Three Studies on Multi-attribute Market Mechanisms in E-procurement

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Abstract

Three Studies on Multi-attribute Market Mechanisms in E-procurement

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Successful e-procurement depends on selecting the appropriate mechanisms that comprise rules governing and facilitating transaction process. Existing mechanisms have theoretical or practical limitations such as limited number of attributes, disclosure of buyer's preferences and costly processes. The present research addresses these issues through three studies.

Study 1 presents two feasible mechanisms for multi-attribute multi-supplier transactions. They allow buyers to control preference representation and information revelation, assuring that suppliers obtain sufficient information in making effective proposals while protecting confidential information. Following the design-science approach, the mechanisms are implemented to support multi-attribute reverse auctions and multi-bilateral negotiations.

Study 2 examines the revelation of information in multi-attribute reverse auctions. Three revelation rules are formulated with admissible bids, winning bids and all bidders' bids. Their effects on the process, outcomes and bidders' assessment are tested in two experiments. The results show significant improvement in process efficiency when more information is revealed. The suppliers reached better outcomes with either admissible bids only or all bidders' bids, while the buyers gained more when revealing the winning bids only. Bidders were more satisfied with the outcomes and system when more information was provided.

Study 3 compares multi-attribute reverse auctions and multi-bilateral negotiations in both laboratory and online experiments. The results show that auctions are more efficient than negotiations in terms of the process. Auctions led to greater gains for the buyers, whereas more balanced contracts were reached in negotiations. Suppliers' assessment was affected by their outcomes, and the winning suppliers were more satisfied with the process, outcomes and system. The buyer's role was also examined. Different types of information conveyed from buyer influence suppliers' behavior in making bids/offers and concessions, which in turn affected buyer's gains.

This research provides implications to future studies and practices in e-procurement, in particular, the formulation of a procedure of two multi-attribute mechanisms and the formulation of general guidelines for strategic use of different mechanisms in various e-procurement contexts.

Dedication

This dissertation is dedicated to my parents, my wife and my daughter.

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Many people have contributed, both directly and indirectly, to this dissertation and to my intellectual growth.

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Abbreviations

AVE	Average variance extracted
B2B	Business to business
BATNA	Best alternative to negotiated compromise
CFA	Confirmatory factor analysis
CFI	Comparative fit index
CMC	Computer mediated communication
DSS	Decision support system
EFA	Exploratory factor analysis
ENS	E-negotiation systems
ERP	Enterprise resource planning
ICT	Information and communication technology
IFI	Bollen’s incremental fit index
Imaras	InterNeg multi-attribute reverse auction system
Imbins	InterNeg multi-bilateral integrative negotiation system
MARA	Multi-attribute reverse auction
MBMN	Multi-attribute multi-bilateral negotiation
MVC	Model-view-controller design pattern
NNFI	Bentler-Bonett nonnormed fit index
NSS	Negotiation support system
RMSEA	Root mean square error of approximation
SARA	Single-attribute reverse auction
SCM	supply chain management
TAM	Technology acceptance model
TCT	Transaction cost theory
TRA	Theory of reasoned action
ZOPA	Zone of possible agreements

1. Introduction

Procurement is a core activity in business operations. Both research and practice have realized the advantages of efficient procurement, including: cost savings, return of investment, and contribution to the bottom line (Brynjolfsson, Hu et al. 2003; Quinn 2005; Seggie, Kim et al. 2006). Between 50 and 70% of corporate revenue is spent on purchasing; hence, savings of even several per cent translate into very significant amounts of money for companies of every size (Peleg 2003; Wagner and Schwab 2004). For these reasons, procurement is considered a strategic activity and core competency for organizations (Matthews 2005; Minahan 2005).

Business-to-business (B2B) transactions have been advanced by the rapid development of information and communication technologies (ICTs) and conducted online through electronic commerce. E-procurement is a key component in B2B commerce, through which businesses obtain goods and services. The traditional manual procure-to-pay processes are inefficient and ineffective as they "waste employees' time in creating, approving, and processing transactions [and] fail to channel spend to the right items from the right suppliers" (Jones, Ross et al. 2011). E-procurement can improve this process; it can increase its efficiency and effectiveness.

Given the advantages of conducting procurement online, e-procurement applications have been growing fast and continuously during the past decade. The market has reached $5 billion (Bartels, Mines et al. 2011) and an annual growth rate of 10% is predicted by AMR Research and Forrester Research (Rizza, D'Aquila et al. 2006; Bartels, Mines et al. 2011).

1.1 Motivation and scope

Successful management of purchasing activities depends on not only selecting the right product or service but also choosing the best method of buying them (Handfield and Straight 2003). These methods are determined by *market mechanisms*, which comprise rules governing and facilitating procurement transactions. Typical market mechanisms include: *catalogues* for fixed-price transactions, *auctions* for transactions that allow multiple suppliers to compete against each other, *exchanges* for transaction taking place among multiple buyers and sellers, and *negotiations* for transactions which allow for individual interactions between the buyer and one or more suppliers. E-catalogues, spot markets and online auctions have gained popularity in procurement transactions for which price is the main concern. Auction mechanisms and tools supporting negotiation have become an essential component in most enterprise resource planning (ERP) and supply chain management (SCM) systems (e.g. SAP ERP, IBM WebSphere).

Standard or forward auction mechanisms deal with the situation in which one seller hosts an auction and many buyers bid on price. In procurement, *reverse auctions* are implemented and used. In these auctions the roles of buyer and seller are reversed, i.e. the buyer organizes an auction and the sellers (suppliers) are bidders. Reverse auctions have been shown to achieve an average gross savings of 5-20 percent (Cohn 2000).

Most auctions are concerned with a single attribute, typically price. However, organizations are 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 negotiations, i.e. procurement managers negotiate with several suppliers in order to select one of them. E-business allows for the searching of suppliers over the world. This is particularly valuable in situations where there may be many potential suppliers, some in close proximity to the business's location others—far away. More advanced and suitable mechanisms than traditional single-attribute auctions and bilateral negotiations are needed in order to determine the best one from among many dispersed suppliers.

Several approaches to deal 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, and collusion and unethical activities.

Negotiations allow the use of price and other issues wherein the value of the issues is agreed upon by two or more parties. In procurement, buyers may negotiate with different suppliers over the same goods or services (sequentially or simultaneously) in order to increase their bargaining power and realize a surplus (Stenbacka and Tombak 2012).

Sequential bilateral negotiations with one supplier at a time or several suppliers simultaneously over multiple attributes are both complex and costly. Negotiations with multiple suppliers simultaneously, i.e., multi-bilateral negotiations, may not be possible or may require the engagement of several procurement managers. Such processes would benefit from ICT support; few studies, however, have modeled and examined multi-bilateral negotiations in an e-procurement context.

Organizations need to select and possibly adapt market mechanisms to suit their particular procurement situation. Models and guidelines have been proposed to aid the mechanism selection in procurement practice (e.g. Kraljic 1983; Handfield and Straight 2003). They are mainly based on normative theories (e.g. transaction cost theory by Williamson 1979). They consider general sourcing strategies (e.g. outsourcing, integration, or reverse auctions) rather than the detailed parameters describing the marketplace and organization with its procurement process. In contrast, experimental economics and market design (Milgrom 2000; Smith 2003) empirically study mechanisms with different design characteristics. These studies are limited to single-attribute auctions; there is a dearth of comparing multi-attribute auction mechanisms (Kagel and Levin to appear).

Multi-attribute auction mechanisms have recently been proposed (e.g. Bichler 2000; Teich, Wallenius et al. 2003). They may be used in solving problems in which formerly, only negotiations could have been employed, thus increasing procurement efficiency. To-date, however, there have been no studies in which such auctions and negotiations are compared.

1.2 Objectives and questions

The impact of procurement mechanisms on the functioning of business, government and other organizations and the above mentioned lack of behavioral studies that focus on the multi-attribute procurements in which multiple organizations participate, provide the rationale for the present study. The goals of this study is thus to gain insights into the two primary mechanisms, auctions and negotiations, in terms of their advantages and disadvantages, their similarities and differences, and their adoption and applications in e-procurement practice.

In order to achieve these goals, firstly, effective multi-attribute mechanisms need to be designed and implemented that allow to study and compare auctions and negotiations in a similar e-procurement context; secondly, following their implementation and using the generated e-procurement systems, experimental studies need to be conducted to examine and compare their impact on the processes, outcomes and assessment. Therefore, the research is carried out in two stages:

The first stage requires process modeling and system development for mechanism design and implementation. Auction and negotiation models and systems are presented in Study 1. The proposed mechanisms need to ensure that the suppliers obtain sufficient information in making effective bids or offers while concealing buyer's secret information. Therefore, the study addresses the following questions:

- *What information do the suppliers need to know?*
- *How to convey the information from the buyer to suppliers?*

The auction and negotiation mechanisms are designed to allow the buyers to control preference representation as well as the level of information revealed to the suppliers. Two systems are developed to implement these mechanisms, which form the basis for the subsequent experimental studies.

In the second stage, the two systems are used to conduct experiments described in Study 2 and

Study 3. These studies address the following two main questions:

- *How will the different mechanisms affect the process and outcomes of e-procurement?*
- *Under what conditions will certain types of mechanisms outperform the other types?*

Study 2 and Study 3 employ the developed systems to experimentally assess the use of different mechanisms and compare their efficacy. In Study 2, multi-attribute reverse auctions are compared with regards to the level of information revelation. In Study 3, multi-attribute reverse auctions and multi-bilateral negotiations are compared. In these two studies, the effects are examined at both the individual and transaction level. The transaction context (e.g. tasks, settings) and the buyer's role are also considered.

1.3 Summary of contributions

The contributions of this research are summarized below:

(1) The research formulates two process models and proposes two multi-attribute mechanisms in e-procurement. Existing mechanisms either support single-attribute transactions or require disclosure of buyer's preferences, which has limited their adoption and application in e-procurement practice. The proposed process models address these practical needs and enable to design and implement effective and comparable mechanisms. In particular, two novel procurement mechanisms, multi-attribute reverse auction and multi-bilateral negotiation, are designed to support e-procurement transactions that involve multiple attributes and multiple suppliers and that allow buyers to control the revelation of their preferences. The approach also allows the design of hybrid and seamless mechanisms between classic auction and negotiation mechanisms.

(2) The research develops two innovative systems that enable to study and compare auction and negotiation processes in a similarly competitive context. Many existing comparative studies were conducted in different settings or for different tasks, leading to inconclusive and even contradictory results. In order to empirically examine the similarities and differences between

auctions and negotiations, the above two comparable multi-attribute procurement mechanisms are implemented with similar user interface and system features. The systems provide a test-bed to conduct experiments in which various contextual factors can be controlled and manipulated to validate and study different mechanism design and their impact. The systems are tested and deployed on the Internet; to-date, they have been used by over 2,000 users for research and education. The systems form a basis for two subsequent studies in this thesis (i.e. Study 2 and Study 3) and many other studies (e.g. human-agent negotiations by Vahidov and Kersten 2012a; 2012b). They can also be used for business training in e-procurement and contract design.

(3) The research provides insights into the similarities and differences between auctions and negotiations. Auctions and negotiations are two classic market mechanisms. Discrepant definitions and mixed use of the two mechanisms exist in different disciplines. This research shows that they are capable to support the same procurement transactions with the advancement of information technologies, yet they are different in several aspects. Their convergence and distinction can and should be noted in terms of their design, implementation and impact on the transaction process and outcomes. The variants of auction and negotiation mechanisms proposed in Study 1 show that they are mainly different in terms of the buyer's role in the processes and the flexibility of information exchange, while technology convergence also makes it possible to design a series of mechanisms between the two classic mechanisms by defining and configuring a set of design parameters. From an information revelation lens, Study 2 compares three variants of mechanisms within the auction family. The results show that different information rules lead to various effects (e.g. anchoring, learning and signaling) that may benefit or harm the buyers and suppliers differently. Taking a further step, Study 3 compares the mechanisms between auctions and negotiations. The results show that auctions do outperform negotiations in terms of process and outcome efficiencies that favor the buyers, while negotiations lead to more balanced contracts. It also indicate that similar effects may be achieved with different mechanisms; for

instance, the public announcement of winning bids in auctions and the buyer's public messages without making offer (and thus no concession-making) in negotiations both can add pressures on the suppliers, result in larger concessions from the suppliers and better outcomes for the buyers.

(4) The research formulates guidelines for strategic use of different mechanisms in various procurement contexts. This research carries out two experimental studies in which the proposed mechanisms are studied and compared. The findings indicate that auctions and negotiations outperform each other on different aspects in different situations, such as buyer's gains versus supplier's gains, process efficiency versus outcome efficiency, individual gains versus joint outcomes, and laboratory setting versus online setting. The results from Study 2 suggest that buyers should realize and distinguish the different types of information and the effects of their revelation in auctions. Insufficient information may increase the suppliers' learning effort that reduces the process efficiency, while revealing too much information can also harm the bidders' interests and thus lead to earlier terminations. The combination of admissible bids and winning bids may be the best candidate if buyers expect higher economic gains. In other situation such as public procurement, higher information transparency and social welfare with more balanced contracts may be given a higher priority. Also, even the same type of information may lead to different effects in different contexts. In Study 3, the private information (buyer's offers and messages) in negotiations show different effects in the laboratory and online settings. The buyer's messages led to reciprocal offers from the suppliers with larger concessions under a higher time pressure in the laboratory setting, while the buyer's offers had the same effect only in the online setting. The findings from this research help practitioners in the selection and utilization of these mechanisms based on business needs and situations.

(5) The research implicates that an interdisciplinary approach is required to empirically study and compare auction and negotiation mechanisms in e-procurement, which typically involves IS research, decision and negotiation analysis, and experimental economics. E-procurement is an

artifact or information system in which business process models are implemented with information technologies. Various mechanisms can be modeled and implemented in such systems through the design science approach, and the systems then provide test beds to experimentally examine and compare the implemented mechanisms. This interdisciplinary approach provides a new avenue to design, implement and assess market mechanisms in e-procurement.

1.4 Organization of dissertation

The rest of this dissertation is organized as follows. Section 2 reviews the relevant literature on e-procurement and market mechanisms, which provides a background of this research. Section 3 presents a research roadmap with a research framework on mechanisms design, implementation and use, through which the three studies are organized and carried out.

The three studies are then presented in the Section 4, 5 and 6, respectively. Each study is a relatively independent work, in which the relevant literature, objectives, approach and results are presented in details. Section 7 concludes the dissertation with the contributions and limitations of this research.

In addition, eight appendices are included: A and B demonstrate the two systems with the relevant screenshots, C presents the implementation of information rules in Imaras for Study 2, D summarizes the profiles and preferences of the participants' roles in the experimental task, E describes the experimental procedure, F provides a sample quiz for the case task and role-play instructions in the experiments, G presents the pre-transaction and post-transaction questionnaires used in the experiments, and H presents the measurement of transaction process and outcomes. The relevant glossary is also provided.

2. Background

An overview of e-procurement is provided in Section 2.1, followed by the key market mechanisms in Section 2.2. Relevant work on multi-attribute auctions and e-negotiations that are the primary interest of this research is discussed in Section 2.3 and Section 2.4. Issues associated with the design and implementation of market mechanisms are presented in Section 2.5. Empirical studies and their results are discussed in Section 2.6.

