AUCTION AND NEGOTIATION MECHANISMS FOR MULTI-ATTRIBUTE E-PROCUREMENT TRANSACTIONS

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AUCTION AND NEGOTIATION MECHANISMS FOR

MULTI-ATTRIBUTE E-PROCUREMENT TRANSACTIONS

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Abstract

This study focuses on mechanism design in order to solve multi-attribute e-procurement problems. In particularly, this study addresses two realistic requirements in mechanism design: (1) specifications of request/proposal on multiple attributes, and (2) incentive compatibility on information exchange/disclosure. Taking into account the needs and emergence of advanced mechanisms in e-procurement, this study presents a generic process model for the design of two feasible classes of mechanisms: multi-attribute reverse auctions and multi-attribute multi-bilateral negotiations. It allows buyers to control preference representation and information revelation, assuring that suppliers obtain sufficient information in making effective proposals while protecting confidential information. Then, it defines a set of design parameters that can be used to design and implement variants of specific mechanisms in these two classes of mechanisms. This study has implications to the research and practice in e-procurement by providing a systematic approach in designing multi-attribute mechanisms and addressing specific business requirements and strategic concerns.

Keywords: E-procurement, Multi-attribute auction, Multi-bilateral negotiation, Mechanism design, System design, Information revelation.
1 INTRODUCTION

Successful management of purchasing activities depends not only on selecting the right product or service but also on choosing the best method of buying them (Handfield and Straight 2003). These methods are determined by procurement mechanisms, which comprise rules governing and facilitating the transaction processes (e.g., catalogues, auctions, negotiations). This study focuses on multi-attribute procurement mechanisms wherein price and other attributes need to be determined during the transaction process, particularly through auctions and negotiations.

In procurement, auctions are reversed; the suppliers bid against each other and the highest bidder obtains the contract from the buyer. Most auctions are concerned with a single attribute, typically price. However, organizations are also often interested in values of attributes other than price. A survey by Ferrin and Plank (2002) found that over 90% of purchasing managers based their decisions on both price and non-price variables (e.g., durability, service, lead-time, and trust). Typically these types of decisions have been made through a sequence of bilateral negotiations; procurement managers negotiated with one supplier at a time and made a decision to award the contract or engage in negotiation with another supplier. More advanced and suitable mechanisms than traditional single-attribute reverse auctions (SARA) and bilateral negotiations are needed in order to determine the best one from among many suppliers.

A recent survey on auction mechanisms called for the design and implementation of multi-attribute auction mechanisms (Kagel and Levin to appear). Several approaches in dealing with auctions when multiple attributes are involved have been proposed. Some aim at combining price with the total costs of all non-price attributes, others in aggregating all attributes into utility functions. Each of these mechanisms has either theoretical or practical limitations such as disclosure of buyer’s preferences, limited number of attributes, collusion and unethical activities.

Negotiations allow the use of price as well as other issues wherein the value of the issues is agreed upon by two or more parties. Information technologies enable buyers to engage in simultaneous, rather than sequential, negotiation with multiple suppliers over the same goods or services, utilizing competition and realizing a surplus in a manner similar to auctions. Stenbacka and Tombak (2012) model both forms of negotiations and show that sequential negotiation yields lower efficiency than simultaneous negotiations. Few studies, however, have discussed the design and implementation of multi-attribute multi-bilateral negotiations (MBMN) as well as multi-attribute reverse auctions (MARA), which deal with similar procurement problems.

In practice, organizations need to select and possibly adapt the mechanisms to suit their particular procurement situation (Handfield and Straight 2003, Kraljic 1983). In many situations, however, the different mechanisms may be used for the same types of transactions. For instance, both reverse auctions and negotiations have been suggested and adopted in the “leverage” transactions (Bajari, et al. 2009, Kaufmann and Carter 2004, Subramanian and Zeckhauser 2004). Advanced mechanisms such as multi-attribute reverse auctions may be used in solving problems in which formerly, only negotiations could have been employed, thus increasing procurement efficiency. Similarly, multi-bilateral negotiations may be used in the situations where traditionally auctions have been adopted. To-date, however, little effort has been put to examine such emergence.

Most of the guidelines for mechanism selection are normative such as transaction cost theory (Williamson 1979). They consider general strategic use (e.g. outsourcing, integration, spot buying or reverse auctions) rather than the detailed characteristics describing the market and organization with the procurement process. In contrast, experimental economics and market design (Milgrom 2000, Smith 2003) have approached mechanism design with detailed parameters and contextual factors. This provides an avenue to explore mechanism selection through experimental studies.

