

A Practical Approach to Multi-Attribute Auctions

Birgit Burmeister, Tobias Ihde

*DaimlerChrysler AG,
Research Information and Communication
Manufacturing and Supply Nets (RIC/EN)
Alt-Moabit 96a
D-10559 Berlin, Germany
{birgit.burmeister | tobias.ihde}@dcx.com*

Thomas Kittsteiner, Benny Moldovanu,
Jörg Nikutta

*Consulting Group Prof. Moldovanu
c/o Universität Mannheim
Lehrstuhl für VWL, insb. Wirtschaftstheorie
D-68131 Mannheim, Germany
{tkittste | mold | nikutta}@
uni-mannheim.de*

Abstract

In most electronic auctions conducted over the Internet today price is still the only decision criteria for the best bid. This is true for all sorts of auctions in the electronic business areas consumer-to-consumer (c2c), business-to-consumer (b2c), and business-to-business (b2b). Especially for many situations in the b2b area there are other important attributes apart from price to be considered for decision making. Therefore the area of multi-attribute auctions gains more and more interest in the scientific community as well as from software vendors of electronic business products. But the approaches offered so far suffer from some limitations. Theoretical approaches are not applicable to (b2b) real world scenarios, commercial software does not cover all situations. To overcome these limitations we developed a practical approach to multi-attribute auctions, that will be presented in this paper.

1. Introduction

A plethora of internet auction houses and marketplaces exists for consumer-to-consumer (c2c), business-to-consumer (b2c), and business-to-business (b2b) auctions. Different auction types (English, Vickrey) are supported for seller or buyer auctions (reverse auctions). For most of these electronic auctions price was and still is the only decision criterion for determining the best bid.

But especially in the area of b2b e-business price is not the only important attribute to consider in the decision making process [1], [2]. Other attributes related to the product and/or to the supplier should also be taken into account. Thus taking price as the only bidding parameter

in an auction leads to lengthy manual pre- and post-processing for the auctions. Therefore the electronic procurement process can be improved by considering other attributes apart from price in the auction. Although different names are used to describe this type of auctions, we will call them “multi-attribute auctions”.

The problem in multi-attribute auctions is to find out which bid is the best one. This problem cannot be solved by simply comparing one variable, as it is the case in single attribute auctions, where the bid with the highest/lowest price is the best. In a multi-attribute auction a combination of variables has to be considered to find out which bid fits best the auctioneer's requirements. For a bidder it is also not easy to bid in a multi-attribute auction: he has to adapt his bid to the attributes and possible valuations of attributes in order to beat the leading bid.

Our main interest lies in the area of b2b auctions. Since DaimlerChrysler has carried out a number of electronic auctions for the procurement of various goods, for the rest of this paper we will concentrate on reverse auctions.

DaimlerChrysler started in 2000 to use electronic reverse auctions in the procurement process. These auctions, or Online Bidding Events (OBEs) as they are called, are carried out over the COVISINT platform, the e-business marketplace for the automotive industry [3]. The OBEs are no real auctions, since the decision making for the best bid is not completed during the on-line process, but is made off-line after the process. The OBE is used to fix the price for the good purchased. In 2002 DaimlerChrysler handled a procurement volume of over 10 billion Euro in over 500 OBEs for non-productive as well as productive material [4]. This shows that OBEs are an important tool in the procurement process and are

widely used in the company. But as mentioned above price is the only attribute considered during the event.

2. Relevant theoretical and commercial approaches

Auctions have been successful mostly because they are simple and stable. Thus to gain wide acceptance the usage of multi-attribute auctions has to be simple and the auction mechanism should be trustworthy for the initiator. Since using an auction obliges him to accept the winning bid, he must be sure that the winning bid is the one he considers best. Several theoretical approaches to this problem exist. The approaches with the most relevance seemed to be the lexicographical order approach, the direct ratio technique, and theory of multidimensional auctions.

The lexicographical order approach, where the attributes are put into a hierarchical order, is too simplistic. The direct-ratio technique on the other hand, where the attributes are ranked according to their "importance" for the buyer, is considered theoretically weak.

Works in multidimensional auctions are [5], who analyses different scoring rules combining bids on price and quality in a quasi-linear environment; and [6], who generalized the model by Che [5] and allows for cost correlation. Both approaches suffer from pre-conditions that do not hold in most real-world applications and are also restricted to two-dimensional (price, quality) cases.

