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Designing multi-attribute auctions for engineering services procurement in new product development in the automotive context

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ABSTRACT

In recent years, use of multi-attribute auctions has been consolidating as a powerful mechanism in procurement settings where multiple drivers affect the transaction outcome. This paper provides a project management approach for multi-attribute auction design for standardized engineering services procurement in the context of new product development in automotive industry. Two variables are taken into account in the bidding process: price and duration of the given engineering activity. From a theoretical viewpoint, we fully determine optimal suppliers' bidding strategies and expected outcomes, i.e. score/utility, price and duration, for the buyer under both first score sealed bid and second score sealed bid auctions. We show that this two schemes are equivalent in terms of score/utility even in presence of multi-dimensional suppliers' private information. Therefore, they could be used interchangeably. Under a specific score function, we also perform a simulation showing that: (i) auction expected outcomes for the Main Contractor are very sensitive when duration reduction is a critical issue and (ii) number of bidders affects score and price but not duration.

1. Introduction

Procurement auctions have become enormously popular in recent years as a result of the emergence of Internet-based transactions (Smeltzer and Carr, 2003; Kalagnanam and Parkes, 2004; The European E-Business Report 2006–2007). From the pioneering use of Web auctions developed in 1995 by General Electric, several big companies such as Procter & Gamble, General Motors, Westinghouse and Whirlpool have been using internet auctions for procurement purposes. Internet has in fact opened up new opportunities for industries, such as electronics, grocery and automotive, where use of procurement auctions was not so common. It has also served as a tool for auction process automation in sectors, such as construction, government, where procurement auctions have always been a major mechanism to exchange goods and services.

Across all the sectors online procurement auctions have been widely conducted by buyers as a mechanism for lowering purchasing costs. Auctions for procuring commodities and MROs still account for the highest slice of the total electronic procurement market. In this context, buyers usually chase only a low price, whereas other variables, e.g. lead-time, quality level and payment conditions, are specified just as a transaction requirement. However, in case of more valuable and less standardized items or when lead-time is a critical factor, the buyer might be interested in purchasing a higher quality product at higher price rather than a lower quality product at lower price or might be willing to spend more for a shorter delivery time. If, for this category of goods/services, issues, such as quality and lead time, are not included in the bidding competition, the buyer may risk to "miss" the other possible value drivers or negotiate them subsequently with a waste of time and resources (Chen-Ritzo et al., 2005). For such a reason, in recent years, use of multi-attribute auctions has been consolidating as a powerful mechanism in procurement settings where multiple drivers, and not only product price, affect the transaction outcome. In their review, Teich et al. (2004) point out that nowadays in numerous successful websites, such as Ariba, CombineNet, Emptoris, FreeMarkets, buyers and sellers are involved in auctions or automated tenders where bids always incorporate multiple transaction attributes, e.g. quality, delivery time, warranty and payment conditions. Furthermore, interest (and need) from e-procurement companies in designing novel multi-attribute auction mechanisms is always growing. For instance, Beil and Wein (2003) have built their work on discussion with the Chief Technology Officer of Frictionless Commerce, who was seeking help with designing a new automated eRFQ (*Request for Quotation*) mechanism.

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1.1. Research motivation and questions

Despite the increasing popularity of multi-attribute auction mechanisms, the number of theoretical works on the topic is still restricted and numerous issues are far from being fully investigated. The opportunity to bid on multiple attributes makes, in fact, the analysis of bidding strategies and the issue of auction design very complex. So far interesting analytical results are obtained under restrictive assumptions, such as mono-dimensional private information of bidders or myopic bidding strategy (Che, 1993; Beil and Wein, 2003). Furthermore, the existing literature focuses on auctions under general procurement setting, which if, on one hand, provides a general framework for approaching multi-attribute auctions, on the other hand, may fail to capture specific aspects arising under specific procurement setting, i.e. suppliers' cost structure and/or specific buyer's needs, making the auction design less effective in terms of predictive effectiveness.

This paper moves, from a theoretical perspective, on the direction of extending current results by considering further features in multi-attribute auction design and, from a practical perspective, on the direction of addressing such an issue in a specific setting. Specifically, this work is based on a research project jointly conducted with Elasis S.C.p.A., the engineering company of FIAT Group, aiming at developing a web-based ICT platform to support engineering supply chain creation and management within the new product development project. Without going into details of other aspects of the project, one task has been related to the analysis of potentials, and subsequent design, of internet-based multi-attribute auctions for suppliers selection, engineering services procurement and collaborative engineering project planning.