The aim of this study is to present effective mechanisms for multi-attribute e-procurement transactions. In particular, it attempts to provide: (1) a generic model and a set of parameters in guiding mechanisms design; (2) an approach to designing and implementing emerging mechanisms; and, (3) two types of mechanisms that are distinct but have the possibility to build a continuum of
mechanisms to address specific requirements and strategic concerns. It allows for the consideration of the needs and incentives of both the buyers and suppliers in terms of the information revelation and exchange during procurement process.

The rest of the paper is organized as follows: Section 2 reviews the role of information in auction and negotiation mechanisms. In Sections 3, a generic process model is presented, followed by a set of design parameters and variants of mechanisms. Section 4 discusses the implications and possible extensions of this study for practice and future research.

2 INFORMATION IN MECHANISM DESIGN

The specification of information that mechanism users provide to and obtain from each other is one of the key aspects of mechanism design. Hence, mechanisms vary in terms of the information types and rules, i.e., who knows what at what time (Farrell 1987, Ströbel and Weinhard 2003).

2.1 Information types and rules in auctions

In auctions, the type of information that the mechanism accepts from and returns to bidders is structured and known to them. It is also made available to all bidders at the same time (McAfee and McMillan 1987). Auction mechanisms require that the rules are explicit, complete and fixed for the duration of the process (Kersten, et al. 2008).

Auction mechanisms need to provide information about the buyer’s preferences so that the suppliers can make progressive bids (i.e., bids that are better for the buyer than the bids made previously). Bidders may obtain information on the buyer’s preferences prior to or during the auction (Koppius and Heck 2003, Strecker 2010).

In SARAs, bidders know that the higher the price the better it is for the buyer and can observe the winning price. In MARAs, however, assuring that a bid is progressive for the buyer is more complex, because of the inability of the bidders to discover the buyer’s preferences solely through bids. The winning bid does not produce sufficient information for bidders to make subsequent bids.

When designing MARAs, there are two main concerns: (1) the representation of the buyer’s preferences that allow for the comparison of bids; and (2) the specification of rules for information revelation during the auction. These concerns have led to the consideration of various information types and the formulation of different information rules in auction design (Bichler 2000, Chen-Ritzo, et al. 2005, Koppius and Heck 2003, Strecker 2010). The three classes of information considered in auction design are listed below:

- **Buyer’s preferences** can be represented and conveyed in a utility format or value function that may be made fully or partially available to the bidders. For instance, in Bichler’s (2000) studies, the bidders may be given the buyer’s value function (Bichler 2000), or only partial information about the buyer’s utility function (Chen-Ritzo, et al. 2005). Recently, Bellosta et al. (2008) proposed the use of non-compensatory methods (e.g., Tchebychev measure and lexicographic ordering) to represent the buyer’s preferences. The non-compensatory preferences allowed the authors to suggest a feedback rule based on attribute values. The suppliers need not consider trade-offs, instead their bids have to contain a value greater than the previous best bid on at least one attribute and not worse on any attribute.

- **Bidder’s information** includes the number of bidders (both initial bidders at the beginning of the auction and active bidders during the auction process), bidder’s identity and preferences, and their status (e.g. inactive or active, winning or losing). The number of bidders has been considered in mechanism design and selection (Handfield and Straight 2003, Kaufmann and Carter 2004, Subramanian 2009). In auctions, an increase in the number of bidders may affect the dynamics of the process and thus the outcomes. Prior research has shown that it may lead to a higher level of competition and uncertainty (Jap 2002, Suter and Hardesty 2005), a higher buyer’s surplus (Carter and Stevens 2007, Klafft and Speckermann 2006), and directly and indirectly, an effect on the buyer-supplier relationship (Jap and Haruvy 2008). Moreover, research indicates that a
competitive market with a large number of bidders may prevent dis-closure of buyer’s preferences and requires a lower level of information revelation (Cason, et al. 2011, Jap 2007).

- **Bids information** includes the actual bids that are submitted by suppliers and bids constraints (e.g. reservation levels) which may define and update the admissible bids (Bellosta, et al. 2008, Kersten, et al. 2012), bid value of utility (for the buyer and the bidders) and bid status (e.g. winning or losing, ranking) (Adomavicius, et al. 2012, Koppius and Heck 2003).