2.1 E-procurement

With the advanced development of information and communication technologies (ICTs), many business operations are conducted online, including procurement. E-procurement, a key B2B component, is a process that utilizes ICTs to identify, evaluate and negotiate with business partners for purchasing goods and services (Minahan 2001). Various tools and solutions have been provided and adopted to automate, simplify and facilitate procurement processes (Minahan 2005). E-procurement evolved from being an integral part in enterprise resource planning systems for procurement of raw material and product components, to procurement of indirect products and services for maintenance, repair and operations, and then has extended to and integrated in e-markets (Puschmann and Alt 2005; Rossignoli, Carugati et al. 2009).

E-procurement has been found to positively affect business performance at both the operational level and strategic level, depending on the ICTs usage (Premus and Sanders 2005) and solutions adopted (Mukhopadhyay and Kekre 2002; Puschmann and Alt 2005). It has been widely accepted that e-procurement favors the buyer companies, providing broader choices of suppliers, increasing efficiency of the process and saving operation costs (Minahan 2005; Xia and Xia 2008). Research has also shown its benefits to the suppliers, given aligned infrastructure and enhanced coordination (Hohner, Rich et al. 2003; Sanders 2005; Sanders 2007). Besides its economic impact, recent studies have called for attention to its consequences on buyer-supplier relationship (Croom and Brandon-

Jones 2005; Kulp, Taylor et al. 2006; Ulaga and Eggert 2006).

It has been acknowledged that there is no a single best practice for all e-procurement processes. To reap the benefits of e-procurement, several contextual factors need to be considered, including: the type of goods and services (Puschmann and Alt 2005), the scope and size of procurement (Chen 2007; Kauffman and Tsai 2009), the maturity and stages of products and technologies (Hobson 1999; Kishore, Agrawal et al. 2004; Croom and Brandon-Jones 2007), and the nature of the business relationship (Skjøtt-Larsen, Kotzab et al. 2003; Daly and Nath 2005; Boeck, Bendavid et al. 2009).

2.2 Market mechanisms in e-procurement

Whether to produce or buy is a fundamental issue that organizations must address with regards to a variety of goods and services. Procurement is a process through which organizations obtain goods and services from markets or other organizations. Market mechanisms are rules that govern such processes.

The overall procurement process can be divided into three general stages (Handfield and Straight 2003; Choudhury and Karahanna 2008):

(1) *Pre-procurement*, in which organizations make decisions in selecting the appropriate goods/services, suppliers and methods of procurement (Nam, Rajagopalan et al. 1996; Handfield and Straight 2003; Dedrick, Xu et al. 2008);

(2) *Procurement*, wherein buyers conduct and complete the transaction using different ways or channels (Anand and Aron 2003; Biagi 2004; Bandyopadhyay and Bandyopadhyay 2009); and

(3) *Post-procurement*, in which organizations monitor, control and evaluate the transaction performance and outcomes (Kern and Willcocks 2000; Choudhury and Sabherwal 2003; Ho, Ang et al. 2003). The present research focuses partially on the pre-procurement stage and partially on the procurement stage.

In this section, the typical mechanisms and their selection in e-procurement are briefly introduced. The auction and negotiation mechanisms are then discussed.

2.2.1 Mechanisms and their selection

There are four types of mechanisms used in e-procurement (Bichler, Field et al. 2001; Bellantuono, Kersten et al. 2008):

(1) *Catalogues*, which usually contain a listing of goods and services with fixed prices and allow for little flexibility such as discounts;
(2) *Reverse auctions*, which automate the pricing process and allow the suppliers to compete against each other on the price or on a pre-defined structure of contract clauses;
(3) *Exchanges*, which allows transactions between multiple buyers and multiple sellers; and,
(4) *Negotiations*, which involve more flexible and complex processes and allow the buyer and suppliers to bargain over ill-defined structure of contracts.

For each type, numerous configurations of parameters which determine the concrete mechanism are possible. Organizations need to decide what type of mechanism and what concrete implementation should be used in a particular situation. Inappropriate selection of mechanisms may cause business failures and harm business relationships (Jap 2003; Croom and Brandon-Jones 2005; Giampietro and Emiliani 2007; Jap 2007). Empirical studies have shown that the same mechanisms perform differently in different procurement conditions (Jap 2002; Kaufmann and Carter 2004; Gattiker, Huang et al. 2007).

Derived from transaction cost theory (Williamson 1979; 1981), different governance structures for business transactions have been proposed each depending on the transaction characteristics (e.g. specificity, uncertainty and frequency). In order to reduce transaction costs, nonspecific resources should be obtained from markets (e.g. catalogs, spot markets) while mixed or customized resources may require relational contracts (Williamson 1979, p. 253). In procurement practice, similar guidelines have been provided (Kraljic 1983; Olsen and Ellram 1997; Handfield and Straight 2003; Sanders, Locke et al. 2007; Radkevitch, van Heck et al. 2009).

Kraljic (1983, p. 111) suggested four types of procurement based on two dimensions: (1) the supply market complexity (determined by market conditions, e.g., monopoly or oligopoly, entry barriers, logistic costs, etc.), and (2) the importance of procurement (determined by profit impact, total costs, importance in production, etc.). Each type, shown in Figure 2-1, differs by the high/low set of values for each dimension associated with the procurement focus: bottleneck, strategic, noncritical and leverage.

High

Supply market complexity

Bottleneck	**Strategic**
• **Goods**: complex, low priority; • **Suppliers**: few available; • ***Mechanism****: posted price, automation;* • **Relationship**: cooperation; • **Horizon**: long-, medium-term.	• **Goods**: complex, critical; • **Suppliers**: few available or very high switching costs; • ***Mechanism****: negotiations;* • **Relationship**: partnership; • **Horizon**: long-term
Noncritical	**Leverage**
• **Goods**: simple, low priority; • **Suppliers**: many, compete for buyers; • ***Mechanism****: spot markets, reverse auctions, automation;* • **Relationship**: none or low; • **Horizon**: short-term.	• **Goods**: simple, high priority; • **Suppliers**: many, compete for buyers; • ***Mechanism****: reverse auctions, negotiation, mix;* • **Relationship**: low, mix; • **Horizon**: medium-, short-term.

Low Importance of procurement *High*

Figure 2-1. Guidelines for mechanism selection in procurement
(adapted from Kraljic 1983; Olsen and Ellram 1997; Handfield and Straight 2003)

Other mechanism selection models and frameworks focus on issues such as transaction task, types of buyers or the stage of buyer-seller relationship. Sanders et al. (2007) proposed a framework that considers the scope and criticality of the transaction tasks (from transactional to relational), business objectives (from financial to strategic) and number of suppliers (from large to small). Accordingly, different mechanisms are suggested in terms of their flexibility. Radkevitch et al. (2009) found four types of buyers (transactional buyers, recurrent buyers, small diversifiers and large diversifiers) which differ in their selection of auction or negotiation mechanisms and selection of suppliers. Boeck and his colleagues (2009) proposed a model to align sourcing strategies with the level and stage of the buyer-supplier relationship: pre-relationship, spot relationship and contractual relationship.

The present research focuses on procurement transactions using reverse auctions and negotiations. Studies have shown that business organizations follow these guidelines in implementing their procurement strategies (Kaufmann and Carter 2004; Subramanian and Zeckhauser 2004; Bajari, McMillan et al. 2009; 2009). Auctions are used in noncritical and leverage transactions when goods or services are simple and have a low-to-medium priority. Also, organizations obtain financial benefits from using auctions when the number of suppliers is large. Negotiations are used in strategic and leverage transactions when the procured items are complex and have a critical-to-high priority. They are also used when the time horizon is medium-to-long and the buyer-supplier relationship is of concern.

2.2.2 Auction mechanisms

In classical auction theories, standard or forward auctions deal with situations wherein buyers bid against each other over price (Klemperer 1999). In procurement transactions, reverse auctions are used with sellers or suppliers bidding against each other.

A mechanism is a set of rules used to determine resource allocation and prices. In auctions, the typical rules include (McAfee and McMillan 1987):

(1) Bidding rules: how bids are formulated and when they can be submitted;
(2) Allocation or winner determination rules: who gets what based on submitted bids;
(3) Pricing rules: what prices the bidders have to pay; and,
(4) Closing rules: when or under what condition the auction is closed.

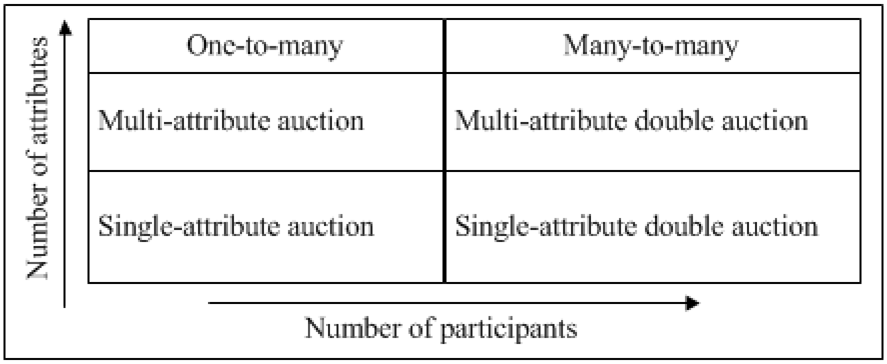
Auction mechanisms require that the rules are explicit, complete and fixed for the duration of the process (Kersten, Chen et al. 2008). The rules are explicit when they are known to the bidder prior to the auction, and they cannot be modified during the auction. The rules describe the mechanisms completely allowing for the determination of winners based solely on the bids. Lastly, neither the auctioneer nor any other party can change the rules or have discretion in the choice of the winner.

Depending on the difference in the auction rules, the following are typical variants of forward auctions (McAfee and McMillan 1987; Kagel 1995; Klemperer 1999):

(1) *Ascending* or English auction: This is an open-cry auction, in which the price increases until one bidder remains and the winner pays the final price;
(2) *Descending* or Dutch auction: The auction starts with a very high price that is reduced continuously until the first bidder calls out. This bidder wins the auction and pays the called price;
(3) *First-price sealed-bid* auction: Each bidder submits only one sealed bid. The bidder with the highest bid wins the auction and pays the price they bid; and
(4) *Second-price sealed-bid* or Vickrey auction: Each bidder makes only one sealed bid. The bidder with the highest price wins the auction and pays the second highest price.

Additional bidding rules may be set with regard to when to submit bids, thus distinguishing asynchronous (i.e. continuous) auctions and synchronous auctions. The sealed-bid auctions may also be extended to multiple rounds, which become iterated or multi-round sealed-bid auctions. These rules and typologies are also used in reverse auctions, wherein the roles between buyers and sellers are reversed.

Auctions can be classified based on the number of participants involved and the number of attributes of the transacted entity (i.e. product or service. Figure 2-2 shows the typical mechanisms for auctions.



One-to-many	Many-to-many
Multi-attribute auction	Multi-attribute double auction
Single-attribute auction	Single-attribute double auction

Figure 2-2. Auctions classified by number of participants and attributes

In a one-to-many transaction, one buyer hosts the auction and a number of suppliers submit bids, which is also called single-sided auction (e.g. eBay). Spot market, which allows both buyers and sellers to submit bids, supports the many-to-many type of transactions (e.g. commodities market).

Most auctions deal with a single attribute (i.e. price). In single-attribute reverse auctions (SARAs), the suppliers bid against each other on the price in order to sell a product or service to the buyer. They rely on the fact that the bidders know what is better for them and for the buyer, and that their interests are strictly opposite.

Several limitations of SARAs have been discussed in literature. Firstly, business transactions for procurement often involve more than one attribute (Burmeister, Ihde et al. 2002; Ferrin and Plank 2002; Teich, Wallenius et al. 2003). Secondly, price-only auctions make trading-off among different attributes impossible, resulting in inefficient deals (Strecker and Seifert 2004). This has led to the design of multi-attribute auctions (Che 1993; Milgrom 2000; Beil and Wein 2003; Teich, Wallenius et al. 2003).

In multi-attribute reverse auctions (MARAs), each bid contains a set of attributes. The overall value (e.g., utility, profit or revenue) of bids increases for the buyer but the corresponding value decreases for the bidders or suppliers until only one bidder remains (Bichler 2000; Beil and Wein 2003; Strecker and Seifert 2004). The bids may be compared and evaluated at the attribute level (specifications of the attribute values) or at an aggregated level (calculated total value of the bid), depending on the formulation of the buyer's preferences. The buyer's preferences may be explicit, implied or even unknown to the bidders (Chen-Ritzo, Harrison et al. 2005; Parkes and Kalagnanam 2005; Adomavicius, Gupta et al. 2009; Strecker 2010). Different information may also be revealed during the process (e.g. winning bids, admissible bids) through which the bidders may discover the buyer's preference. When an auction is closed, the winner is required to fulfill the exact specifications of the winning bid.

One mechanism used in practice is the buyer-determined auction; it is similar to SARA except for the rules of winner determination (Anderson and Frohlich 2001; Engelbrecht-Wiggans, Haruvy et al. 2007). The buyer reserves the right to determine the winning supplier by analyzing information other than the bids—some of which may be unknown to the bidders during the auctions (Engelbrecht-Wiggans, Haruvy et al. 2007; Haruvy and Katok 2007). Typical additional information includes the business characteristics of the suppliers (e.g. production capabilities and financial performance) and the previous or potential relationship with the suppliers. The bids are evaluated taking into account the specifications of the attributes, while post-auction communication is possible to obtain the additional information for final decision on the winner. That information is considered together with the bids in choosing the winner according to certain scoring rules. These auctions have led to some issues such as collusion and selection of inferior offers (Elmaghraby 2004; Katok and Wambach 2008).

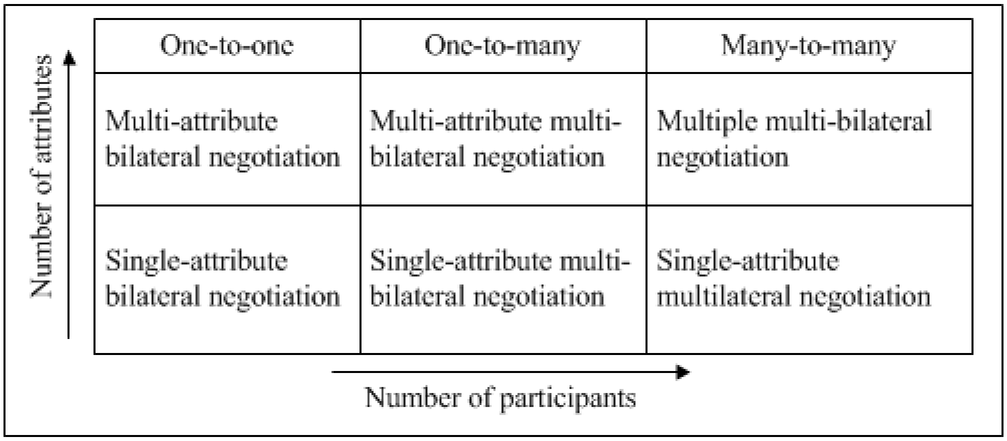
In procurement practice, tendering is also often used for contracting of products and services with non-price attributes (e.g. Quinnox, UK local government). It is also known as the first-price sealed-bid auction, where the buyer sends the specifications of the products to suppliers and requests quotes or bids. It may involve exchanges of documents related to the transaction; normally however, there are no iterations of bidding and thus no possibility to improve the bids (e.g. making trade-off among the attributes).

