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Bid evaluation behavior in online procurement auctions involving technical and business experts

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ABSTRACT

Multi-attribute reverse auction-based procurement has been widely used by large organizations. The attributes of the auctioned objects are usually divided into two groups: technical and business attributes. They are reviewed and scored by technical and business experts who act as referees in the bid evaluation process. To analyze their bid evaluation behavior, we built a model for a multi-attribute reverse auction. With correlations between the bid evaluations of the different referee groups across the attributes, the bid evaluation problem is not the usual multi-attribute decision-making problem. We assess the cause–effect relationship that is present, and show that antagonism between referee groups tends to grow over time. We tested how this works with data from simulated auctions. To diminish the potential for antagonism between the two referee groups, we propose a modified bid evaluation mechanism. We also conducted role-playing experiments involving the referee behaviors as a means for assessing the proposed mechanism. Our results suggest that the modified bid evaluation mechanism is beneficial.

1. Introduction

Reverse auctions on the Internet can save purchasing expenses, reduce costs, and benefit auctioneers (Olson and Boyer 2003, Hur et al. 2007). They are widely used for centralized procurement and construction projects of large enterprise groups and government departments. Because the purchased supplies in reverse auctions usually possess multiple attributes, such as quality, performance, service level and price, the focus has typically been on *multi-attribute reverse auctions* (David et al. 2006, Cheng 2008). Also, since there is more than one criterion for bid evaluation, the determination of the winner in a multi-attribute reverse auction is not as simple as when there is only a single attribute such as price. Generally, a bid evaluation process determines the winner. Because some attribute values of the supplies are described in other than quantifiable terms, they need to be initially assessed by using attribute scores (Lin and Chen 2004). Then, the total score for all of the bids can be calculated based on the weighted sums of the scores of all of the attributes. The bid with the highest total score will be the winner of the reverse auction.

Bid evaluation for large construction projects and equipment procurement is professional work for experts. Generally, the attributes for procurement auctions, including large projects and equipment, can be divided into two types: *technical attributes* and *business attributes*. They are usually reviewed and scored by technical and business experts. The two groups of bid evaluation experts have difference objectives and responsibilities to the enterprises that engage them. As a result, they may be cooperative and antagonistic in how they play their roles in the bid evaluation process. Their behavior will affect the fairness of the auction results. From bid evaluation data obtained from real-world enterprises, we found that the antagonism between the two expert referee groups tends to grow as they participate in more auctions. This may affect the perceived fairness of the auctions and cause the procuring organization to experience an economic loss. This research is intended to analyze the behavior of technical and business experts, and to design and assess a new mechanism to reduce antagonism between the groups.

Reverse auctions have studied for a long time (Tunca and Wu 2009), and increasing attention has been paid to the models and mechanisms they use. Wagner and Schwab (2004) surveyed research and applications of web-based reverse auctions. Amelinckx et al. (2008) studied the relationship between sellers and buyers in this context, and Ray et al. (2011a) assessed the efficiency of reverse auction mechanisms when the number of bidders is limited.

Multi-attribute reverse auctions have been a key area of study in the literature (David et al. 2006). Perrone et al. (2010) presented an overview of multi-attribute reverse auctions and discussed the attributes of price and time in product design and development. The *winner determination problem* is a multi-attribute decision-making problem that is interesting due to its computational

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complexity (Sipahi and Esen 2010). In practice, e-procurement auctioneers require information on the standards that must be met for the different attributes of the supplies that are to be procured (Costa et al. 2002, Lai et al. 2004). Then, expert referees score all of the attributes according to the agreed-upon standards for the bid evaluation process. Winner determination is based on the total scores for all of the bids. Ray et al. (2011b) presented a Markov decision process model for the winner determination problem in multi-attribute reverse auctions. Padhi and Mohapatra (2010) solved the problem of bid evaluation with a binary goal programming model, and Hosny and Elhakeem (2012) suggested a novel bid evaluation approach called *optimum markup estimation*.

In recent years, behavioral operations management has become an active research area (Bendoly et al. 2006, Loch and Wu 2007). When the traditional assumption of perfect rationality is relaxed, individual behavior is no longer negligible in the operational performance of any system with human participation (Leeuw and van den Berg 2010). Most of the prior work has been on the behaviors of bidders and auctioneers in auction games (Peters and Bodkin 2007, Onur 2010). Expert referee behavior for bid evaluation has not received much attention. An exception is Rodriguez et al. (2007), who studied referee behavior for conference bidding. The authors conducted a behavioral analysis of bid evaluation in a multi-attribute reverse auction for a Chinese conference (Wang 2010).