Teich et al. (1999) suggest an information revelation rule in which the buyer prescribes a preference path i.e., an ordered set of price combinations and non-priced attributes. The preference path begins with an anchor point and the rule specifies that a point further from the anchor is preferred by the owner over the point that is closer to it. This allows the sellers to decrease the worth of their bids (as seen by the buyer) by proposing a combination that is more preferred by the buyer than that combination previously proposed. Burmeister (2002) notes that one drawback of this method is the imposition of a restriction on bidders’ choices, i.e., they are only allowed to bid on the preference path. Another limitation is the possibility for sellers to use the preference path to re-construct the buyer’s value function.

In the framework proposed by Bellosta et al. (2008), the information imparted by the buyer de-pends on the way she represents her preferences. When the representation includes a linear additive utility function, the owner passes this utility and its lower bound based on the current winning bid. When the preferences are represented as a lexicographic aggregation model or a Tchebychev function, then the owner conveys the attribute value bounds. This dependency is difficult to implement when the buyer does not make her preferences public (Burmeister, et al. 2002, Parkes and Kalagnanam 2005).

Bidders who participate in multi-attribute auctions need to be given either the buyer’s preferences or dynamically updated constraints in order to make progressive bids. Otherwise they “bid in the dark” or “bid with trial and error” expecting to make an admissible bids. The first rule gives the bidders the buyer’s utility (score) of every bid so that they can compare bids. The buyer’s utility need not be fully and explicitly revealed; several schemes have been proposed that differ in the assumption of the number of attributes (two or more), the type of utility functions, and the accuracy of disclosure.

The admissible bid-set tells the bidders what bid they can make so that their subsequent bids are better than the earlier ones. The revelation of bid constraints and actual bids is optional and can be included when the first two rules are used in auctions. The information provides the bidders with the bidding status and/or direction, which helps them in making progressive bids.

### 2.2 Information types and rules in negotiations

Negotiation is a different class of mechanism used in procurement and business contracts. It allows the participants to have more flexibility than auctions because the negotiation protocol may be modified at any point of time while auction protocol has to stay fixed during the whole process. Negotiations also allow for various types of information exchange (e.g. partial offers, complete offers, and free-text messages) (Kersten and Noronha 1999, Ströbel and Weinhard 2003).

In procurement and contract negotiations, suppliers and buyers communicate in order to exchange goods and/or services for, typically, money. Non-price issues or attributes are, however, often important to both sides and need to be negotiated. With the advanced development of e-commerce, negotiations can now be conducted online, i.e. e-negotiations.

Various negotiation mechanisms have been implemented in e-negotiations, which support, facilitate and mediate negotiations (Kersten and Lai 2008). Negotiation analysis provides a theoretical basis for the design of such mechanisms; it is concerned with modeling of negotiation problems and processes (Raiffa, et al. 2002 , Sebenius 1992). Similar to auction mechanisms, Kersten and Lai (2007b) identified the following three types of models or model components related to information in negotiations:

- **Negotiation problem** identifies and describes the problem structure (e.g. attributes, bounds, constraints and alternatives). Negotiation problems may be complex; described by many
constraints and variables (e.g., environmental problems, mergers and acquisitions). Such problems are formally represented and tools to simulate and construct a scenario are used.

- **Negotiators** pertain to information about the negotiators (e.g., objectives, preferences and constraints) that can also be represented using compensatory and non-compensatory methods as mentioned in auctions. In addition, it may also include negotiation-specific concepts such as the best alternative to the negotiated compromise (BATNA), reservation and aspiration levels, and the estimation of the zone of possible agreements (ZOPA).

- **Negotiation process** describes the ways in which participants interact (e.g., exchange of offers and/or free-text messages) and rules of engagement (e.g., negotiation in good faith, agreement and termination). Based on behavioral studies of negotiations, several negotiation process models have been proposed (Ghee-Soon Lim and Murnigham 1994, Gulliver 1979, Holmes 1992). In general, there are three sequential phases in negotiation: pre-negotiation, negotiation, and post-negotiation.

Most existing mechanisms support bilateral negotiations. In procurement the buyer may want to award the contract to one or more suppliers from among many. Multi-bilateral negotiation may be an alternative to reverse auctions.

Thomas and Wilson (2005, 2002) compared a number of single-attribute auction and multi-bilateral negotiation mechanisms. In their first study, the first-price auctions and multi-bilateral negotiations were compared in a procurement scenario. In their second study, they compared second-price auctions and multi-bilateral negotiations with verifiable offers. By comparing the results of the two studies, the four mechanisms were ordered in terms of the yielded transaction prices, from highest to lowest: second-price auctions, verifiable negotiations, non-verifiable negotiations, and first-price auctions.