2.2.3 Negotiation mechanisms

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 time point while auction protocol has to be determined prior the auction begins and it cannot be changed during the auction process (Ströbel 2001; Kim and Segev 2003). This flexibility includes the participation of both sides (e.g. buyers and sellers) and their ability to exchange various types of information (e.g. partial offers, complete offers, and free-text messages) (Kersten and Noronha 1999; Ströbel and Weinhard 2003).

In procurement and contract negotiations, sellers 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.

Similar to auctions, negotiations may be distinguished based on the number of participants and attributes (Figure 2-3). Bilateral negotiations are one-to-one, that is, one buyer and one seller bargain for a deal. In many instances several sellers interact with one buyer with the purpose of providing the buyer with same product or service. The buyer chooses one or more sellers to award the contract. This is an example of multi-bilateral negotiation. In a more general situation, there are many buyers who interact with many sellers (many-to-many); this is a process called “multiple multi-bilateral negotiations”.



One-to-one	One-to-many	Many-to-many
Multi-attribute bilateral negotiation	Multi-attribute multi-bilateral negotiation	Multiple multi-bilateral negotiation
Single-attribute bilateral negotiation	Single-attribute multi-bilateral negotiation	Single-attribute multilateral negotiation

Figure 2-3. Negotiations classified by number of participants and attributes

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). The process can be either sequential (bilateral negotiation with one supplier after another) or parallel (bilateral negotiation with multiple suppliers simultaneously).

Sequential multi-bilateral negotiations have 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). ICT makes simultaneous negotiation possible (Kersten, Pontrandolfo et al. 2011) with decision aids supporting the negotiators' decision making and communication activities (Kersten and Lai 2007; Schoop, Köhne et al. 2008). This form of negotiation is comparable to reverse auctions in which multiple suppliers submit bids to the same buyer.

2.3 Multi-attribute auctions

Multi-attribute auctions are designed to deal with transaction problems that involve multiple attributes. There are two main concerns when designing multi-attribute auctions: (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. Relevant studies are reviewed to address these two issues, followed by a brief discussion about auction systems and decision support.

2.3.1 Preference representation and information revelation

There are two main types of preference representation methods (Fishburn 1976; Dieckmann, Dippold et al. 2009): compensatory methods, which include additive value functions or more complex utility functions based on multi-attribute utility theory (MAUT); and non-compensatory methods, which include attribute lexicographic ordering and the Tchebychev measure.

Compensatory methods are based on the assumption that decision makers' preferences are defined by both attributes and attribute values, and that they can formulate trade-offs (i.e. change of the value in one attribute accompanied by a change in value of another attribute). This assumption allows for the aggregation of preferences which measures the total worth of an alternative. There are several types of measures used in decision analysis, including utility functions which measure both preferences and risk attitude, and value functions which measure only preferences (Kenney and Raiffa 1976; Dyer and Sarin 1979). An often used type of value function is an additive scoring function.

Multi-attribute auction mechanisms have been designed using several scoring methods (e.g.

Bichler 2001; Beil and Wein 2003; Engel and Wellman 2010). One typical approach is the attribute monetization method (Parkes and Kalagnanam 2005); it expresses non-price attributes in monetary terms and then considers only two items in the valuation: price and monetized attributes (e.g. costs). Attribute monetization is the result of the standard assumption of multi-attribute auctions, which is that the buyer's and the sellers' utilities are quasi linear functions (Che 1993; Strecker and Seifert 2004; Bichler and Kalagnanam 2005).

Let's denote

$\boldsymbol{x} \in X \subset R^n$ – the set of alternative goods (services) described by n attributes;

p – price of the good;

I ($I = \{i=1, \ldots, M\}$ – set of sellers;

$V(\boldsymbol{x})$ – the value function of the good (service) $\boldsymbol{x}$ for the buyer; and

$C_i(\boldsymbol{x})$ – the cost function of producing and delivering good (service) $\boldsymbol{x}$ for seller i;

Given the above notation and assuming the value and cost functions are strictly convex, the quasi-linearity assumption means that the buyer's and the sellers' utility functions are of the form:

$U_b(\mathbf{x}) = V(\mathbf{x}) - p$ (for the buyer) and

$U_i(\mathbf{x}) = p - C_i(\mathbf{x})$ (for seller i, i=1, …, M, M—number of sellers),

The second and complementary standard assumption is risk-neutrality: both the buyer and the sellers must be risk-neutral so that they do consider price differently (e.g., assign different weights to price) and price p does not depend on the attributes of the good $\boldsymbol{x}$.

Quasi-linearity and risk-neutrality assumptions allow for the consideration of value and costs in the same monetary terms as price (Krishna 2010). The implication of these assumptions is that efficient (i.e., Pareto-optimal) winning bids also maximize social welfare (expressed as the sum of the buyer and the winning bidder utilities) and assure that the auction mechanism is allocative efficient.

Approaches that do not relay on the quasi-linearity and risk-neutrality assumptions of the auction models have also been proposed. They include models based on non-compensatory decision-making and utilities based on the Tchebychev measure. These models can be used to evaluate bids at the attribute level but not between the attributes. Two well-known methods are: lexicographic ordering and the Tchebychev function. Lexicographic approaches are simple heuristics in which the attributes are ordered from the most important to the least important. The alternatives are compared first using the most important attribute. If they differ on this attribute then the more preferred alternative is selected. If they do not differ on this attribute, then the second most important is used, and so on. These heuristics were found to perform well and sometimes better than a compensatory method (i.e., conjoint analysis) in ranking of alternatives but not in rating them (Dieckmann, Dippold et al. 2009). In their study as well as earlier studies (e.g. Dhar 1996) the participants were given little time and needed to choose from among several alternatives. When participants were given more time and could explore information, as well as when the problem was more complex (i.e., measured by the number of attributes and alternatives) compensatory models outperformed lexicographic strategies (Yee, Dahan et al. 2007). If the number of alternatives is large, then lexicographic models may fail because they do not allow for differences in values of several attributes of lower importance to outweigh a small difference in the value of a single more important attribute.

Bellosta et al. (2004) proposed the use of Tchebychev distance to represent the buyer's preferences. The non-compensatory character of this distance allowed the authors to suggest a feedback rule based on attribute values. The sellers 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. In another study, Bellosta et al. (2008) proposed MERA, a procedure for mechanism design for both synchronous and asynchronous multi-attribute reverse auctions in which, in addition to the Tchebychev distance, lexicographic ordering and weighted sum function could be incorporated. The framework relies on the notion of reservation levels for which constructing the preference aggregation method is used.

Another common and related concern in multi-attribute auctions pertains to information that is revealed to the bidders. The minimum requirement for information revelation is that the information be sufficient for the bidders to make progressive bids, i.e., consecutive bids that are increasingly better for the buyer. The revealed information may be directly or indirectly related to the buyer's preferences.

Studies have put much effort in designing the rules with regard to information revelation in auctions, including: disclosure of the complete value function of the buyer (Bichler 2000; Chen-Ritzo, Harrison et al. 2005), winning bids (Koppius and Heck 2003; Strecker and Seifert 2004), bids from all bidders (Koppius, Kumar et al. 2000; Koppius and Heck 2003), aggregated value of bids (Adomavicius, Gupta et al. 2009), and constraints on bids (Bellosta, Kornman et al. 2008; Strecker 2010). The efficacy and impact of the proposed rules were experimentally studied. These studies have shown that information revelation affects a bidder's bidding strategies, market competition, and both transactional and relational outcomes.

In the framework proposed by Bellosta et al. (2008), the information imparted by the buyer depends on the way she represents her preferences. When the representation includes a linear additive utility function, then the owner passes this utility and its lower bound. When the preferences are represented as a lexicographic aggregation model or a Tchebychev function, then the owner passes bounds imposed on the attribute values. This dependency is difficult to implement when the buyer does not make her preference model public, as is often the case (Burmeister, Ihde et al. 2002; Parkes and Kalagnanam 2005).

2.3.2 Auction systems and decision support

Auctions as mechanisms are implemented in market systems (Smith 1982). One such popular system with standard English auctions is e-Bay (Hasker and Sickles 2010). In e-procurement, reverse auctions are conducted online, i.e. online auction or electronic auction (e-auction).

The main purpose of economic studies is to design general models for solving economic problems and to verify theoretical predictions with efficient solutions. The auction mechanisms are thus either designed and proved with abstract models or implemented and tested within rudimentary systems. Additional models (e.g. decision support) and features (e.g. fancy user interface) are not required and even prevented in order to maintain the simplicity and generalizability of the models. Moreover, users' behavior is mainly prescribed by their preferences, constraints and objectives, which have been considered as parameters to control and automate the bidding process. Research in computer science has put much effort into automating the auction process (Jennings, Faratin et al. 2001). Empirical studies, however, have shown user heterogeneity in terms of their bidding strategies and behavior and suggested to provide decision support in auctions (Bapna, Goes et al. 2004).

In standard single-attribute auctions the information about buyers and sellers preferences is transparent so that the bidders are able to make admissible bids without difficulty. The bidders may be provided with basic support tools such as the history of bids in tables and/or charts (e.g. eBay, stock exchanges).

In multi-attribute auctions, the problems are more complicated due to the availability of many alternatives and the implicitness of the buyer's preferences. The bidders are allowed to make trade-offs among different attributes and are also required to make progressive bids. If the buyer's preferences are completely disclosed, then tools supporting the generation of admissible bids and the calculation of their values are helpful (e.g. Bichler 2000; Chen-Ritzo, Harrison et al. 2005; Strecker 2010). However, if the buyer's preferences are not explicitly provided, then more advanced supporting models and tools are required, such as the identification of admissible bids based on the bound values on each attribute, evaluation of bids based on values of each attribute and visualization of bidding process.

2.4 E-negotiations

Negotiation is a decision making process in which two or more parties exchange ideas and offers in order to resolve initial differences in preferences (Lewicki, Saunders et al. 1997). Research in negotiation is very rich; it has been conducted within anthropology, history, political science and psychology among others. This research deals with negotiation mechanisms used in e-procurement, that is, the adoption of information technologies and systems supporting negotiations for procurement. The review focuses, therefore, on aids and support tools used in e-negotiations.

With the advanced development of Internet technologies, negotiations can be conducted online, i.e. e-negotiations. They are conducted via e-negotiation systems (ENSs), which support, facilitate and mediate negotiations (Kersten and Lai 2008). A number of ENSs have been developed, in which different models are implemented to provide various support (Kersten and Noronha 1999; Schoop and Quix 2001; Thiessen 2002; Yuan, Head et al. 2003).

2.4.1 Problem, negotiator, and process models

Negotiation analysis provides a theoretical basis for the design of support tools embedded in e-negotiation systems; it is concerned with modeling of negotiation problems and processes (Sebenius 1992; Raiffa, Richardson et al. 2002). It is distinct from purely theoretical models based on the assumption of perfectly rational behavior, and also advances in supporting negotiators rather than merely explaining their behavior. Kersten and Lai (2007) identified the following three types of models used in negotiation support:

(1) *Model of the negotiation problem* identifies and describes the problem structure (e.g. attributes, bounds, constraints and alternatives);
(2) *Model of the negotiator* describes the negotiators (e.g., objectives, preferences and constraints);
(3) *Model of the 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).

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 (Hordijk 1991).

Negotiator's model includes preference representation as discussed in Section 2.3.1. This model 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) (Watkins and Passow 1996; Raiffa, Richardson et al. 2002). Depending on the negotiator's preferences and objectives, the negotiation may be distributive or integrative (Walton and McKersie 1965; Hobson 1999; Kersten 2001). Distributive negotiation means the parties involved are sharing a "fixed pie," also known as a "win-lose" situation. Integrative negotiation involves the creation of value and openness of information exchange which ends up with a "win-win" situation.

Kersten and Noronha (1999) used conjoint analysis to construct a pairwise linear value function. This method, which was designed in marketing research (Green and Srinivasan 1978) is simple and robust. It has been implemented in several ENSs (Kersten and Noronha 1999; Kersten and Lo 2003).

Köhne et al. (2004) evaluated three methods of preference elicitation: self-explicated approach, conjoint analysis and analytic hierarchy process. Each has been suggested for use in dealing with different negotiation situations, considering the number of attributes, change of preference and change of problem (e.g. adding new attribute). They called for several issues related to preferences in negotiation support: problem complexity, dynamics of preferences, and dynamics of problem structure itself.

Bui et al. (2001) used a combination of utility theory and multi-criteria decision making to propose heuristic algorithms for multi-attribute transactions in e-markets. They also incorporated market information, including: current market activity, price trends and other parties' alternatives. Together, they may lead to a more efficient and transparent market.

Based on behavioral studies of negotiations, several negotiation process models have been proposed (Gulliver 1979; Holmes 1992; Ghee-Soon Lim and Murnigham 1994). In general, there are three sequential phases in negotiation: pre-negotiation, negotiation, and post-negotiation. *Pre-negotiation* refers to the initial planning period. Before initiating a negotiation, negotiators prepare and identify their preferences. *Negotiation* phase is when the negotiation takes place, negotiators exchange offers and messages in order to reach an agreement. *Post-negotiation* is the process where the agreement (contract) is verified and, if possible, improved, and finally is implemented.

2.4.2 Negotiation systems and negotiation support

In every ENS at least one of the three types of models (problem, negotiator and process) is implemented, i.e. the process model through which the negotiators interact with each other online. Some systems also include two other types of models (i.e. negotiator and problem).

It has been noted that computer-based negotiation systems provide support for decision making (based on a problem and/or negotiator models) in addition to support for communication (based on a process model) (Lim and Benbasat 1992). Inspire (Kersten and Noronha 1999) and SmartSettle (Thiessen 2002) are two examples of systems which implemented all three of these models, including preference elicitation and representation, alternatives comparison and decision making, and offer/message exchange. Some systems may focus on communication support, such as messaging, multimedia, documentation, and coordination (Yuan, Rose et al. 1998; Schoop and Quix 2001).

Inspire provides support to negotiations through three pre-defined phases (Kersten and Noronha 1999): preparation, negotiation and post-settlement:

(1) In the *preparation* phase, Inspire assists users to prepare for the negotiation by helping them to understand the negotiation problem, the main negotiable issues and their options (issue values), and provides some possible packages (which may form the basis of offers and counter-offers). Using a conjoint analysis method, the system helps users in preference

elicitation by specifying the rating of issues and options and the ratings of packages. This enables users to specify the importance of the interrelations within the issues and to verify their overall preference, through which the system constructs the value function for each user;

(2) During the *negotiation* phase, the users negotiate by constructing and exchanging messages and/or offers. They can communicate using free text messages and offer packages—each offer contains user-selected options for every negotiable issue. Based on the user's preferences, the system calculates the values (ratings) of alternatives considered by the user and offers submitted by each party. Users also can review the negotiation process in a text-table list and also with graphical dynamics. The offer-history graph depicts the offers from both the user and the counterpart during the negotiation time span; the ratings of the offers are calculated based on the user's preferences;

(3) Once an agreement has been achieved, the Inspire system checks for the agreement's efficiency. If it is an inefficient compromise, the system presents the efficient alternatives and the users may continue their negotiation in the *post-settlement* phase until they reach an efficient compromise. It also provides the nego-dance graph for an overview of the negotiation process, in which all offers are depicted based on both parties' preferences.

