyer has a requirement for 3,000 units of an item and that suppliers are requested to submit bids in quantity-discount format, bids are made by three potential suppliers as follows.

Bid #1

Fewer than 500, \$5.00 each;
500-799, \$4.90 each; and
800-2000, \$4.80 each.

Bid #2

Fewer than 300, \$4.95 each;
300-499, \$4.90 each; and
500-800, \$4.85 each.

Bid #3

Fewer than 200, \$4.95
each; and 200-1000, \$4.90
each.

To meet the demand for 3,000 units the buyer selects to order 2,000 units at \$4.80 each under Bid #1, 800 units at \$4.85 each under Bid #2, and 200 units at \$4.90 each under Bid #3. As the bids are structured in this case, the buyer must order from each of the three bidders to minimize the cost of the 3,000 units. However, buyers will often want to minimize the number of suppliers to reduce the administrative costs of ordering. If, for this example, it is estimated that order cost is \$400 for each supplier from whom a purchase is made, then the problem solution changes. As seen by inspection, the least cost

solution is to order 2,000 units under Bid #1 at \$4.80 each and 1,000 units under Bid #3 at \$4.90 each. This solution provides a total cost of \$15,300, \$14,500 for the 3,000 units plus \$800 for ordering costs. The initial solution would have a total cost of \$15,660, \$14,460 for the 3,000 units plus \$1,200 for ordering costs.

In conducting procurement auctions, the buyer notifies suppliers in advance of the time of the auction and of the quantities and specifications of the items being purchased. Often, suppliers are certified in advance by the buyer. The time window in which the suppliers can make bids is usually short, approximately 30 minutes, which reduces the possibility of price collusion by suppliers at the option of the purchaser, bidders may or may not be given information regarding bids made by other suppliers. Shortly after the bidding is concluded, the buyer will notify the bidders regarding selection and the obligation they are assuming if they were the selected suppliers.

This procurement problem can be structured as a linear programming model that minimizes the total costs, made up of the cost of the units purchased and the order cost of dealing with each supplier. The model for this example contains 19 decision variables and 28 constraints. This quantitative approach to evaluating bid alternatives captures the

structure of the suppliers' cost curves. The developed linear program could be solved at regular intervals during the bidding process to determine the low cost set of bids, which would be referred to as in the money at that time. Release of this information could enhance the bidding resulting in even lower total procurement costs for the buyer.

The buyer-structured procurement example can also be structured as a linear program. This model, along with the supplier-structured example, demonstrates how auctions may be structured to encourage competitive pricing. Of course, auctions can be structured in a variety of ways. The choice of approaches to structuring an auction depends on the characteristics of the suppliers, such as their size, the level of competitiveness among potential suppliers, and the capacity utilization level in the suppliers' industry.

The technical model formulations for both the seller- and buyer-structured problems are available from the authors upon request.

Conclusions

The need to develop rationales and methods for structuring multi-unit procurement auctions to reduce supply chain costs is growing. Buyers and suppliers need to take full advantage of the efficiencies created by auctions that allow both to

reach broader markets, increase market liquidity, and reduce transaction costs. This need is a direct consequence of the rapid and continuing growth in B-to-B negotiations and transactions supporting the U.S. and world economies and the power of the Internet to facilitate B-to-B transactions. Auctions are a crucial link in realizing the full potential of B-to-B transactions in that auctions provide a rational and efficient means by which buyers and sellers can negotiate the prices for goods and services that are changing hands. A critical aspect of the rationale of structuring procurements is to request bids that provide information on the suppliers' cost curves and to incorporate this information into the decision on the selection of bids. The examples of structuring auctions presented in this article only scratch the surface since the variants of methods for conducting multi-unit auctions are numerous.

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