European Journal of Operational Research 242 (2015) 1–9

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Invited Review

Multi-attribute online reverse auctions: Recent research trends☆

Long Pham[a,b], Jeffrey Teich[c], Hannele Wallenius[d], Jyrki Wallenius[e,*]

[a] National Economics University, Hanoi, Vietnam
[b] Minot State University, Minot, USA
[c] New Mexico State University, Las Cruces, USA
[d] School of Science, Aalto University, Finland
[e] School of Business, Aalto University, Finland

ARTICLE INFO

Article history:
Received 30 September 2013
Accepted 21 August 2014
Available online 7 October 2014

Keywords:
Multiattribute auctions
Procurement
Bidding

ABSTRACT

This paper provides an updated overview of the rapidly developing research field of multi-attribute online reverse auctions. Our focus is on academic research, although we briefly comment on the state-of-the-art in practice. The role that Operational Research plays in such auctions is highlighted. We review decision- and game-theoretic research, experimental studies, information disclosure policies, and research on integrating and comparing negotiations and auctions. We conclude by discussing implementation issues regarding online procurement auctions in practice.

1. Introduction

Since the late 1990s E-commerce has been changing the way firms do business. E-commerce can be described as business transactions that occur via open-networks, such as the Internet.

Online procurement (reverse) auctions play an important role in E-commerce. The basic principles of such auctions originate from the concept of dynamic pricing and a bidding process to set the prices and determine the allocation of goods/services being auctioned. Auctions always follow a pre-defined set of rules. Two-attribute sealed bid reverse auctions, known as $A+B$ auctions, have been extensively used by US Government agencies over two decades. Online reverse auctions have also been used by a number of large corporations in business-to-business transactions. Many of them have saved millions of dollars through online reverse auction usage in comparison to traditional procurement approaches (for example, Brunelli, 2000; Hohner et al., 2003; Metty et al., 2005; Sandholm, 2013; Sandholm et al., 2006a).[1] It is not uncommon that auctions are run as price-only. Such auctions may not be binding, since buyers want to consider other attributes besides price (ex post). This is not ideal and may lead to problems, since bidders cannot be sure if and when they win an auction.

Despite high expectations, online reverse auctions have also faced criticism and in some cases such auctions have been discontinued after a few initial successful years (Emiliani & Stec, 2005; Gupta, Parente, & Sanyal, 2012; Tassabehji, Taylor, Beach, & Wood, 2006).[2] One of the criticisms is that online reverse auctions only concentrate on the interests of the buyer, while ignoring the interests of the suppliers. Buyers may also exhibit resistance to change for various reasons (Peng & Calvi, 2012)[3] . It is true that long-term relationships between buyer and supplier can be damaged, if price is the sole priority of the buyer (Jap, 2007).[4] Gupta et al. (2012) analyze the reasons why initially successful procurement auctions for health insurance contracts in the US were discontinued in early 2000. The authors conclude that the fault lay with the design and implementation of the auction mechanism. The bidding was price-only. How the different attributes were weighted by the buyer was not explicitly told to the sellers. Another concern was that full disclosure of bids might have hindered bidder participation. In order to overcome this criticism, new auction mechanisms that take non-price attributes, such as quality, delivery and payment terms explicitly into consideration have been suggested. Also in multi-attribute settings, it is important to provide incentives to losing bidders to maintain their future interest in a business relationship (Ray, Jenamani, & Mohapatra, 2013).

Several commercial software vendors provide platforms for conducting such auctions (e.g., Perfect, Ariba, CombineNet (acquired by SciQuest), Bravo Solution, Epicor, Digital Union, TradeExtensions,

☆ The authors wish to thank two anonymous reviewers, whose comments and suggestions considerably improved the paper. The research was supported by the Academy of Finland grant number 253583.

* Corresponding author. Tel.: +358 40 3538100.
E-mail address: jyrki.wallenius@aalto.fi (J. Wallenius).

[1] The Mars Inc. procurement auctions were discontinued after a few years.

[2] Interestingly, Snir and Hitt (2003) point out that many auctions, despite active bidding, do not result in a contract. The auction literature is surprisingly silent on this (Carr 2003).

[3] Another concern is sellers' collusion. We do not cover this topic, however.

[4] Foroughi et al. (2007) identify a number of variables that can be used to study the design and use of electronic reverse auctions.

http://dx.doi.org/10.1016/j.ejor.2014.08.043
0377-2217/

and Negometrix[5]) known as Multi-Attribute Online Reverse Auctions (MAORAs).

In the academic literature, quite a bit of attention is being paid to MAORAs. The objective of this paper is to gain a deeper understanding of MAORAs and how to implement them. This is achieved through a state-of-the-art literature review of articles published in academic journals. Only in exceptional cases have we cited conference papers. We have used both google scholar and web of science (ISI) with a variety of keywords to aid us in finding all recent and relevant references. Our focus is on recent trends in this research, mainly iterative reverse auctions. We deal with issues such as buyer– seller relationships and information revelation, among others. We only briefly comment on the state-of-the-art in practice. The auctions that we discuss are primarily targeted for human users and not software agents, although many of the auction formats allow humans to use a (computerized) proxy. Our paper builds upon Teich, Wallenius, Wallenius, and Koppius (2004).