The "multi-attributive utility functions" approach as introduced in [7] aims at the n-dimensional case. Although looking quite elegant, the approach also has several limitations, concerning theory and practice.

For theoretical correctness preferential independence is a necessary precondition for using additive multi-attributive utility functions.¹ Unfortunately, preferential independence is rarely met in real world procurement situations. If the decision criteria are not preferential independent, the additive model cannot be applied [8]. Moreover, if the number of alternatives is huge, there is no easy reliable way to ensure that preferential independence is given [9].

Concerning practicability, the approach poses two problems: optimization and strategy. First, suppliers face a new optimization problem; they have to maximize their own profit function and the utility function simultaneously. This optimization problem must be solved within the duration the auction process. Hence

further acceptance problems from the suppliers' side may arise.

Second, strategic considerations may be important. For instance, announcing a wrong utility function can be quite useful for the purchasing agent: under-rewarding quality to price may lead to better prices from high quality suppliers. On the other hand, utility functions may be quite confidential, a point often passed over too quickly in decision analytical literature.

Finally in [10] several approaches for auctions and market algorithms that incorporate multi-attribute aspects are described. Most of the paper deals with multi unit auctions where a given quantity of goods has to be procured from several sellers. For the case of general attributes Teich et al. suggest an auction mechanism in which the seller prescribes a so called preference path (i.e. an ordered set of combinations of prices and specified attributes). Bidders increase their bids by accepting a combination that is more preferred by the auctioneer than that combination previously accepted by some bidder). The drawback of this method in comparison to the one suggested below is that bidders are quite restricted in what they can bid (i.e. they are only allowed to bid on the preference path). In particular as along the preference path price and specification of attributes change a bidder is not able to compete by only lowering the price, which discriminates bidders who are restricted to certain specifications.

On the other side of the spectrum of existing approaches a growing number of vendors of sourcing systems provide ad hoc solutions for multi-attribute auctions. These approaches also have certain shortcomings and are definitely not suitable for all situations.

The commercial approaches found to date can be roughly classified into two groups:

- The weighted-sum approach, where parameters or attributes of the goods are associated with some numerical or non-numerical weight. The best bid is the one with the best value for the weighted sum. Examples are systems like B2eSourcing [11], LiveExchange [12], and MarketProcess [13]. Attaching numerical weights to the different parameters might be difficult for the user. Using some fuzzy representation of the weights as demonstrated by e.g. perfect.com [14] seems to overcome this difficulty. Nevertheless the attributes are weighted independently, so possible relations between different attributes can not be expressed.

Cp. [9], p. 115-118.

This approach corresponds to the theoretical direct-ratio technique mentioned earlier.

The total-cost approach, where all parameters have monetary values or can be associated with some monetary value. The bid with the best total cost (i.e. lowest for reverse auctions) is the best bid. This approach is mainly usable when monetary values can be easily attached to parameters or calculation of monetary values is not too complicated. Examples for this approach are the systems eBreviate [15], e-Source [16] or the Portum auction engine [17].

3. A practical approach to multi-attribute auctions

Due to the limitations of theoretical and commercial approaches we developed a new idea to tackle the problem.

The main idea of our approach is to bundle relevant combinations of attributes into packages. The buyer, who defines the packages according to his needs, has to specify the value he assigns to each package as a whole. This frees the buyer from assigning a value to each attribute individually. From the valuation for each package, an "on-target index" is calculated for each package that reflects how close the package matches the most preferred (ideal) package. In the auction this index is used to "normalize" bids for different packages and make them comparable. Thus in our approach a bid consists of a price and a package that the supplier is willing to deliver for this price.

A *package* is a detailed specification of the good, i.e. every attribute is precisely specified (hence a package consists of one good defined by specified attributes). In a Multi-Attribute Package Auction (MAPA) the initiator of the auction has to specify not only one good, but several packages that he is willing to accept. Even though the theoretical number of packages can be quite large if numerous specifications of attributes are acceptable, in practice the auctioneer will restrict the auction to a small number of relevant packages. For each package he has to give an *on-target index*, i.e. a percentage of how close the package comes to the most valuable package. (Other definitions of the on-target index are feasible, e.g. the on-target index of a given package can be calculated as its absolute (monetary) difference to the most preferred package. The appropriate definition has to be chosen according to the buyer's preferences. Since the aim of this paper is to illustrate the multi-attribute package approach, we restrict attention to relative bid- and on-target-indices as described above.)