By engaging in multi-bilateral negotiations buyers may increase their bargaining power (Stenbacka and Tombak 2012) but it requires time and effort (Kaufmann and Carter 2004). A sequence of bilateral negotiations has an obvious disadvantage; it is not possible to determine if the best offer was selected. This form of negotiation has been used in practice because simultaneous negotiations have been prohibitively costly and placed the buyer under psychological strain (Casson 2003, p.58). Information technologies make simultaneous negotiation possible with decision aid supporting the negotiators’ decision making and communication activities. This form of negotiation is comparable to reverse auctions in which multiple suppliers submit bids to the same buyer.

### 2.3 Motivation and approach

Review of relevant literature indicates that many auction mechanisms disclose the buyer’s preferences in order to provide sufficient information for bidders to make progressive bids. Disclosure of preferences, however, is problematic when the buying organization views these preferences as secret; disclosing them may endanger their competitive position.

Taking into account the role of both representation of preferences and information revelation, MARA mechanisms that allow for the separation of these two activities and the control of disclosure are required. The degree of disclosure should be controlled by the buyer so that it is possible to move from giving the bidder the ability to re-construct the buyer’s preferences to having preferences completely hidden so that their re-construction is not possible. Such a mechanism should also allow both the buyer and bidders to use a compensatory method to compare or construct bids in which the information exchanged is within the constraints or reservation levels on the attribute values.

A review of information types and rules indicates that multi-attribute reverse auctions and multi-bilateral negotiations can be used in the same types of transactions, hence they are comparable mechanisms. There are however, important differences, which are primarily due to: (1) the buyer’s active participation; and (2) the possibility to augment rules. Figure 1 illustrates MARA and MBMN, each involving one buyer and three suppliers.
Figure 1. Two comparable procurement mechanisms: MARA vs. MBMN

In the reverse auction (Figure 1a), the buyer hosts an auction and posts certain information (e.g. preferences, constraints, reservations) and the suppliers bid against each other. The submitted bids are validated and compared based on the buyer’s preferences, through which the winning bid can be identified. Note that the buyer does not explicitly make a counter-bid, but respond to the suppliers with the feedback about their submitted bids and for their prospective bids (e.g. current winning bid, updated constrains). The suppliers, however, do not communicate with each other and only obtain feedback from the buyer. Through this information revelation mechanism, each supplier is able to “communicate” with the buyer and proceed with the auction pro-cess.

In the multi-bilateral negotiation (Figure 1b), the buyer and the suppliers negotiate by exchanging offers and/or messages. Both the buyer and suppliers can make offers and counter-offers. The buyer can selectively bargain with one or more suppliers. The buyer’s preferences, constraints and reservations may be implicitly or explicitly conveyed to the suppliers through those offers and/or messages. There is no restriction or constraints on the suppliers’ offers, while the buyer may refer to the current outstanding offer as a constraints in order to request better offers from the suppliers. Similar to the reverse auction, there is no communication between the suppliers and each supplier only communicates with the buyer.

Given the similarities in these mechanisms, this study aims to develop a generic process model that can be used to design and implement such mechanisms by specifying a number of design parameters. In particular, this study focuses on the various information types and rules that are essential in mechanism design and implementation. This will not only allow us to explore alternative mechanisms for multi-attribute procurement transactions but also enable us to address specific needs and practical concerns in terms of information revelation in e-procurement.

To carry out these goals, this study adopts a design science approach in which mechanism design in economics and system design in information systems are linked together to address the design and implementation issues. Market mechanisms, being sets of rules governing transaction process and participants’ behavior, are models of processes and procedures that are implemented with other components in e-procurement systems (e.g. online auction systems and e-negotiation systems). Mechanism design aims to build concrete models with different rules and parameters, and these models are then implemented in information systems. In a review of e-negotiation systems, Kersten and Lai (2007a) discussed three design issues: model, architecture and configuration. Mechanism design and implementation become a system design issue, i.e. how the models are represented and
specified, how they are related to other system components, and how they interact with users and other system components.