Use of multi-attribute auctions for engineering services procurement is motivated by the absolute relevance of non-price attributes in the context of new product development. In a *time-based competition* environment such as the automotive industry, indeed, firms' competitive advantage and profitability strongly depend on how able firms are to shrink more and more the duration of the new product development process (Stalk, 1988; Clarke and Fujimoto, 1991; Hendricks and Singhal, 1997; Droge et al., 1999; Kessler and Chakrabarti, 1999). In addition to lead-time, product quality and performance level also matters for a successful new product development. Overall performance of new product development activities actually depends on tradeoffs among cost, lead-time and quality (Cohen et al., 1996; Swink et al., 2006).

However, as better explained in the next section, an auction may be a suitable mechanism for engineering services/activities that are standardized or whose transaction outputs do not critically affect performance of final product. For such a category of activities, quality/technical parameters, e.g. tolerances of CAD (Computer Aided Design) outputs are either imposed as a contractual requirement or regulated by standards and can be managed outside the auction mechanism through a pre-qualifying process. Therefore, for this kind of activities the cost–time trade-off becomes the major aim. One could argue that, when reducing the lead-time matters, firms could set the shortest feasible duration for the given activity as a contractual requirement and still use a price-based auction. However, this procedure leads to sub-optimal outcomes just as the opposite procedure, i.e. requirement of the longest activity duration, since the unavoidably existing trade-off between cost and lead-time is not explicitly considered. Indeed, if suppliers cannot bid on the activity duration, transaction price is likely to be high or low depending on the required duration. On the other hand, a multi-attribute auction mechanism incorporating the lead-time as a further issue for suppliers' selection more suitably addresses the cost–time trade-off and, therefore, allows firms to reach a higher overall performance.

Furthermore, a multi-attribute auction mechanism can contribute to realize a collaborative planning for the category of standardized engineering activities better than a price-based auction since it allows to involve suppliers in determining more project planning variables, i.e. duration and cost. Advantages of using multi-attribute mechanism are, in fact, also associated to reliability issues. For instance, by asking suppliers to propose a delivery time in addition to price, firms are able to get more accurate information on current time performance of suppliers. The issue of planning variables reliability is of great relevance in new product development process. In fact, most of the crucial decisions are made at a very early stage of the project in presence of scarce and incomplete information. The lack or low reliability of information at the beginning, often, forces firms to review the planning several times during project execution because the project needs a longer completion time and/or allocated budget is not sufficient. Supplier involvement in determining variables, such as activities cost and duration, can contribute to improve reliability of project planning at early stages and, as a result, reduce number and effort of subsequent changes.

In sum this paper provides an approach for multi-attribute auction design for engineering services procurement in new product development. A primary goal in auction design is, from a buyer perspective, to analyse outcomes of several auction schemes in order to choose the best scheme and the best rules for the bidding process, while, from suppliers' perspective, to properly formulate a potentially successful bid for a given auction scheme. One important issue is about the modelling of agents' structure and behaviour in a price and time based auction. We recur to Project Management (PM) concepts to characterize cost–duration relationship for a given activity and, overall, define suppliers' cost structure. To the best of our knowledge, PM has never been applied for auction modelling. However it seems to be very appropriate since it synthesizes all the relevant elements characterizing a project-oriented context such as the new product development process and allows us to answer to the questions regarding the suppliers' optimal bidding strategy and the expected outcomes for the buyer, i.e. score/utility, price and duration, under two multi-attribute schemes, i.e. first score sealed bid and second score sealed bid auctions. From a theoretical viewpoint, we show that these two schemes are equivalent in terms of score/utility even in presence of multi-dimensional suppliers' private information. Therefore, they could be used interchangeably. We also perform a simulation to study impact of score function parameters and number of suppliers on auction expected outcomes by showing that (i) auction expected outcomes for the buyer are very sensitive when duration reduction is a critical issue; (ii) number of bidders affects score and price but not duration which, rather, very slightly increases if more suppliers are invited to the tender.

The paper is organized as follows. In Section 2 the context of automotive engineering in new product development is widely discussed whereas a literature overview on both auction and multi-attribute auction theories is presented in Section 3. In Section 4 the model is set up and analysed whereas in Section 5 we report and discuss numerical results from simulation. Finally the paper ends in Section 6 with discussion, conclusions and future developments.

2. The context of automotive engineering in new product development

Within the development process of a new automobile, the engineering phase includes the design, engineering and testing