The rest of the paper is organized as follows. To lead the way to more complex multi-attribute auctions, the two-attribute A+B auctions are briefly covered in Section 2. Section 3 presents a classification of online multi-attribute reverse auctions. A general description of MAORAs is provided in Section 4. Important preference elicitation schemes are reviewed in Section 5. Research trends in MAORAs over the last decade are described in Section 6. The paper concludes in Section 7. A short glossary is provided to aid the reader with the terminology.

2. A+B auctions

A+B auctions, also known as cost/time auctions, are two-attribute sealed bid procurement auctions, where bidding takes place on cost (A) and time to deliver (B). Such auctions have been described by Ellis and Herbsman (1990), Herbsman and Ellis (1992), and Herbsman (1995). The A part of the equation is the bidder's cost and the B part is the estimated time, which is then multiplied by the Road User Cost (RUC) in highway construction projects. The RUC incorporates attributes such as "traffic delays (time, distance) and agency costs, such as inspection, and other elements" (Herbsman, 1995). The winner of the auction has the "lowest combined bid" which incorporates the actual cost of the project (A) plus the cost of the time of the project ($B \times$ RUC). If the project is not completed by the contractor's time estimate, then the contractor may be penalized by the number of days late $\times$ RUC, and likewise, if the project is completed early, there may be an incentive, i.e. days early $\times$ RUC (Herbsman, 1995).

Herbsman (1995) claims that these cost/time bidding systems have been used since around 1980 by early users such as the US Army Corps of Engineers. In 1991, the US Federal Highway Administration encouraged the states' Departments of Transportation to begin experimenting with these auctions (Herbsman, 1995). The success of the $A + B$ auctions in highway construction projects is pretty clear. Herbsman (1995) compared 101 projects using this bidding system to projects where only the lowest bid was awarded. He concluded that in most cases there were savings in construction time costs without additional project costs themselves. More recently, Gupta, Snir, and Chen (2014) report similar results based on 38 projects of the Minnesota Department of Transportation. Additionally, similar results were reported by Lewis and Bajari (2011) based on over 1300 projects awarded by the California Department of Transportation.

[5] If one compares this list with that provided in the Teich et al. (2004) article, one notices that consolidation has taken place in the marketplace. Moreover, several companies who were early players, no longer are in business.

3. A classification of online multi-attribute reverse actions

An auction is a common name for transactions where the price is discovered through a competitive bidding process.[6] An auction determines how the winner is determined, how the payments of the winning bidder(s) are determined, and how the bid information is collected from the bidders. Auction literature recognizes four basic mechanisms, which are most commonly used: the English auction, the Dutch auction, the first-price sealed-bid auction, and the second-price sealed-bid auction (also known as the Vickrey auction). These basic mechanisms are special cases of the generic mechanism. For a discussion and definitions see Milgrom (2004), Parsons, Rodriguez-Aguilar, and Klein (2011), Teich et al. (2004).

The basic mechanisms, although originally defined for single item and price-only auctions, can be extended to more complex settings, e.g., settings with multiple attributes. Interestingly, most auction mechanisms used in practice contain elements of one or more of the four basic mechanisms.

Teich et al. (2004) provide a comprehensive classification of auction situations based on 18 characteristics. The first four characteristics concern the number and nature of the good(s)/services to be auctioned. Characteristics 5–14 deal with the auction rules and format. Characteristics 15–18 are related to the nature and composition of bids.

(1) Number of items of a good/service auctioned
(2) Number of goods/services auctioned
(3) Nature of goods/services (homogenous, heterogeneous)[7]
(4) Number of attributes
(5) Type of auction (forward, reverse)
(6) Nature of auction (one-round or progressive)
(7) English vs. Dutch auction (ascending vs. descending price)
(8) Who can participate (by invitation vs. open to anybody)?
(9) Are agents used or not?
(10) Price paid by winner (first price, second price, etc.)
(11) Is price discrimination applied (yes or no)?
(12) Do constraints exist (explicitly, implicitly)?
(13) Is there a follow-up negotiation?
(14) Is a value function elicited for the buyer?
(15) What is the nature of bids (open cry, semi-sealed, sealed)?
(16) Dimensionality of the bid vector (1, 2, or n-dimensional)
(17) Are bids divisible?
(18) Are bundle bids allowed?

We concentrate on the online single-lot (contract) and not-single lot reverse English auctions with multiple attributes. A single-lot auction often refers to a contract, for example building a bridge or a highway stretch (with specified qualifications). The single-lot auction typically has multiple units of a product supplied by only one supplier. The not-single-lot auction includes multiple winners in the event. Hence the key demarcating feature is the number of winners.

4. A generic description of MAORAs

We consider a situation where the buyer makes an announcement that she would like to organize an auction for contracts or acquire a given quantity of a good/service and asks (invited) suppliers to submit their bids based on k attributes of the item. A bid vector consists of k dimensions. This usually includes price and the level of each of the other attributes. If quantity is relevant, it should be treated separately, since it is by nature different from the other attributes. Ceteris paribus,

[6] Negotiations are not considered as auctions, although auctions may incorporate features of negotiations.

[7] Strictly speaking, homogenous goods do not have quality differences. However, they may be of interest for MAORAs because of differences in delivery terms and warranties. A contract usually defines such terms.