Design science approach has been adopted in information systems research to study the process, methods and models that can be used to build. A number of guidelines have been provided with some exemplars artifacts (Hevner, et al. 2004, March and Storey 2008). The approach aims at producing generic system solutions to practical problems, while the type of system solutions proposed by a design researcher is a class of systems, or “meta-systems” (Livari 2003, Walls, et al. 1992). E-procurement transactions vary with regard to the products/services, participants and procedures. Thus, a class of e-procurement systems is needed to facilitate these different transactions. Vahidov (2006, 2012) suggested that a “what” (e.g. what type of systems) question may need to be answered before asking the “how” question. He thus proposed a framework for analysing and designing systems from four perspectives, including: analytical, synthetic, technological, and implementation. Based on such analysis, various mechanisms can be designed and implemented with the procurement process model and design parameters.

3 MECHANISMS DESIGN

A generic process model is developed from a novel procedure for multi-attribute auctions in order to extend and incorporate the design of alternative mechanisms. The design parameters are then defined for the specifications in mechanism design and a set of variant mechanisms are presented.

3.1 A generic process model

Based on the literature review of multi-attribute auctions and negotiations, existing mechanisms have overlooked several practical requirements for feasible e-procurement mechanisms, including: (1) buyer’s preferences need not be revealed; (2) separation of the information representation for buyers and suppliers; and (3) information exchange between the buyers and suppliers being composed with each attribute.

A novel multi-attribute auction procedure was recently proposed in order to meet these requirements (Kersten and Wu 2012). The proposed procedure builds on the work by Bellosta et al. (2008) and Teich et al. (1999). Auction design for multi-attribute reverse auctions relies on the notion of reservation levels for which constructing the preference aggregation method is used. The proposed procedure also uses the buyer’s reservation levels for auction design. The key difference is the space in which these levels are constructed. While in both procedures the levels originate in the utility space, we transform the reservation from the utility space to the space of alternatives. This has an important and desirable impact on the information types and rules: similarly to Teich et al. (1999), any information conveyed to the suppliers refers to the space of alternatives. Figure 2 shows a sequence diagram of this procedure.

In this procedure, the preferences, reservation levels and aspiration levels are confidential for the buyer and suppliers (i.e. bidders). The buyer initiates an auction with a set of parameters (e.g. auction deadline, increment value). The buyer is not required to disclose her preferences; instead, the information that is given to the bidders is similar to that in a SARA. The information is comprised of the value range or value set for each attribute, which is called a “limit”. It constrains or directs the acceptable attribute values based on the buyer’s preferences and reservation levels. Taking into account the limits for all attributes, a “limit-set” is generated. For example, price is not higher than $1000, lead time is not longer than 60 days, and warranty is not shorter than 36 months. There may be one or more sets of limits, depending on the buyer’s preference structure and the alternative values. In auctions, the limits during one time period set the permissible bids that the bidders can submit.
From the bidder’s perspective, knowledge of the current limit-sets is sufficient to make bids. An allowable bid is one that conforms to at least one of the limit-sets. Bidders make bids according to the limit-sets. This means that every bid has to follow the limits formulated in one of the limit sets. The bidder cannot choose one limit from one set and another limit—from another set. After the bidders submit their bids, the auction validates and compares the bids and selects the best bid from the buyer’s perspective (i.e., the winning bid yielding the highest utility for the buyer). Then, the auction updates the limit-sets based on the winning bid and the buyer’s preferences.

The auction is closed either when the deadline is reached or when the buyer has obtained the best possible bid (i.e., no more bidders are submitting bids; or, no more alternatives are available for bidding). Then, the winner can be identified based on the winning bid. The auction fails if none of the bidders submit a bid by the deadline. The results are announced to all bidders.

A similar procedure is developed for the negotiation mechanism (Figure 3). Both the buyer and the
suppliers can exchange offers and/or messages, and while the offers are not restricted to any explicit limits, they may disregard or reject worse offers based on their preferences. The suppliers are able to view their own offers and/or messages and those from the buyer, but they do not have direct access to the information about other suppliers’ offers and/or messages. The buyer, however, can view and compare the offers from all suppliers. Either one of the suppliers or the buyer can accept an offer which leads to an agreement. The buyer will then announce the winner of the contract for the procurement transaction.

The two mechanisms are comparable as they meet the requirements regarding the preference representation and information revelation and mainly differ in terms of information exchange (see also Figure 1 in Section 2.3). In MARA, depending on the information revelation rules, the suppliers may be provided with the limit-sets only, the winning bid, and/or even all bidders’ bids. In MBMN, the buyer may strategically negotiate with either selective supplier(s) or all suppliers. Requesting a proposal from all suppliers allows the buyer to obtain bargaining power by comparing and analyzing their offers, using BATNA to push other suppliers, and thereby increase the competition level.