These three phases are also implemented in SmartSettle (Thiessen 2002). Both Inspire and SmartSettle facilitate the discussion of multiple issues simultaneously, i.e. each offer is a selected alternative which contains the value for each attribute. This allows the negotiators to make trade-offs among different issues.

WebNS supports negotiations via various communication means (Yuan, Rose et al. 1998). It mimics face-to-face negotiation in an online environment and distinguishes between two phases (preparation and negotiation). The system facilitates communication using short messages, real-time chat, and video conference within dialogue windows. The parties then discuss each issue separately without consideration of trade-offs. When they reach an agreement on one issue, they discuss the next issue, and so on.

In all of the above three systems, an agenda of the negotiable issues needs to be set up by all parties before conducting the negotiation (i.e. in the preparation phase). Two other systems allow the negotiators to add new issues during negotiation.

INSS, an extension of Inspire, supports business partners to negotiate over open and dynamically modifiable problems (Wu, Kersten et al. 2006). The system allows problem specification and issue modification during the negotiation phase. The negotiator's preferences of new issues can be elicited using the conjoint analysis method, while the rating value of new alternatives can be automatically calculated based on the preferences on existing alternatives.

Negoisst attempts to enable complex negotiation between human negotiators by relating a document management component to a communication system (Schoop and Quix 2001). The system provides categories that can be selected to form the structure of a contract. Through the negotiation, semi-structured message contents are obtained, in which the system defines categories for part of the message content while a message body with free text remains. The final contract is composed of these contents (issues and clauses).

These systems do not automate the negotiation but support the decision making procedure for reaching joint acceptance by providing communication means and analyzing available information. Bilateral multi-attribute negotiations can be conducted in most of the existing systems, while other types of negotiations (e.g. multi-bilateral and multilateral) are basically supported with communication technologies in which mediators need to be involved. E-procurement, which often involves multiple suppliers, requires advanced support such as communication simultaneously and instantly with the suppliers, decision analysis of offers from different suppliers and visualization of the negotiation process.

2.5 Mechanism design and implementation

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, such as preference representation and information revelation. These models are then implemented in concrete systems with other supporting models and tools, such as analytical support and visualization support. In a review of e-negotiation systems, Kersten and Lai (2007) 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.

In this section, mechanism design in economics and system design in information systems are linked to address the issues in mechanism design and implementation. The Invite platform which supports the implementation of varies mechanisms is then introduced.

2.5.1 Mechanism design and system design

Markets and market mechanisms have been the interest of economists, particularly those who study auction theory (Milgrom 2004), experimental economics (Smith 2003), and market design (Roth 2002). A general market system involves economic environment, individual preferences and behavior, mechanism, outcomes and performance (Smith 2003). Auction theorists use mathematics and logic to design various types of auction models (i.e., mechanisms) and study their features (e.g. Gächter and Riedl 2005; Gallien and Gupta 2007; Engelbrecht-Wiggans and Katok 2008).

Economists seek mechanisms which are incentive compatible; that is, the bidders can achieve the best possible result when they truthfully reveal all private information the mechanism requires (Maskin 2007). Typically the market participants are assumed to behave according to the economic theory axioms (i.e., rationality, risk aversion, opportunistic behavior). Furthermore, they are homogenous with the exception of their endowment (e.g. funds available) and preferences.

In behavioral economic research, the main purpose is to design and experimentally validate market mechanisms which are implemented in the simplest form of information systems. In these systems, the embedded model (i.e. the mechanism) is of main concern, and user interface and system features are not the focus due to the homogeneity of market participants. The effort is to use mechanism, which are as much as possible devoid of any additional features due to user interface, data visualization tools or decision support aids.

From the information systems (IS) view, e-procurement is an IT artifact in which market mechanisms are implemented and which also includes many components that help its users using these mechanisms and conduct auxiliary activities. A number of such artifacts or systems have been developed to support e-procurement transactions (Croom and Brandon-Jones 2005; Minahan 2005; Talluri, Narasimhan et al. 2007).

Design science approach has been adopted in IS research to study the process, methods and models that can be used to build artifacts (March and Smith 1995; Hevner, March et al. 2004). A number of guidelines has been provided with some exemplars (Hevner, March et al. 2004; March and Storey 2008). It 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” (Walls, Widmeyer et al. 1992; Livari 2003). 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, requiring different design and implementation. When implementing auction and negotiation mechanisms in e-procurement systems, they become different types of systems.

Vahidov (2006; 2012) suggested that a “what” (e.g. what type of systems) question may need to be specified or answered before asking the “how” question. He thus proposed a framework for structuring representation of IT artifacts with two dimensions: perspectives and categories. Systems can be represented from four perspectives or layers, including: analytical, synthetic, technological, and implementation. They can also be categorized depending on their motivation, structure, behavior, and instantiation. This framework has been applied to represent e-negotiation systems (see Chapter 7 in Vahidov 2012).

2.5.2 Invite platform and mechanism implementation

Different mechanisms can be implemented in the same environment or platform to build different e-procurement systems with the same user interface. Only a few platforms support the implementation or deployment of different mechanisms. For instance, CNSS (Benyoucef, Alj et al. 2001), SilkRoad (Ströbel 2003) and Meet2Trade (Weinhardt, van Dinther et al. 2005) support various auction mechanisms by setting different parameters. Invite (Kersten, Law et al. 2004; Kim, Kersten et al. 2006) was initially developed to support negotiation mechanisms but recently has been extended to support auction mechanisms (Kersten, Pontrandolfo et al. 2011; Kersten, Pontrandolfo et al. 2012).

Invite is designed as a typical three-tier Web application illustrated in Figure 2-4. It is based on a database management system in the persistency layer, a Web-enabled application server in the business logic layer, and Web browser technology in the presentation layer.

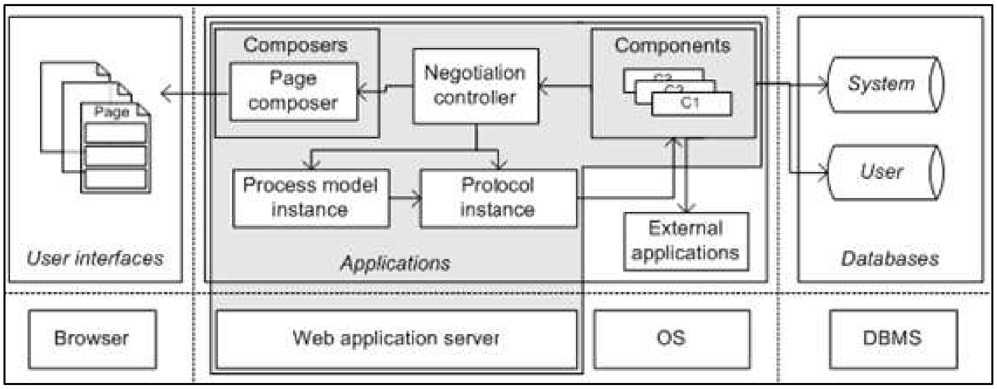


Figure 2-4. Architecture of the Invite platform (Kersten, Law et al. 2004)

The Invite platform separates user data from system data into two databases, i.e. the system and user database. This facilitates model implementation and data analysis. The platform consists of the negotiation controller, page composers and components that together determine and generate model instances, protocol instances and user interfaces.

Design patterns are "descriptions of communicating objects and classes that are customized to solve a general design problem in a particular context" (Gamma, Johnson et al. 1994, p. 13). The Invite platform adopts a Model-View-Controller (MVC) design pattern which has its roots in Smalltalk (Reenskaug 1978-79; Burbeck 1987), incorporating the transitions and rules (controllers), functional elements (models), and information representation and user interface (views). Figure 2-5 demonstrates the Invite platform with MVC design.

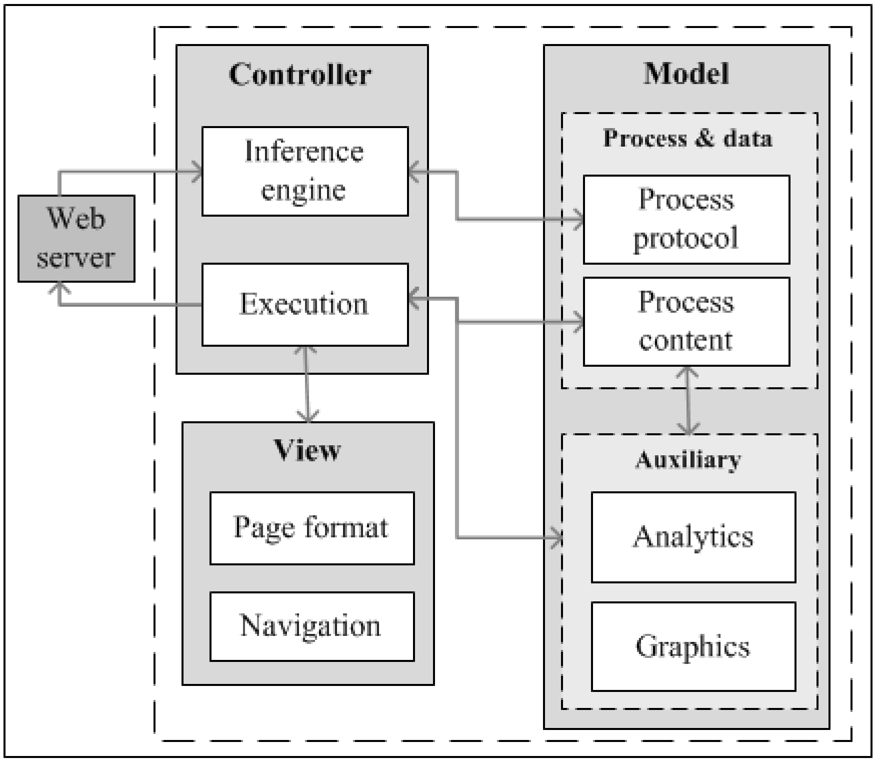


Figure 2-5. MVC design of the Invite platform (Kersten, Pontrandolfo et al. 2011)

The *model* represents data and the logic that governs access to and updates of this data. The *view* specifies how the data contents of a model should be presented. The *controller* translates interactions with the view into actions to be performed by the model. Based on the user interactions and the outcome of the model actions, the controller responds by selecting an appropriate view.

This design allows for the separation of the user interface from the embedded process models and execution rules. The mechanisms which incorporate the actions, interactions and their rules in a process can be decomposed into activities, procedures and rules; different configurations or sets of these elements are instantiations of these mechanisms. The user interface can be decoupled and implemented with different technologies, resulting in different system features such as tabular or graphical views of bids or offers.

Invite adopts a component-based software development approach. This allows extending or adding components to the component-base and assembling selected components for the design and deployment of many different protocols depending on the protocol specification. The rules are implemented with a database-driven approach (Wu 2009).

The underlying theory of transaction protocol design and implementation allows system designers to implement various mechanisms by configuring and reusing MVC components (Kersten and Lai 2007). A variety of mechanisms can be implemented in this platform, including: bilateral negotiations, multi-bilateral negotiations, and single-attribute or multi-attribute auctions.

2.6 Empirical studies: Use, impact and assessment

E-procurement systems are concrete implementations of different market mechanisms that are supported with other system components. Mechanisms may be implemented in different ways and generate different systems. The differences between systems in terms of their design characteristics and implemented models may affect system usage and outcomes (Benbasat and Zmud 2003). The study of the ways a system affects its users' behavior is the concern of, among others, information system research (Orlikowski and Iacono 2001; Benbasat and Zmud 2003).

E-auctions and e-negotiations have been used for business transactions. Empirical studies have investigated the determinant factors of adoption and use of such technologies and systems. Both economic indicators and subjective measures have been used in assessment of their use and outcomes. In Section 2.6.1 and Section 2.6.2, the empirical studies on the use, impact and assessment of e-auction and e-negotiation are discussed respectively.

2.6.1 E-auction use, impact and assessment

Empirical research on e-auctions has examined the factors that affect system use and assessment, including: users' perceptions and attitude (Quaddus, Xu et al. 2005; Stern, Royne et al. 2008; Tassabehji 2010), information technologies and security (Vesa and van Heck 2005; Hartley, Lane et al. 2006), buyer-supplier relationship (Tassabehji, Taylor et al. 2006; Lösch and Lambert 2007; Pearcy, Giunipero et al. 2007) and behavior (Heyman, Orhun et al. 2004; Carter and Kaufmann 2007; Hasker and Sickles 2010).

Several studies have adopted and extended the Technology Acceptance Model (TAM) (Davis 1989) and Theory of Planned Behaviour (TPB) (Ajzen 1991) to investigate users' perceptions and attitude in e-auction use. In addition to the original cognitive TAM variables (i.e. perceived usefulness, perceived ease of use, behavior intention), Stern et al. (2008) considered three new consumer-oriented variables: *affinity with the computer*, *impulsiveness*, and *risk tolerance*. They analyzed the data collected from eBay and found that the extended model can be used to explain consumer behavior in online auctions. Quaddus et al. (2005) developed an integrative adoption model based on TPB to study the adoption of e-auctions in China. The results indicate that the use of online auctions for buying was affected by subject norms, trust and behavioural control, but not by personal innovativeness and attitude. Recently, Tassabehji (2010) investigated the factors that affect e-auction use in procurement practice. The data was collected using an online survey from senior procurement professionals in various industries. The results indicate that e-auction use for procurement is not only suitable for optimising prices but also for building relationships with suppliers. It also shows the professionals' resistance to use e-auctions and suggests using these systems in a more strategic way.

Research has examined other factors of e-auction use and resistance. Hartley et al. (2004)

compared adopters and non-adopters of e-auctions using survey data from purchasing managers. The results show that no differences between them on the level of importance placed on the purchasing objectives of cost management and on supplier collaboration. It shows significant difference considering organization size, where the adopters have higher annual sales than non-adopters. They suggest that e-auction use and supplier collaboration are not mutually exclusive. Vesa and van Heck (2005) analyzed five consumer auction markets in Finland and determined four factors affecting the adoption of multi-access technologies: *perceived appropriateness of a given multi-access technology*, *media richness of various multi-access technologies*, *support of multiple modes of communication relationships*, and *the level of experience in using multiple marketing channels*. They suggest that media richness and the ability to provide multiple modes of communication relationships stimulate the adoption of multi-access technologies. Hartley et al. (2006) addressed the perceived barriers to e-auctions in American buying organizations. Based on the literature and case studies in eight companies, they developed four propositions with measures: *lack of e-auction knowledge*, *lack of supplier participation*, *information security concerns* and *importance of supplier relationships*. The analysis of survey data shows that e-auction adopters perceived information security to be less of a concern than non-adopters. However, there was no difference between adopters and non-adopters on other factors.

Buyer-supplier relationship has also been considered in empirical studies. Pearcy et al. (2007) studied the effects of existing buyer-supplier relationships on reverse auction usage. The results show that such relationships lead to supplier cooperation in the auctions, while auctions focusing on the transactions lead to lower purchase prices and higher procurement productivity. Lösch and Lambert (2007) adopted a grounded theory approach to analyze comprehensive data from business buyers and suppliers who were users or non-users of reverse auctions. They found that reverse auctions led to positive buyer-supplier relationships when a high valuation of types and sources of information were combined with high quality information exchange and communication. Tassabehji et al. (2006)

examined reverse auctions in the UK packaging sector with case studies and interviews. The results show that the benefits of using such auctions to suppliers are less obvious than to the buyers on short-term price reductions. No evidence was found in terms of the reductions of overall transaction costs for either buyers or suppliers.