Especially this last part has to be conducted with care. The initiator might know which package he prefers, but he also has to express this difference in monetary terms. The process of assigning the on-target indices can be divided into the following steps:

1. Defining the objective package

The goal is to identify the most preferred package, which is called *objective package*. By definition, this package has an on-target index of 100%.

2. Identifying further acceptable packages

Every identified package must be acceptable to the initiator. If packages are defined by a set of attributes, the initiator selects the combinations of attributes which are acceptable to him.

3. Finding the on-target index for each package

The correct on-target index t_i for each package i is given via the money equivalent m_i for each of the packages relative to the money equivalent of the objective package m_{obj} , i.e.

$$t_i = m_i / m_{obj}$$

A *bid* consists of a price p for a package i . It states the bidder's commitment to supply the good as specified in package i for the price p . A valid bid would be 'EUR 100 on package 1'. Given a bid 'price p for package i ' and the on-target index t_i for package i , the corresponding bid-index g is calculated via the formula:

$$\text{Bid-index} = (\text{price}) / (\text{on-target index}), \text{ i.e. } g = p / t_i$$

Note that a price for the objective package (which has an on-target index of 100%) is also its bid-index.

Even though the described procedure can be implemented in a number of different auction formats a multi-round auction is particularly suited. This ensures active bidding of all bidders during the auction process. Thus preventing strategic "last minute" bidding which is commonly observed in "regular" auctions and often distorts the auction outcome. The bidding process is organized in subsequent rounds where, in each round, every bidder submits at most one bid. After bidding in each round is over the resulting bid-indices are compared and the leading bidder determined, i.e. the bidder with the lowest bid-index. The auction continues with the next round or ends. Each round consists of the following three steps:

1. Announcements at the beginning of a round

Last round's leading bid and the resulting maximum price for each package are announced. The leading bidder is informed that he does not have to submit a bid in this round.

2. Bidding

Each still active bidder can submit one valid bid until the bidding time for this round expires. This means that the bidding price has to be below or equal to the maximum price for the corresponding package.

3. Evaluation of bids

Bids are translated into bid-indices which are then ranked. The supplier with the lowest bid-index is the leading bidder. If more than one supplier submitted a bid that translates into the lowest bid-index, the time of submission is taken into account. The maximum prices for the next round are given by the lowest bid-index reduced by some smallest decrement. If no bids were submitted, the auction ends and the leading bidder is the winner of the auction. His last bid determines the price and specifications of the good.

The described auction module and format can also be used to evaluate suppliers with different properties willing to deliver a uniquely specified good. The attributes are then found on the supplier side and not on the object side. Obviously the supplier's bid is an important parameter in procurement decisions, but it might not be the only one. Different suppliers have different merits and advantages, e.g. past experiences or reliability. Even if a supplier asks for a higher price, it might nevertheless be worthwhile to accept his offer. To make different suppliers comparable it is necessary to identify desired properties. For each property, e.g. past record, quality management etc, the supplier is awarded a score which reflects the supplier's strength. Similar to the MAPA each supplier's bid is translated into a bid-index according to the supplier's score (which is 100% if he is the most preferred supplier).

Concerning this Multi-Attribute Supplier Auctions (MASA) our approach is comparable with the ideas described in NegotiAuction [18]. They also aggregate several supplier attributes into a bidder (i.e. supplier) ranking. For different ranks so called bid-premiums are defined, that lead to bid penalties for non-top bidders.

4. Conclusion

Electronic bidding and auctions that take into account multiple attributes and parameters apart from price will be the next step in online auctions in real world b2b e-business.

The theoretical work analyzed so far is not applicable in most real world cases. Nevertheless a number of software vendors offer products with pragmatic approaches to the problem of identifying the best bid in a multi-attribute auction. For most of these approaches the problem of (in)transparency for the supplier exists. In

case the attribute weights are private to the user, a supplier with a bad rank cannot see why he had received such a bad position. So the decision process is not transparent for him. Transparency is a core prerequisite for supplier to take part in online auctions. On the other hand publishing the parameters and their weights or monetary valuations may give the supplier insights to private data of the potential buyer.

Due to the problems mentioned above we presented a different approach to multi-attribute auctions. The "package-oriented" approach seems to be very practical. It reduces the choices of combinations of attributes for buyer and supplier to the ones really relevant. Assigning valuations to these packages seems to be much more adequate for the buyer than other existing theoretical or commercial approach that were sketched in this paper.

Therefore the approach will be further evaluated with the background of practical requirements from the procurement organization of DaimlerChrysler.

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