The closing rules are theoretically indifferent for the two mechanisms. The transaction process will be ended, if: (1) the deadline is reached; or, (2) the buyer has obtained the best possible offer from one of the suppliers. It is possible that the auction will close when no bidders are competing (e.g. no profitable alternatives available). The negotiations will be concluded when either the buyer or one supplier is satisfied and accepts an offer. In both situations, however, if the participants are rational and self-interested, then the closing bid/offer is equivalent to the best offer that the buyer may obtain.

These two procedures are further extended to a generic procedure, which incorporates the models of process, participants and problem into three phases (Table 1):

- **Preparation**, during which the participants specify the transaction problem (e.g. products, attributes and alternatives) and their preferences, constraints and objectives;
- **Interaction**, during which the participants bid or bargain with each other on the attributes and alternatives; and
- **Conclusion**, during which the transaction is either completed with a contract agreement or terminated without any agreement by the deadline.

<table>
<thead>
<tr>
<th>Mechanisms and specifications</th>
<th>Process and phases</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARA</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td><strong>Preparation</strong></td>
<td><strong>Interaction</strong></td>
</tr>
<tr>
<td></td>
<td>Define auction problem; Set buyer’s preferences; Set bidders’ preferences</td>
<td>Buyer: Set bid limits; Evaluate bids; Accept/Reject bids Bidders: Submit bids; Revise bids</td>
</tr>
<tr>
<td>MBMN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Preparation</strong></td>
<td><strong>Interaction</strong></td>
</tr>
<tr>
<td></td>
<td>Define negotiation problem; Set buyer’s preferences; Set bidders’ preferences</td>
<td>Buyer: Send offers/messages; Evaluate offers; Accept/Reject offers Bidders: Send offers/messages; Evaluate offers; Accept/Reject offers</td>
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<tr>
<td>Generic</td>
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<td></td>
<td><strong>Preparation</strong></td>
<td><strong>Interaction</strong></td>
</tr>
<tr>
<td></td>
<td>Define decision space; Define utility space</td>
<td>Buyer: Revise decision space Evaluate proposals; Make decisions Bidders: Make proposals; Revise proposals</td>
</tr>
</tbody>
</table>

*Table 1. A generic process and its phases with two types of mechanisms*

### 3.2 Design parameters

Based on the review of the auction and negotiation mechanisms and the generic process model, a set
of parameters can be defined for mechanism design. This study focuses on the information types and rules in mechanisms, i.e., who knows what at what time. Moreover, from the system design perspective, the format of information is also considered. This leads to the following categories of parameters:

- **Types of information**: This considers the different types of information analyzed in Section 2, including information about buyers, suppliers and proposals (i.e. bids or offers).

- **Scope of information revelation**: The information may be revealed in different scopes so that it is available to individuals, a selective set or all participants in the transactions.

- **Time of information revelation**: This considers at what time point the information is made available to the participants in the transactions. It may be prior, during and/or after the auctions and negotiations.

- **Format of information**: The information may be presented in different formats such as textual, tabular and graphical.

Table 2 summarizes these categories and parameters. The mechanisms can be designed by specifying and combining these parameters. While several parameters are mandatory for mechanism design, others are optional. For instance, the MARA mechanisms can be designed with admissible bids revealed to all bidders at the beginning or end of each round. In addition, they may also reveal actual bids and their status (e.g. winning bids) in tables or graphs.

These categories and parameters make it possible to design alternative and comparable mechanisms for the same or similar procurement transactions. For example, auctions and negotiation appear to be two different types of mechanisms as the information types and information revelation on scope and time are normally quite different. However, considering MARA and MBMN mechanisms, they may become equivalent if: (1) in MARA, the buyer reveals only the current admissible bids in a table without explicitly disclosing her preferences; and (2) in MBMN, the buyer does not send any offers/messages but only reveals and updates the acceptable offers in a table. In such design, the suppliers are able to proceed in the auctions or negotiations with better proposals for the buyer. Note that this may undermine certain capabilities of different mechanisms.

<table>
<thead>
<tr>
<th>Categories and options</th>
<th>Type</th>
<th>Scope</th>
<th>Time</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Decision space</strong>: Admissible proposals; Proposal constraints; Actual proposals Utility space: Preferences; Utility of proposals; Status of proposals</td>
<td>All participants; Selective set; Individual</td>
<td>Beginning of transaction; Beginning of round; After certain proposals; End of round; End of transaction</td>
<td>Textual; Tabular; Graphical</td>
</tr>
</tbody>
</table>

*Table 2. Design parameters in auction and negotiation mechanisms*

It is also worth noting that mechanism design requires a systematic analysis and integration of these parameters. The parameters from different categories should not be simply put together to compose a mechanism. In fact, several parameters may not be compatible with each other. For instance, actual proposals and their status are not available at the beginning of transactions but only when at least one proposal has been submitted.