Other studies also examined bidders' behavior when using e-auctions. Carter and Kaufmann (2007) investigated the mediating effects of relationship variables in e-auction use and outcomes, particularly the perceptions of opportunism. They found that opportunism would harm supplier relational performance (e.g. trust and commitment). Heyman et al. (2004) examined the effects of quasi-endowment and opponent behavior in e-auctions. The findings show that such effects may result in over-bidding and repeated bidding, while sniping was observed in second-price online auctions such as eBay. The cheating and fraud in auctions have also been observed (Jenamani, Zhong et al. 2007). The study indicates that adoption of rational bidding strategies can combat cheating.

Hasker and Sickles (2010) reviewed the economic literature on eBay auctions, in particular, the behavior of buyers and sellers. They discussed bidder behavior and proposed estimates to measure the consumer surplus. The also analyzed the trustworthiness of eBay sellers and the effects of the feedback system on bidder behavior.

2.6.2 E-negotiation use, impact and assessment

E-negotiation research has empirically investigated the determinant factors of acceptance and use of ENSs. Vetschera et al. (2006) presented an integrated model to analyze factors that affect users' assessment of systems. The results show a positive relationship between users' assessment and their intention to use such system. Lim (2002) conducted an experiment involving executives and managers in Singapore and found that the acceptance of systems mainly depended on the subjective norm and perceived behavioral control. Wang et al. (2010) investigated negotiators' satisfaction in the e-negotiation context. The results show that negotiators' satisfaction was affected by their objective confirmation and their perceptions of fairness, control and collaborative atmosphere.

Other studies also found that positive disconfirmation (i.e. users' actual experience in using system exceeds their expectations) (Doong and Lai 2008) and perception of the counterpart's intention to engage in e-negotiations (Turel and Yuan 2007) positively affect negotiator's intention to use ENSs.

The participants in e-negotiations are the users of ENSs. Empirical studies have shown that users' characteristics, such as experience, gender, culture and prior relationship, affect their use and perception of system features (Koeszegi, Vetschera et al. 2004; Koeszegi, Pesendorfer et al. 2006; Vetschera, Kersten et al. 2006; Lai, Lin et al. 2010). The results show, in general, that experienced negotiators reached a better outcome and female negotiators were more cooperative than male negotiators. Female and eastern culture negotiators were found to provide more information about their needs by exchanging more messages, while negotiating in native-language led to higher negotiation self-efficacy and thus more persuasion behavior. In addition, existing relationships may lead to more strategies for value creation in dealing with increased conflict and difficult situations.

Research has also investigated the effects of negotiators' objectives, orientations and strategies. Recent exploratory studies (Kersten, Wu et al. 2011; Wu, Kersten et al. 2012; Kersten, Gimon et al. 2013) have shown that the participants in e-negotiations may have different types of objectives, including: substantive objectives that focus on transactional and economic outcomes, relational objectives that focus on relationship building and development, and other objectives related to their tasks. Negotiators with different objectives behaved differently and thus reached different outcomes. Kersten and Wu (2010) identified the negotiators' profiles based on the Thomas Kilmann Instrument (Thomas and Kilmann 1974) and then examined their effects on concession patterns and values. The results show joint effects of negotiators' profiles and their gender and negotiation knowledge affected their aspiration levels and behavior. Profiles and opening-offer were found to jointly affect concession pattern and value.

Lai et al. (2006) compared cooperative and non-cooperative strategies in e-negotiations. They found that the non-cooperative negotiators submitted more offers but fewer messages and perceived less control over the process than the cooperative negotiators. Also, cooperative negotiators felt that the process was friendlier and they were more satisfied with both the agreement and their own performance. The likelihood of reaching an agreement was higher for the cooperative group than for the non-cooperative group.

Aside from the amount and type of information exchange, negotiator's behavior has also been examined through content analysis of the negotiation transcripts (Koeszegi, Pesendorfer et al. 2011). This helps to analyze the actual phases, activities and dynamics in negotiation process. Empirical results have shown the different communication modes and negotiation strategies in different phases (Pesendorfer, Graf et al. 2007).

3. Research Roadmap

A roadmap is presented to organize this research, including: the research framework and the purpose and approach of the three studies.

3.1 Research framework

Several implications can be drawn from the literature of mechanisms in e-procurement:

(1) Much effort has been put into designing various mechanisms to solve multi-attribute auction problems. However, feasible mechanisms that meet both the buyer's and the suppliers' needs with regard to preference representation and information revelation are not available. Specifically, mechanisms are needed that allow for context-dependent control of information revelation by the buyers and for information revelation to be independent from preference representation.

(2) Auctions and negotiations differ both in theory and practice. However, the similarities of multi-attribute auctions and multi-bilateral negotiations and their complementarity need to be recognized.

(3) Normative guidelines proposed for mechanisms selection need to be validated in procurement practice. Results from experimental economics have been used to design and validate market mechanisms. The design science approach can be used to build e-procurement systems and IS research to study their use and the usage outcomes.

(4) Empirical comparison of mechanisms has focused on single-attribute auctions and bilateral negotiations. There is a need to compare multi-attribute auctions and multi-bilateral negotiations.

(5) Effects of different mechanisms in terms of their design and implementation have been examined. Both economic measures and subjective measures have been used.

The above research implications motivate the present research to: (1) design and implement multi-attribute market mechanisms in e-procurement; and (2) compare these mechanisms within different transaction contexts. The goal is to reach a better understanding of how to successfully conduct e-procurement. Towards this goal, a framework is proposed that guides the present research in design, implementation, use and assessment of market mechanisms. The framework is presented in Figure 3-1.

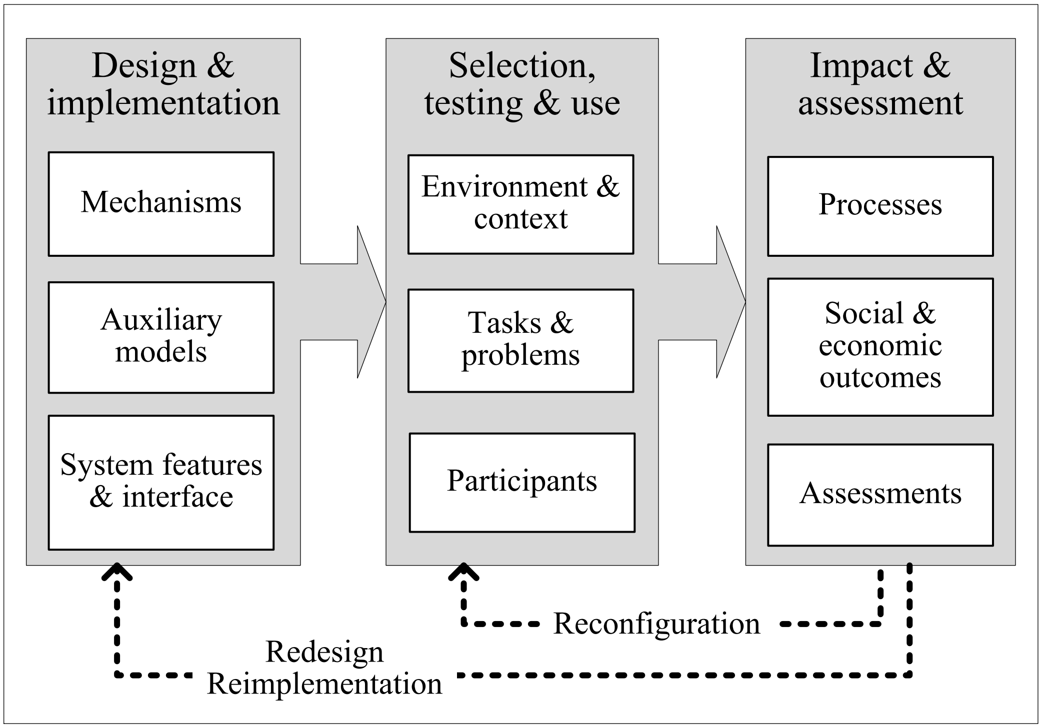


Figure 3-1. Research framework for mechanism design, implementation and use

This framework is derived from the Times model (Kersten, Chen et al. 2008) by incorporating different mechanisms, systems, transactions and participants in a contingency and dynamic view. It considers both the internal components of systems (i.e. mechanisms and auxiliary models) and the surrounding factors of system use (i.e. participants and problems). The selection and use of these mechanisms and systems may lead to different outcomes and assessments, which can be used to redesign and reimplement the internal components and reconfigure them with external factors. Detailed description of the framework is given below.

The design and implementation of market mechanisms and other supporting models result in different e-procurement systems. Two types of mechanisms have been designed: multi-attribute reverse auction (MARA) and multi-attribute multi-bilateral negotiation (MBMN). Specifications of information revelation rules and other design parameters allow us to derive many concrete mechanisms from these two classes.

In MARA, information rules concern the level of revelation (admissible bids, winning bids, all bidders' bids and bidder's profile), time of revelation (before, during and after auction; before and after rounds) and differentiation (to all bidders, active bidders, certain groups of bidders, or winners only). Note that information exchange in auctions is mainly one-way (i.e. bidders submit bids) with formal proposals (bids with alternatives for contract). Buyers do not participate during the auction process, and the information conveyed from buyer to bidders is automatically generated and announced to all bidders. In MBN, the information rules are similar to MARA whereas information can be exchanged in one-way (i.e. no offers from buyer) or two-way (i.e. both buyer and suppliers can make offers), and with formal proposals (i.e. offer package with values on all attributes) or informal communication (i.e. free-text messages). Buyers actively participate in the process and can customize and send different offers and/or messages to different suppliers.

The Invite platform was used to build two systems in which the mechanisms are implemented. MARA was implemented in the Imaras system (InterNeg multi-attribute reverse auction system) while MBMN was implemented in the Imbins (InterNeg multi-bilateral negotiation system). The implementation and use of these two mechanisms are supported with the auxiliary models, including: analytical support (e.g. bid/offer comparison and analysis), communication support (e.g. messaging) and visualization support (e.g. graphical display of bids/offers through auction/negotiation process).

These systems can be used for different transaction problems in various contexts by the market participants. Recent IS research in studying system use has suggested to take into account the interaction between users, the system and tasks involved (Burton-Jones and Straub 2006; Barki, Titah et al. 2007). Several dimensions that can be used to differentiate e-procurement problems have been identified in Section 2.2.1. Other differentiating characteristics of problems include levels of complexity and time length allocated to obtain a solution (i.e., contract). The context in which e-procurement takes place may include different number of suppliers.

The participants in procurement transactions may vary in their preferences, constraints, and reservations. Their objectives may be more substantive (e.g. revenues, costs) or relational (e.g. strategic partnership). They may also have different strategic orientations and thus employ different approaches in the transactions, such as, competitive (i.e. focusing on self-gains and against those of others) and cooperative (i.e. considering both self and others with the intention of reaching a better joint outcome).

The framework illustrated in Figure 3-1 takes into account both the conditional and joint effects of typical entities involved in procurement on the outcomes. It also includes the participants' assessment of the process, outcomes and system. The outcomes and assessments are examined at both the individual and transaction level, including: (1) economic outcomes (e.g. revenue, profit) and relational outcomes (e.g. joint gains, business relationship), and (2) participants' assessments (e.g. subjective evaluation of process, outcomes and system).

The results of using various systems within different contexts and participants may suggest an alignment or misalignment among these factors, i.e. under certain circumstances the selection and utilization (of *which* system by *whom* for what *problem*) will reach better or worse outcomes and assessments. The observation of the system usage and the outcomes and assessments may provide information to:

(1) Redesign the mechanisms with different parameters and rules;
(2) Reimplement the mechanisms with different models and technologies;
(3) Reconfigure the factors in system selection and use with different systems, participants and problems.

Through these iterations, more feasible and appropriate mechanisms can be designed, implemented and identified for certain participants and transactions, which can be used to guide and improve e-procurement practice.

3.2 Purpose and approach of the three studies

The literature review indicates a need for effective multi-attribute mechanisms in e-procurement. For e-procurement to be successful, an alignment between the design of the mechanisms and the context in which they are used is required. Accordingly, the following two main questions are addressed in this research:

- *How to design and implement feasible mechanisms for e-procurement which involves multiple attributes and multiple suppliers?*
- *Under what conditions will certain mechanisms outperform the other types?*

These two questions are answered through two complementary approaches: design science research and experimental research.

In Section 2.5, the interplay between mechanism design and design science in IS research was discussed. In this research, the design of mechanisms follows the results coming from economic studies and market design. Economic and market research provide process models which can be embedded in e-procurement systems.

A model (mechanism) may be implemented in a system in different ways and it may be accompanied by various aids and tools. The first study applies a design science approach in designing and implementing two types of mechanisms that can be used in e-procurement (Figure 3-2). This study, i.e. Study 1, is presented in Section 4.

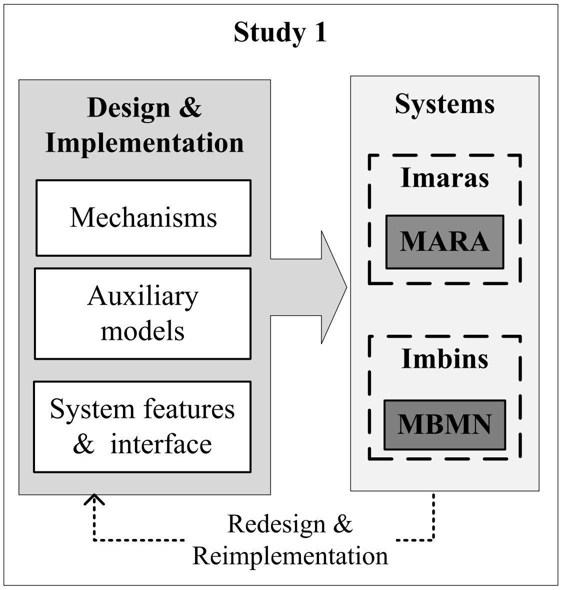


Figure 3-2. Conceptual model for Study 1

Empirical studies on auctions and negotiations in e-procurement were reviewed in Section 2.6. In particular, experimental research was conducted in the comparison of mechanisms and in the use and assessment of e-auctions and e-negotiations. Well-designed experiments can represent causalities without losing the reality and generalizability by carefully manipulating the independent variables (Kerlinger and Lee 2000; Colquitt and Gainesville 2008). In the second part of the present research, the use of different mechanisms and systems in various procurement situations are experimentally investigated.

The components of the research framework shown in Figure 3-3 are considered in the experimental research, comprising two studies. Study 2 examines the effects of three different information rules in multi-attribute auctions (Section 5). Study 3 compares multi-attribute auctions and multi-bilateral negotiations with the two systems (Section 6). The experiments and treatments are highlighted in the darker boxes in Figure 3-3.