To study bid evaluation behavior for groups of expert referees, we adopted a number of empirical approaches in this research. We initially describe a process model for the bid evaluation of multi-attribute reverse auctions. Then, we will discuss problems with the current bid evaluation mechanism, and analyze auction data from an actual organization. To reduce antagonism between the two expert referee groups, we propose a modified bid evaluation mechanism. To verify the effectiveness of the mechanism, we will conduct a role-playing experiment on the behavior of two expert referee groups. The results show that the new bid evaluation mechanism can efficiently reduce antagonism between the two groups, and increase the perceived fairness of the auction results.

Hereafter, Section 2 describes the online procurement process, and our model for multi-attribute reverse auctions. Section 3 discusses problems with the bid evaluation process. Section 4 analyzes the causal relationship among factors and roles in reverse auction bid evaluations, and we present a modified mechanism. Section 5 presents the design and results of a role-playing experiment on bid evaluation behavior, and Section 6 concludes with thoughts on what has been learned in this research.

2. Modeling the online procurement process

2.1. Process background

The online procurement process of large enterprise groups and government agencies can be described as in Fig. 1 flowchart (see Fig. 1). We note the following activities in the process:

- **Procurement initiation.** A firm in an enterprise group proposes a procurement action. The details of performance, quality, and other criteria on the supply items for purchase are submitted to the e-procurement center of the enterprise group.
- **Call tender through the Internet.** Then, the e-procurement center will draft the call tender for supply bids and publish it on the Internet using the website of the enterprise group. Meanwhile, it may inform qualified suppliers by phone or e-mail about the call tender.
- **Bidding.** Once they obtain the appropriate information, interested suppliers will prepare and submit sealed bids via the Internet.
- **Bid opening.** Once the bidding closes, the e-procurement center will review all of the bids. Then, all the qualified bids will be announced via the website. Bids that are not competitive or appropriate will be eliminated. The details of the bids will not not be changed to guarantee fairness and transparency in the auction.
- **Bid evaluation.** After the bidding has finished, two groups of referees will evaluate the bids. These technical and business experts will be separately selected from among experienced engineers and managers of the enterprise group.
- **Scoring technical attributes.** The technical experts will score the technical attributes of the bids received via the Internet. The expert technical referees will not be permitted to communicate with others who are not involved in the process.
- **Scoring attributes.** Simultaneously, the expert business referees will score the business attributes of the bids and also not be in contact with the technical experts.
- **Winner determination.** Once the two review groups have scored the results, the e-procurement center will calculate and rank all bids based on scores from the two referee groups. A winner will be determined, and the result will be announced to on the website.
- **Entering into a contract.** Thereafter, the winner and the buyer will sign a purchase contract.

The above business process is almost paperless and is executed off-site. The low cost of online auction-based bids will attract more bids from different suppliers. Competition in online auctions usually is much fiercer than in traditional auctions. The fairness of the bid evaluation process is an important problem, and one we focus on in this article.

2.2. Bid evaluation model for a multi-attribute reverse auction

The bid evaluation model for multi-attribute reverse auctions such as we are considering is as follows. Assume the auctioned project or supply item has n attributes and they are divided into K groups according to their different kinds of characteristics. Group $k = \{1,\ldots,K\}$ has n_k attributes which are reviewed and scored by the kth group of expert referees. The number of referees in group k is m_k, so:

$$\sum_{k=1}^{K} n_k = n. \tag{1}$$

Assume there are R valid bids for the auctioned project. The score on attribute j in group k of bid r given by the ith referee in group k is $b_{ij}^k(r)$, $j = \{1,\ldots,n_k\}$, $k = \{1,\ldots,K\}$, $r = \{1,\ldots,R\}$, and $i = \{1,\ldots,m_k\}$. If the assigned score range of attribute j in group k is $[Bmin_j^k, Bmax_j^k]$, we can normalize the score by using the following formula:

$$a_{ij}^k(r) = \frac{b_{ij}^k(r) - Bmin_j^k}{Bmax_j^k - Bmin_j^k}, \quad \forall j,k,i,r \tag{2}$$

with $a_{ij}^k(r) \in [0,\ 1]$, for all j, k, i, and r. For attributes in group k, we set attribute j's weight as w_i^k, and:

$$\sum_{i=1}^{n_k} w_i^k = 1, k = 1,\ldots,K, \tag{3}$$

We assume the weights of scores of all expert referees are identical. Then, the total score of bid r for attribute group k marked by the expert referee group k is calculated by

$$C^k(r) = \frac{1}{m_k}\sum_{i=1}^{m_k}\sum_{j=1}^{n_k} w_j^k a_{ij}^k(r), \quad r = 1,\ldots,\ R,\ k = 1,\ \ldots,\ K. \tag{4}$$