### 3.3 Variants of mechanisms

Based on the generic process model and the design parameters, a number of different mechanisms can be designed even within the same family of mechanisms (Table 3).

In the SARA mechanism, the value and status of each bid is known to both the buyer and the bidders. When using price only, the value is also known to all bidders. It may further vary on the scope and time of information revelation, which then leads to: (1) reversed open-cry or English auctions (to all bidders) and sealed-bid auction (to bidder-self only); and, (2) asynchronous or continuous auctions (right after each bid submitted) and synchronous or round-based auctions (at end of each round or
after bids are submitted by all bidders). The preferences, value and status of bids can be shown in tables or depicted on graphs.

In the MARA mechanisms, four variants are given with their specifications on the design parameters using the same process model. They differ mainly in the types and time of information revealed in the auctions, including: the different bids and their status (MARA1, MARA2, MARA3), and the different rules to disclose this information (MARA2, MARA3, MARA4). It is also possible they may vary on the scope and format of information revelation. For example, the first three variants convey the same information to all bidders (e.g. limit-sets, winning-bid details) while MARA4 can generate and provide different admissible bids to different bidders based on the buyer’s preferences on the goods and the suppliers (Kersten, et al. 2012). Optionally, the information can be displayed in tables or graphically.

<table>
<thead>
<tr>
<th>Type</th>
<th>Scope</th>
<th>Time</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>SARA</td>
<td>Buyer’s preferences; Bidders’ preferences; Value and status of bids;</td>
<td>All bidders (open-cry); Bidder-self (sealed-bid)</td>
<td>After each bid (asynchronous); End of round (synchronous)</td>
</tr>
<tr>
<td>MARA1</td>
<td>Admissible bids</td>
<td>All bidders</td>
<td>End of round</td>
</tr>
<tr>
<td>MARA2</td>
<td>Admissible bids; Winning-bids</td>
<td>All bidders</td>
<td>After two bids</td>
</tr>
<tr>
<td>MARA3</td>
<td>Admissible bids; All bids and their status</td>
<td>All bidders</td>
<td>End of round;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>After each bid</td>
</tr>
<tr>
<td>MARA4</td>
<td>Admissible bids; Winning-bids</td>
<td>Selective set</td>
<td>End of round;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>After each bid</td>
</tr>
<tr>
<td>MBMN1</td>
<td>Offers/messages; Counter-offers/messages</td>
<td>Individual</td>
<td>After each offer</td>
</tr>
<tr>
<td>MBMN2</td>
<td>Buyer’s offers; Supplier’s offers/messages</td>
<td>Individual; Selective set</td>
<td>After offers from each supplier</td>
</tr>
<tr>
<td>MBMN3</td>
<td>Buyer’s messages; Outstanding supplier’s offers</td>
<td>All suppliers</td>
<td>After offers from two suppliers</td>
</tr>
</tbody>
</table>

Table 3. Variants of auction and negotiation mechanisms

In addition, three variants of the MBMN mechanisms are designed. The main differences here are the types and scope of information exchanged between the buyer and the suppliers. The buyer can negotiate as in bilateral negotiations (MBMN1), make only verifiable offers but send no messages (MBMN2), or send only messages and the outstanding supplier’s offer to request for new proposals without making her own offer (MBMN3). The information exchange may be between the buyer and individual, selective or all suppliers. The time concern is similar to the MARA mechanisms. MBMN1 may be seen as a set of sequential bilateral negotiations, while MBMN2 and MBMN3 are similar to round-based and parallel negotiations. Also, the information exchanged may be textual messages and/or offers in tabular or graphical format.

Note that MARA1 and MBMN1 are quite different and appear to be classic auction and negotiation mechanisms. Several variants, however, can be similar or equivalent. For instance, MARA2 and MBMN3 can both support round-based transactions with same information type, scope and time for the suppliers. The winning bids in MARA2 and outstanding offers in MBMN3 are both verifiable information revealed to the suppliers so that they can submit better proposals for the buyer.