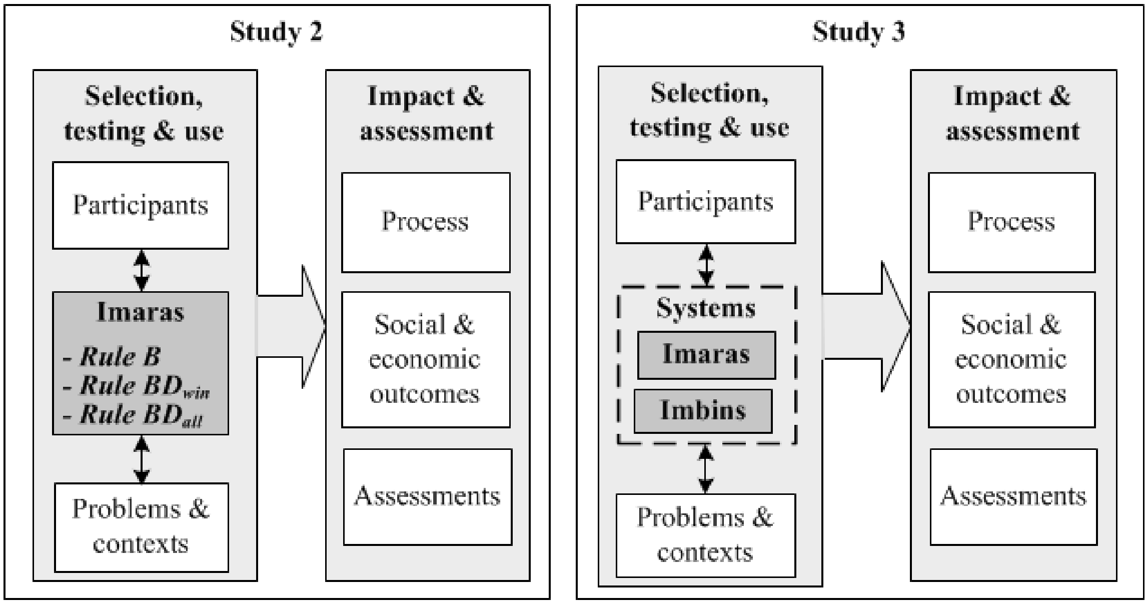


Figure 3-3. Conceptual model for Study 2 and Study 3

Moreover, the participants and transaction problems are controlled and manipulated in the experiments. These treatments together can be considered as different configurations, which may lead to different outcomes and assessments.

During the transaction process, the participants interact with each other using the systems. The process may change the participants' perception and attitude towards their objectives, the systems they use, and the counterparts they interact with. The information exchanged (e.g. number of bids/offers) and the time spent (e.g. the time it takes to reach agreement) can also be observed and compared.

The findings of these experiments may provide insights into revising the mechanism design, implementation and selection.

4. Study 1: Design and Implementation of Multi-attribute Mechanisms

4.1 Introduction

Business-to-business (B2B) transactions have been advanced by the rapid development of information and communication technologies (ICTs). E-procurement is a key area of B2B and supply chain management in which catalogs and reverse auctions have been widely used (Anderson and Frohlich 2001; Jap 2003). On average, about 70% of corporate revenue is spent on purchasing; savings of 5% can translate into hundreds of millions of dollars (Peleg 2003; Wagner and Schwab 2004).

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). E-catalogues have gained popularity in procurement transactions for which price is the main concern and often fixed. This study focuses on multi-attribute procurement mechanisms wherein price and other attribute values need to be determined during the transaction process, i.e., auctions and negotiations.

In procurement, auctions are reversed; the suppliers bid against each other and the lowest bidder (offering the highest value to the buyer) obtains the contract. 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 procurement 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.

E-business allows for the search of suppliers anywhere in the world. This is particularly valuable in situations where there may be many potential suppliers, some in close proximity to the business's location and others—far away. The importance of procurement activities and the survey of procurement managers suggest that 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 dispersed 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. ICT allows 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 negotiations yield 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 mechanisms to suit their particular procurement situation. Several guidelines have been proposed to aid the mechanism selection in procurement practice (e.g. Kraljic 1983; Handfield and Straight 2003). In many situations, however, the different mechanisms may be used for the same or similar types of transactions. For instance, both reverse auctions and negotiations have been suggested for the "leverage" transactions (Kaufmann and Carter 2004; Subramanian and Zeckhauser 2004; Bajari, McMillan et al. 2009).

Advanced mechanisms such as multi-attribute reverse auctions may be used in solving problems which formerly, only negotiations could have been employed, thus increasing procurement efficiency. Similarly, multi-bilateral negotiations may be used in situations where traditionally auctions were adopted. To-date, however, little effort has been made to examine the emergence of these advanced mechanisms.

Most of the guidelines for mechanism selection are normative (e.g. based on transaction cost theory by Williamson 1979). They consider general strategic use (e.g. outsourcing, integration, spot buying or reverse auctions) rather than detailed characteristics describing the market and organization within 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 number of generic models and a set of parameters in guiding mechanism design; (2) an approach to implementing and testing emerging mechanisms; and, (3) two types of mechanisms that are distinct but have the possibility to build a continuum of mechanisms to address more specific requirements and strategic concerns. It allows for the consideration of the needs and incentives of both buyers and suppliers in terms of the information revelation and exchange during the process.

The rest of the paper is organized as follows: Section 4.2 reviews the role of information in auction and negotiation mechanisms. Section 4.3 provides the motivation of this study and an interdisciplinary approach for mechanism design and implementation. In Section 4.4, a number of generic models are proposed, followed by a set of design parameters and variants of mechanisms. Section 4.5 describes the implementation of two types of mechanisms in the same platform and summarizes the testing and results. Finally, the implications and possible extensions of this study for practice and future research are discussed in Section 4.6.

4.2 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).

4.2.1 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 during the process (Kersten, Chen et al. 2008). The rules need to describe the mechanisms completely, allowing for the determination of winners based solely on bids.

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 lower the price, the better it is for the buyer; and, they can also 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 formulation of different information rules in auction design (e.g. Bichler 2000; Koppius and Heck 2003; Chen-Ritzo, Harrison et al. 2005;

Strecker 2010; Adomavicius, Gupta et al. 2012; Gwebu, Hu et al. 2012). Three classes of information considered in auction design are listed below:

(1) *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 were given the buyer's value function. Chen-Ritzo et al. (2005) introduced a multi-attribute English auction where only partial information about the buyer's utility function was revealed. 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.

(2) *Bidder's information* includes the number of bidders (both initial bidders at the beginning of the auction and active bidders during the auction process), the 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 (Klafft and Spiekermann 2006; Carter and Stevens 2007), 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 disclosure of buyer's preferences and requires a lower level of information revelation (Jap 2007; Cason, Kannan et al. 2011).

(3) *Bids information* includes the actual bids which are submitted by suppliers and bids constraints (e.g., reservation levels) which may define and update the admissible bids (Bellosta, Kornman

et al. 2008; Kersten, Pontrandolfo et al. 2012), bid value of utility (for the buyer and the bidders) and bid status (e.g. winning or losing, ranking) (Koppius and Heck 2003; Adomavicius, Gupta et al. 2012).

Koppius and van Heck (2003) proposed several information schemes which specify the type of information that is given and when, how and to whom it becomes available during the auction. They studied two types of multi-attribute English auctions: (1) auctions with unrestricted information availability, in which suppliers are provided with the winning bid, the corresponding bidder and the rating of losing bids; and (2) auctions with restricted information availability, wherein the bidders are informed only about the winning bid and corresponding bidder.

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 depends on the way she represents her preferences. When the representation includes a linear additive utility function, the owner conveys 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, the owner announces the attribute value bounds. This dependency is difficult to implement when the buyer does not make her preferences public (Burmeister, Ihde 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 the bids become comparable. 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 (scoring) 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 earlier ones. The revelation of bid constraints and actual bids is optional and can be included when the first two rules are used. The information provides the bidders with the bidding status and/or direction, which helps them in making progressive bids.

Existing studies have implemented various information revelation rules with different types of information. For instance, revealing buyer's preferences (Bichler 2000; Chen-Ritzo, Harrison et al. 2005), revealing buyer's preferences and winning bids (Bellosta, Kornman et al. 2008), revealing buyer's preferences and bids (Koppius and Heck 2003), and revealing bidding constraints and winning bids (Strecker 2010). Studies using the experimental economics approach have shown that the rules and configurations of information types have different effects on the bidders' strategies, market competition, and the outcomes for both buyers and bidders.

4.2.2 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 in time while auction protocol has to stay fixed during the whole process. Negotiations also allow for various types of information exchange (e.g. offers, 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-negotiation systems (ENSs), 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 (Sebenius 1992; Raiffa, Richardson et al. 2002). Similar to auction mechanisms, Kersten and Lai (2007) identified three types of models or model components related to information in negotiations: (1) *Model of the negotiation problem* identifies and describes the problem structure (e.g. attributes, bounds, constraints and alternatives); (2) *Model of the 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; and (3) *Model of the 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).

It has been noted that ENSs provide both decision support and communication support (Lim and Benbasat 1992). Inspire (Kersten and Noronha 1999) and SmartSettle (Thiessen 2002) are two examples which implemented both models, including preference elicitation and representation, alternatives comparison and decision making, and offer/message exchange. Some systems focus on communication support, such as messaging, multimedia, documentation, and coordination (Yuan, Rose et al. 1998; Schoop, Jertila et al. 2003).

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

Thomas and Wilson (2002; 2005) 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). ICT makes 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.

4.3 Motivation and approach

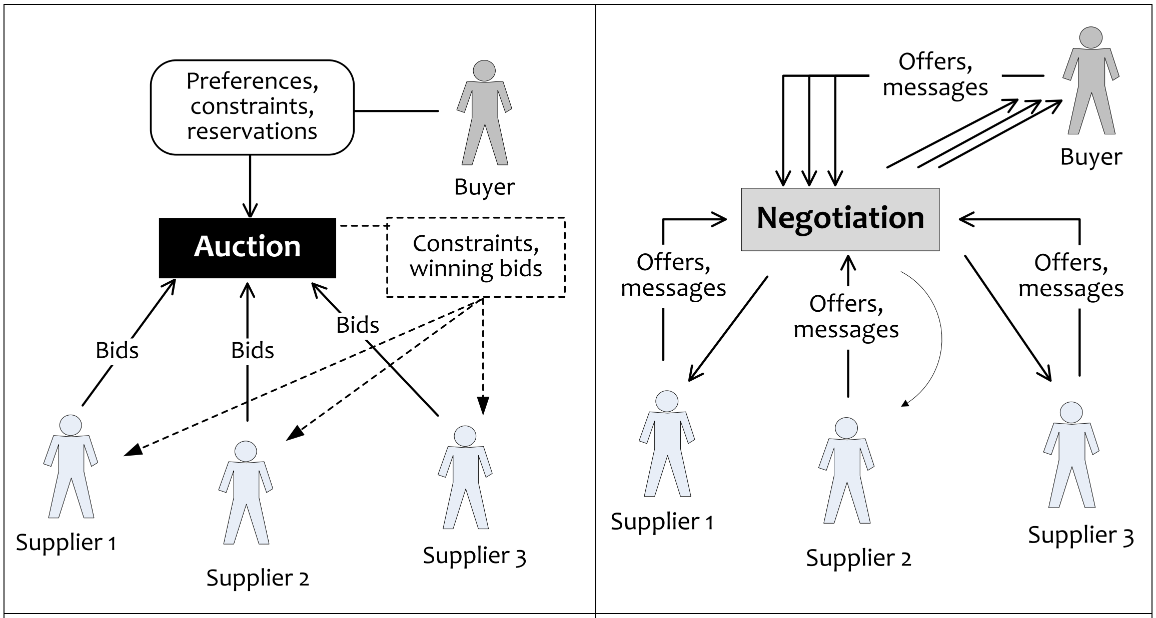
The review of relevant literature motivates this study to design and implement multi-attribute mechanisms for e-procurement practice. An interdisciplinary approach is adopted to guide this study and to carry out the objectives.

4.3.1 Motivation and objectives

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 flexibility of information exchange. Figure 4-1 illustrates MARA and MBMN, each involving one buyer and three suppliers.



a. Multi-attribute reverse auction (MARA)

b. Multi-attribute multi-bilateral negotiation (MBMN)

Figure 4-1. Two comparable procurement mechanisms: MARA vs. MBMN

In the reverse auction (Figure 4-1a), 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 make bids or counter-bids; instead, the buyer specifies the rules that are followed by the auction mechanism to respond to the suppliers, including the feedback about their submitted bids and for their prospective bids (e.g. current winning bid, updated constraints). 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 process.

In the multi-bilateral negotiation (Figure 4-1b), 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 constraint 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. The buyer's active participation in negotiations and passive participation in auctions is an important difference. Active participation significantly increases the negotiation's flexibility and it allows the participants to exchange partial offers, request clarifications, and add or remove issues. In this study, however, these possibilities are not considered because our concern is the design of auction and negotiation mechanisms which can be applied to the same types of exchanges.

Given the similarities in these mechanisms, this study aims to develop generic models 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.

4.3.2 A design science approach

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 issues and implementation. 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, such as preference representation and information revelation. These models are then implemented in concrete systems with other supporting models and tools, such as analytical support and visualization support. In a review of e-negotiation systems, Kersten and Lai (2007) 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.

Markets and market mechanisms have been the interest of economists, particularly those who study auction theory (Milgrom 2004), experimental economics (Smith 2003), and market design (Roth 2002). A general market system involves an economic environment, individual preferences and behavior, market mechanism, outcomes and performance (Smith 2003). Auction theorists use mathematics and logic to design various types of auction models (i.e., mechanisms) and study their features (e.g. Gächter and Riedl 2005; Gallien and Gupta 2007). Economists seek mechanisms which are incentive compatible; i.e., the bidders can achieve the best possible result when they truthfully reveal all private information the mechanism requires (Maskin 2007). Typically market participants are assumed to behave according to the economic theory axioms (i.e., rationality, risk aversion, opportunistic behavior). Furthermore, they are homogenous with the exception of their endowment (e.g. funds available) and preferences.

In behavioral economic research, the main purpose is to design and experimentally validate market mechanisms which are implemented in the simplest form of information systems. In these systems, the embedded model (i.e. the mechanism) is the main concern while the user interface and system features are not the focus due to the homogeneity of market participants. The systems are as much as possible devoid of any additional features due to the user interface, data visualization tools or decision support aids.

From the information systems (IS) view, e-procurement is an IT artifact in which market mechanisms are implemented and which also includes many components that help its users in using these mechanisms and conduct auxiliary activities. A number of such artifacts or systems have been developed to support e-procurement transactions (Croom and Brandon-Jones 2005; Minahan 2005; Talluri, Narasimhan et al. 2007).

Design science approach has been adopted in IS research to study the process, methods and models that can be used to build artifacts (March and Smith 1995; Hevner, March et al. 2004). A number of guidelines have been provided with some exemplars (Hevner, March 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" (Walls, Widmeyer et al. 1992; Livari 2003). E-procurement transactions vary with regard to the products, participants and procedures. Thus, a class of e-procurement systems is needed to facilitate these different transactions, requiring different design and implementation. When implementing auction and negotiation mechanisms in e-procurement systems, they become different types of systems. Vahidov (2006; 2012) suggested that a "what" (e.g. what type of systems) question may need to be specified or answered before asking the "how" question. He thus proposed a framework for structuring the representation of IT artifacts with two dimensions: perspectives and categories. This framework has been applied to represent e-negotiation systems (see Chapter 7 in

Vahidov 2012).

The approach and main phases of this study are demonstrated in Figure 4-2. During the mechanism design phase, the requirements of information exchange and revelation in e-procurement transactions are considered. Two procedures are developed to meet these requirements in e-procurement auctions and negotiations, incorporating the models of process, participants and problem. Two classes of mechanisms are designed: MARA and MBMN. These mechanisms are then implemented in a generic e-market platform which supports both auction and negotiation mechanisms. A set of auxiliary models and tools are designed and implemented to support these mechanisms, resulting in two new systems: Imaras and Imbins. These systems are tested in both laboratory and online environments in order to improve their design and implementation.

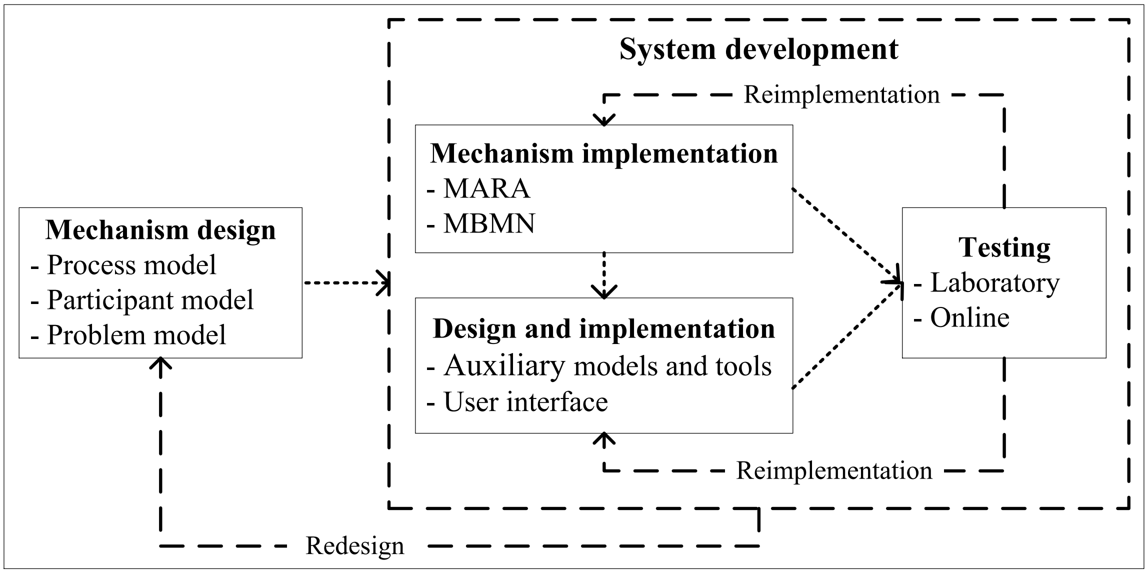


Figure 4-2. Mechanism design and implementation

4.4 Mechanisms design

In this study, generic models are proposed to define the problem, participants and process for the design of alternative mechanisms. The main design parameters are then defined for the specifications in mechanism design and a number of variant mechanisms are presented.

4.4.1 Generic models

As suggested in the auction and negotiation literature (Section 2.3 and Section 2.4) and the specific approaches for information revelation, a set of models firstly need to be developed to define the transaction problems, participants and processes, based on which various mechanisms can be designed and implemented. The present research intends to study and compare auction and negotiation mechanisms in similar contexts for e-procurement practice (i.e. a multi-attribute procurement problem that involves multiple suppliers). Thus, this study focuses on the process modeling, while define and use the same problem and participant models for such realistic situations.

To simplify the situation and focus on mechanism design, the problem in this study is modelled with a set of discrete alternatives; each alternative is comprised with multiple attributes and the discrete values of the attributes. The participant (i.e. bidder and negotiator) model is represented with her preferences on the attributes and alternatives, which are non-decreasing additive utilities. The process model defines the procedure and rules that govern and facilitate information exchange, while the information that is being exchanged is based on the problem and participant models (i.e. who knows what at when).

Existing mechanisms have overlooked several practical requirements for e-procurement practice, 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), Brigui-Chtioui et al. (2011), 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 4-3 shows a sequence diagram of this procedure.

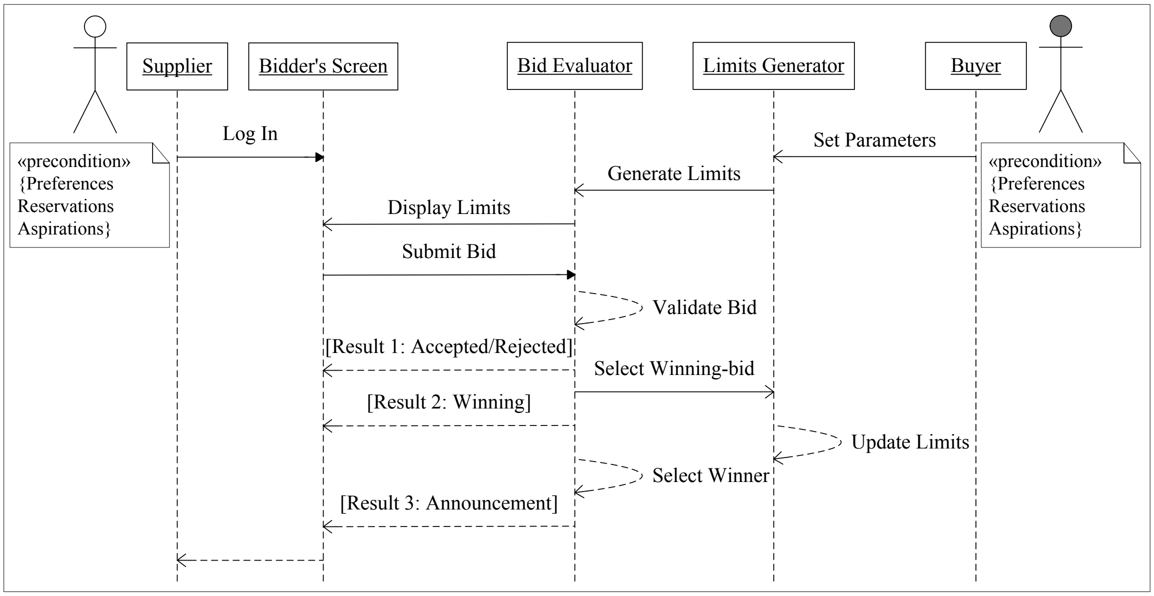


Figure 4-3. Sequence diagram of auction procedure (MARA)

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 moths. There may be one or more sets of limits, depending on the buyer's preference structure and the alternative values. The limits on each attribute also restrict the possibilities for trade-offs between attributes, which is partly overcome by defining multiple limit-sets. The number of limit-sets should be sufficient and jointly to maximize the coverage of feasible bidding space and to minimize the possible exclusion of feasible alternatives. These limit-sets are also dynamic during the auction process as the feasible bidding space is reduced. 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 the 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 4-4). 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 4-1 in Section 4.3.1). 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 the best alternative to the negotiated agreement (BATNA) to push other suppliers, and thereby increase the competition level among them.

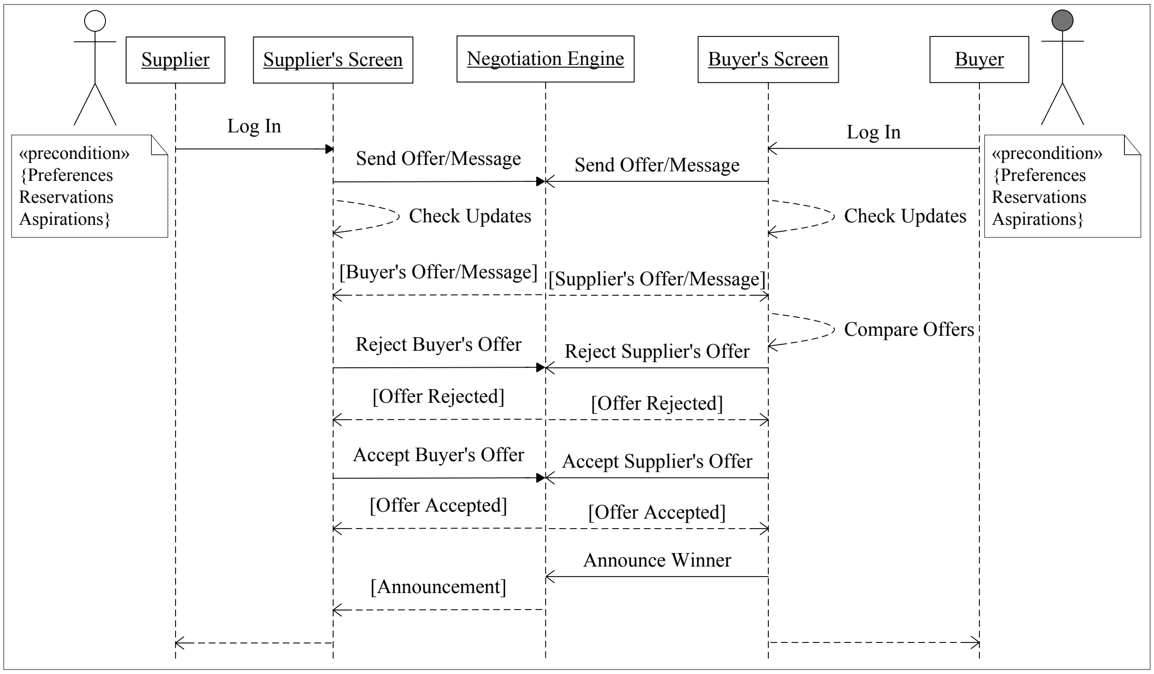


Figure 4-4. Sequence diagram of negotiation procedure (MBMN)

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 or 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 4-1):

Table 4-1. A generic process and its phases with two types of mechanisms

	Process and phases		
	Preparation	Interaction	Conclusion
MARA	Define auction problem; Set buyer's preferences; Set bidders' preferences	Buyer: Set bid limits; Evaluate bids; Accept/Reject bids Bidders: Submit bids; Revise bids	Close auction; Announce results
MBMN	Define negotiation problem; Set buyer's preferences; Set bidders' preferences	Buyer: Send offers/messages; Evaluate offers; Accept/Reject offers Bidders: Send offers/messages; Evaluate offers; Accept/Reject offers	Close negotiation; Announce results
Generic	Define decision space; Define utility space	Buyer: Revise decision space Evaluate proposals; Make decisions Bidders: Make proposals; Revise proposals	Close transaction; Announce results

(1) *Preparation*, during which the participants specify the transaction problem (e.g. products, attributes and alternatives) and their preferences, constraints and objectives;

(2) *Interaction*, during which the participants bid or bargain with each other on the attributes and alternatives; and

(3) *Conclusion*, during which the transaction is either completed with a contract agreement or terminated without any agreement by the deadline.

4.4.2 Design parameters

Based on the review of the auction and negotiation mechanisms and the generic models proposed in above section, 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:

(1) ***Types of information***: This considers the different types of information identified in previous

sections, including information about buyers, suppliers and proposals (i.e. bids in auctions or offers in negotiations).

(2) ***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 transaction.

(3) ***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.

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

Table 4-2 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 in tables or graphs.

Table 4-2. Design parameters in auction and negotiation mechanisms

	Type	Scope	Time	Format
Parameters and options	Decision space: Admissible proposals; Proposal constraints; Actual proposals Utility space: Buyer's preferences; Supplier's preferences; Utility of proposals; Status of proposals	All participants; Selective set; Individual	Beginning of transaction; Beginning of round; After certain proposals; End of round; End of transaction	Textual; Tabular; Graphical

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 a 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.

It is also worthy to note 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.

4.4.3 Variants of mechanisms

Based on the generic models and the design parameters, a number of different mechanisms can be designed even within the same family of mechanisms. Table 4-3 shows several variants of such mechanisms for both auctions and negotiations while other specific mechanisms can be designed with different configurations of these parameters.

Table 4-3. Variants of auction and negotiation mechanisms

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

In the SARA mechanism, the value and status of each bid is known to both buyer and bidders.

When using price only, then 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 auctions (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 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. They differ mainly in the types and time of information revealed in 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 that 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. admissible bid, winning bid) 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, Pontrandolfo et al. 2012). Optionally, the information can be displayed in tables or graphically.

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 requests for new proposals but does not make offers on her own (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 exchange may be textual messages and/or offers in tables or on graphs.

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.

4.5 Mechanisms implementation

The generic models are implemented using the Invite platform, which provides an integrated environment for the implementation of auction and negotiation mechanisms and the development of related systems. In this section the implementation of the proposed mechanisms with two systems is presented.

4.5.1 Platform and auxiliary models

Different market mechanisms can be implemented in the same environment or platform to build various e-procurement systems with the same user interface. Invite (Kersten, Law et al. 2004) was initially developed to support negotiation mechanisms but recently has been extended to support auction mechanisms (Kersten, Pontrandolfo et al. 2011; Kersten, Pontrandolfo et al. 2012).

The Invite platform adopts a Model-View-Controller (MVC) design pattern (Reenskaug 1978-79; Burbeck 1987), incorporating the transitions and rules (controllers), functional elements (models), information representation and user interface (views). The *model* represents data and the logic that governs access and updates of this data. The *view* specifies how the data contents of a model should be presented. The *controller* translates interactions with the view into actions to be performed by the model. Based on the user interactions and the outcome of the model actions, the controller responds by selecting an appropriate view.

This design allows for the separation of the user interface from the embedded process models and execution rules. The mechanisms which incorporate the actions, interactions and their rules in a process can be decomposed into activities, procedures and rules; different configurations or sets of these elements are instantiations of these mechanisms. The user interface can be decoupled and implemented with different technologies, resulting in different system features such as tabular or graphical views of bids or offers. The underlying theory of transaction protocol design and implementation allows system designers to implement various mechanisms by configuring and reusing MVC components (Kersten and Lai 2007). A variety of mechanisms can be implemented in this platform, including: bilateral negotiations, multi-bilateral negotiations, and multi-attribute auctions.

In multi-attribute auctions, the problems are more complicated due to the availability of many alternatives and the implicitness of the buyer's preferences. The bidders are allowed to make trade-offs among different attributes and are also required to make progressive bids. If the buyer's preferences are completely disclosed, then decision support on generating admissible bids and calculating their values is helpful (e.g. Bichler 2000; Chen-Ritzo, Harrison et al. 2005; Strecker 2010). However, if the buyer's preferences are not explicitly provided, then more advanced supporting models and tools are required, such as the identification of admissible bids based on the bound values on each attribute, evaluation of bids based on values of each attribute and visualization of the bidding process. Empirical studies have shown user heterogeneity, in terms of their bidding strategies and behavior, and suggested providing decision support in auctions (Bapna, Goes et al. 2004).

Similarly, a number of ENSs have been developed to implement various negotiation mechanisms (e.g. Kersten and Noronha 1999; Thiessen 2002). E-negotiation studies have also designed and tested various auxiliary models that provide different forms of support, including: analytical support, communication support and visualization support (e.g. Kersten and Noronha 1999; Swaab, Postmes et al. 2002; Schoop, Jertila et al. 2003; Weber, Kersten et al. 2006; Gettinger, Koeszegi et al. 2012). Their results suggest that these supporting features and tools are useful in e-negotiations: analytical support helps users to identify and use their preferences in decision making;

communication support mediates and facilitates offer and message exchange between the participants; and, visualization support presents and predicts the negotiation process. It also indicates that the effectiveness of these tools requires certain conditions and they can be complementary to each other.

Figure 4-5 demonstrates the implementation of these two types of mechanisms with other supplementary models (e.g. analytical support, communication support and visualization support) in Invite.