4 DISCUSSION

E-procurement practice often involves multiple suppliers and requires agreement on multiple attributes of the products or services. Also, the buyers may not fully reveal their preferences due to realistic conditions such as market competition. Taking into account these practical issues, this study aims to provide a set of feasible mechanisms in such e-procurement situations. In particular, two
classes of mechanisms are designed and implemented: multi-attribute reverse auctions (MARA) and multi-attribute multi-bilateral negotiations (MBMN).

The two different mechanisms both support e-procurement transactions with multiple suppliers and multiple attributes. Considering the information rules, they also share several common design parameters, which allow us to design and implement the variants of those mechanisms for different e-procurement situations. A set of mechanisms are then proposed with the process model and information rules.

### 4.1 Implications for mechanism design and implementation

Auctions and negotiations are two different classes of mechanisms, and the advancement of information technologies has enabled convergence between them leading to several emerging mechanisms. For instance, the two sets of mechanisms in this study have both extended the existing and classic models, i.e. MARA from single-attribute reverse auctions and MBMN from bilateral multi-attribute negotiations. Such extensions technically allow both mechanisms in supporting e-procurement with multiple suppliers and multiple attributes. Also, focusing on the information rules, it is possible to create a continuum of mechanisms between those two classes. The variants of mechanisms can then be used to address more specific business requirements and strategic concerns.

Information as a key aspect can be used to define the rules to facilitate and control the procurement process, i.e. what is available to whom and when. This requires the analysis of information structure to identify the different types, scope and timing of information in the process. The distinction of these dimensions of information allows market designers and procurement managers to customize and adapt the mechanisms for different business situations. However, there needs to be caution when formulating the rules with these dimensions. The compatibility between the dimensions needs to be ensured; otherwise, issues may arise and the mechanisms may be violated, for example, buyer-determined auctions with additional information in post-auction phase (Katok and Wambach 2008). Differentiations among the suppliers, however, are possible if they receive different information that follows the pre-defined rules (e.g. Kersten, et al. 2012).

The separation of utility space and decision space allows the parties to control the level of information disclosure depending on their strategies and market conditions. This makes the mechanisms more compatible with both the buyers and suppliers’ information incentives and needs. The buyers do not need to reveal their preferences to the public, and the information they provide to the suppliers is still sufficient to obtain progressive bids. The suppliers, on the other hand, are capable to make their decisions based on the information provided by the buyer and their own preferences. The “communication” between the two sides falls in the decision space rather than directly in the utility space. Note that the mapping function between the two spaces should not be discoverable by the suppliers through the feedback information (Kersten and Wu 2012).

The mechanism design and implementation is an iterative process, which may require redesign and reimplementation to revise and improve the mechanisms based on the results of experimental and field studies. Note that the testing is not only for validating the design of a single mechanism but also for applying the variants of mechanisms into different contexts. For generalizability considerations, the same mechanisms may need to be tested and validated within different settings.

### 4.2 Extensions and future research

A series of experimental and field studies may be conducted, in which the mechanisms can be implemented and validated. Researchers can also assess e-procurement system design with different models and features, construct bidding behavioral models, and observe bidding strategies in different contexts. It is expected that the findings will provide insights in designing and implementing feasible mechanisms for real-life procurement strategies and operations.

Also, this research addresses the multi-attribute transactions in e-procurement which only allows exchanging packages or complete offers. In practice, partial offers may be allowed and nested auctions or negotiations may be more required. Future work may consider the relative importance and
The interdependency of the attributes, which can be used to transform the problems to either single-attribute or similar multi-attribute transactions.

Studies in decision support systems have also noticed the effects of information format (e.g. Kamis, et al. 2008), while its joint effects with the number of attributes and different information types need to be further examined in multi-attribute business transactions. This will help address not only “what” information but also “how” the information is managed during the process. Also, the process model can be implemented to facilitate the process and support decision making, while their impact may vary. For instance, models with analytic support may be useful in both auctions and negotiations, whereas communication-driven models may be more useful in negotiations. This may be related to both the type and format of information exchanged in the process (e.g. Kersten, et al. 2010).

Besides the information rules in mechanism design, other rules can be considered together in future work, for example, winner determination rules and closing rules. The auction mechanisms in this study are equivalent to first-price auctions with hard close (i.e. fixed deadline), where the supplier who submitted the best bid for the buyer wins the auction. Research has shown the effects of overbidding with first-price auctions and late bidding with hard close auctions (Kagel and Levin to appear, Roth and Ockenfels 2002). Future research may design and implement the mechanisms with different winter determination and closing rules, and investigate the effects on the process and outcomes.
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