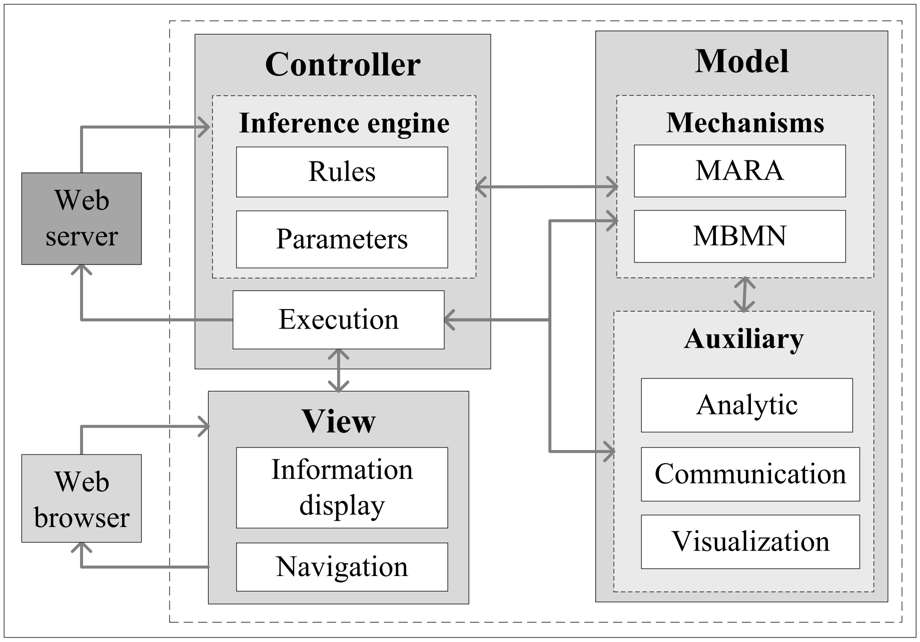


Figure 4-5. Implementation of MARA and MBMN in the Invite platform

These two mechanisms are the core models that are implemented through a generic procedure. They are supported by auxiliary models and tools. All these models are built as executable components, which can be invoked and integrated by the controller. Depending on the transaction situations (e.g. settings of rules and parameters), the model components are used to generate different composite components (e.g. activities in auction and negotiation such as bid/offer construction). These components may generate information that can be transmitted from the web server to the web browser on the user's computer (e.g. recent bids/offers), while they may also require the user's input and requests from the browser (e.g. specifications of a new bid). The different views (information display and navigations) are implemented with the view components. The page composers combine the model components and view components to obtain, generate and display the required information.

Following the design framework proposed by Vahidov (see Chapter 6 & 7 2012), Invite is a synthetic meta-artifact, through which the technical meta-systems can be designed and implemented. This distinction allows the specification of the requirements and system design at different levels of layers. Depending on the requirements and purposes of the systems, various mechanisms, features and their configurations can be implemented. In this research, the focus is on mechanism design, implementation and comparison. Thus, the systems can be discrepant mainly at the process model level and mechanism specifications (i.e. different mechanisms). The system functions and features can be implemented on higher levels without affecting the process and mechanism design. The different implementation of the mechanisms is then represented with the design characteristics of the systems. This allows the comparison of different mechanisms using the systems as the instrument in which the mechanisms are embedded. By controlling or eliminating the differences in the design characteristics of the systems, the differences in mechanism design can be examined.

4.5.2 Systems and user interface

Two systems are developed to implement the mechanisms. Imaras, as a technical-level meta-system, supports different auction settings at the implementation level including: information display (limit-sets only, bidder's own bids, winning bids and all bidders' bids), continuous bidding or round-based bidding, fixed or flexible round duration and auction length (i.e. hard deadline, extendable). Also, a set of relevant features can be used and configured to provide analytical support for bidding, (e.g. bid construction, validation and generation using the bidder's preferences and the limit-sets), visualization support for reviewing the bidding history and predicting the trend (i.e. bids distributed over a time span).

Imbins supports negotiations in which one buyer simultaneously negotiates with several suppliers by exchanging offers and/or messages. It may also vary at the system implementation level with different features, including: analytical support (e.g. offer construction, comparison and generation), communication support (e.g. messaging) and visualization support (e.g. offer-history graph).

In order to implement and compare mechanisms, similar system features and user interfaces are developed in these systems. Figure 4-6 and Figure 4-7 show the main user interface of each system. More relevant system screenshots are provided in Appendix A for Imaras and Appendix B for Imbins to demonstrate the system user interface, key features and functionalities, and their use in a business procurement scenario. Video demonstrations of the two systems are also available online (see the demo at Imaras 2011; Imbins 2011).

The Imaras screen in Figure 4-6 is the bidding screen of a round-based auction in which the bidder can see her own bids as well as the winning bids. The Imbins screen in Figure 4-7 shows the message and offer submission screen in which the negotiator can see her own offers and messages as well as those of the counterpart.

Both screens have four main components. The clock (A) shows the time from the beginning of the auction and the time left to the deadline. The systems' navigation bars are located on the right-hand side (B) where links to active pages are listed. For auctions, the round number and clock are also given. The clock is reset at the beginning of every round.

In both bidding and offer screens, the most recent bids or offers made by the supplier (who sees this screen) and by the buyer are shown (C). In auctions, only winning bids and bids made by the bidder who sees this screen are shown. In negotiations, only offers made by the buyer to all suppliers or to the supplier who sees the screen are shown.

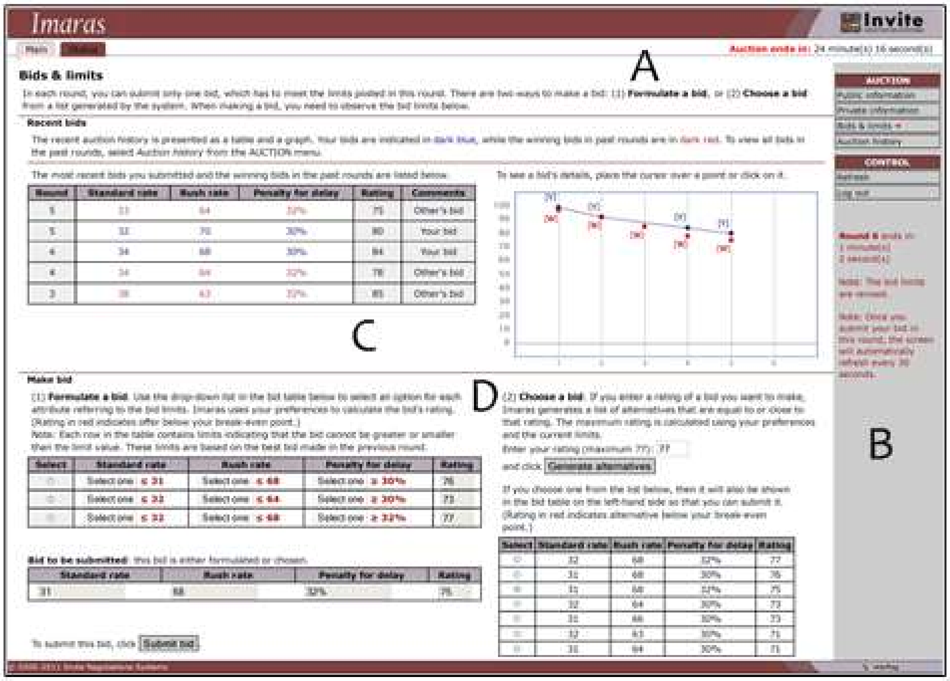


Figure 4-6. System screen of bid construction and submission in Imaras

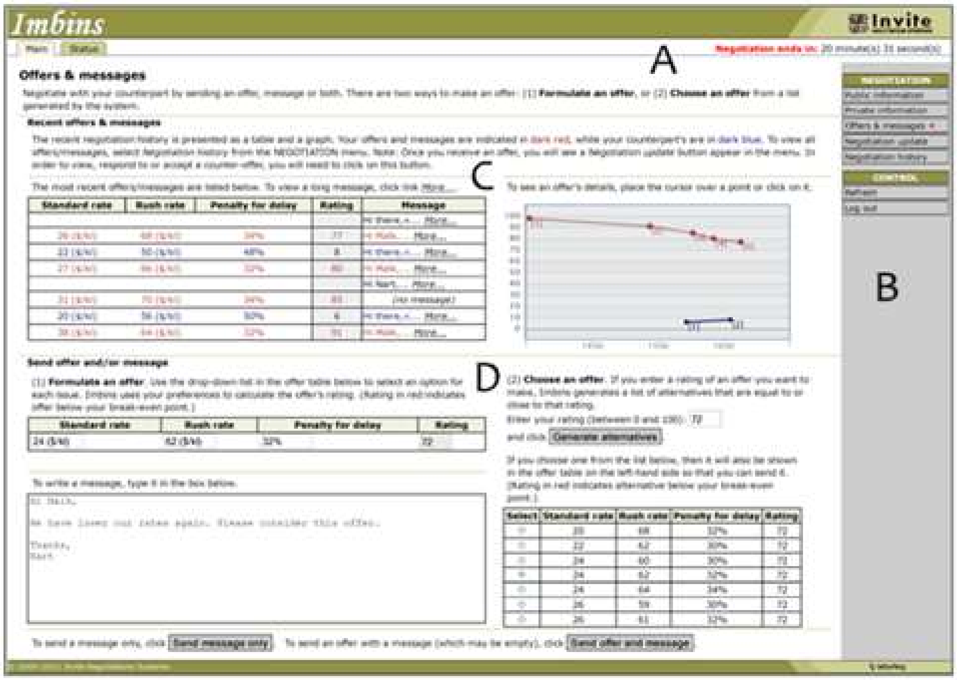


Figure 4-7. System screen of offer/message construction and submission in Imbins

The most recent bids and offers are shown in both tabular and graphical forms. (The complete list of bids and offers can be seen on separate pages: Auction history and Negotiation history pages are accessible from the menu in (B). One difference between the auction and negotiation pages is that in the auction page, the round is given as well as the bidder who submitted the winning bid. In the negotiation page, messages sent by a counterpart can be accessed (they are expandable). Bids and offers are constructed and submitted in (D).

The two main differences between auctions and negotiations are in the limit-sets for the former and messaging facility for the latter. In the Imaras screen (left-hand side of D), three limit-sets are provided. The bidder can select one set (table row) and then select admissible attribute values for the given set (Figure A-2 in Appendix A). Then in the next table (bid submission) the selected values will appear thus composing a complete bid to submit. In the Imbins screen (D), there is a message box that allows the user to write and send a message to the counterpart.

Moreover, to assist the cognitive effort in decision making and communication in a one-to-many situation, the two systems provide additional support. In Imaras, aside from the list of bids in a table, the bidding process is also graphically visualized. Based on the bidder's preferences, the graph depicts the bids during the process (Figure A-5a in Appendix A). This visualization provides a holistic view of the auction process, allowing the comparison of the bids and the prediction of the bidding process. The system can also generate a similar graph from the buyer's perspective, which depicts all bidders' bids as compared to the value of limits in each round (Figure A-5b in Appendix A). As the selection of winning bids and calculation of limit sets are automatically completed by the system, this may be used to monitor the real-time bidding status and to review the bidding process.

In Imbins, as the offer comparison and construction are performed by human buyers, a negotiation update screen was designed in which the most recent offers and/or messages from each supplier are listed together (Figure B-1 in Appendix B). This screen dynamically updates the negotiation status and provides real-time information to the buyer, who can evaluate and reply to the offers, reply to the messages, or accept a preferable offer to reach an agreement. Similar to Imaras, the offers exchanged during the process are also depicted on a graph (Figure B-2 in Appendix B). From the suppliers' perspective, the negotiation process is visualized by showing their own offers and the buyer's offers based on the suppliers' preferences over time. From the buyer's perspective, the graph shows the buyer's offers and all suppliers' offers based on the buyer's preferences. This visualization provides a holistic view of the negotiation process and supports offer comparison and prediction.

4.5.3 System testing and results

Following the approach in Figure 4-2, the two systems are tested to validate the design and implementation of the mechanisms. The results can be used to make revisions and improvement of the mechanisms.

The systems have been tested by a team involved in the project and over fifty external users who were paid. The testing was conducted in both laboratory and online environments. The former allows controlling factors on the client side (e.g. computer, web browser, activities and scalability), while the latter mimics a real-world situation where people conduct procurement transactions online. The users were asked to record errors and difficulties when using the systems and to provide comments and suggestions related to the systems and process at the end of the testing.

The systems were tested and improved on three levels following the approach:

(1) Market mechanisms (the core models), which are directly related to the rules and parameters in the design and implementation of MARA and MBMN;

(2) Auxiliary models and tools (the supplementary models), which support the users in constructing, generating and comparing alternatives;

(3) User interface (the representation or views), which focuses on the layout and format of information displayed on user's screen.

The system testing and results are summarized in Table 4-4. Firstly, the algorithm of limit-sets generation was implemented and tested. The parameters with regard to the number of sets and the increment were manipulated, through which the minimum value of these parameters was identified. Different rules on information revelation were also considered and controlled in order to support various auction settings. Moreover, the closing rules were improved with regard to both the auction deadline and the number of available bids and bidders. The testing and revisions resulted in a set of parameters for different auctions at the mechanism level.

Table 4-4. Summary of system testing

	Imaras		Imbins	
	Phase 1	Phase 2	Phase 1	Phase 2
Layer 1: Mechanism	Algorithm (rules and parameters)	Round duration, closing rules	Information exchange	Information exchange
Layer 2: Auxiliary models and tools	Bid construction and comparison	Bid generation	Offer construction and comparison	Offer generation
Layer 3: User interface	Activity-oriented design, navigation	Information-oriented design, server pushing, visualization	Activity-oriented design, navigation	Information-oriented design, server pushing, visualization
Environment	Laboratory	Laboratory, online	Laboratory	Laboratory, online
Problem	with 125 alternatives	with 216 alternatives	with 216 alternatives	with 3375 alternatives
Participants	Project team	Project team and students	Project team and students	Project team and students
Results	Poor process tracing	Unexpected termination of auction, generated unacceptable bids	Poor process tracing	Message not fully displayed
Revision	Information-oriented design	More flexible closing rules, bid generation incorporated with limit-sets and break-even points	Information-oriented design, negotiation update page	Full message display

The bid construction, generation and comparison functions were tested within different auction settings. They were perceived as very useful in making efficient bids. Based on user's feedback, the bid generation was dynamically incorporated within the limit-sets, i.e. only permissible bids are generated. Moreover, the break-even points of bidders are also indicated when bidders construct and generate alternative bids.

At the user interface level, an initial activity-oriented design was changed to an information-oriented design. The former decomposes the auction process into activities and the users can select and undertake these activities. This design is simple and easy to use but requires users to navigate between web pages. The latter integrates the available and relevant information on the main page (i.e. the screen shown in Figure 4-6), which allows the users to make decisions and take actions in one place. As multi-attribute auctions are information intensive, the information-oriented design was recommended. Moreover, besides the list of bids and alternatives in tables, a visualization tool was tested and improved to present the bidding process.

In Imbins testing, information exchange at the mechanism level has been a major concern. The method of information exchange was revised so that the buyer can send both offers and messages to one or more suppliers. This maintains the flexibility of negotiation mechanisms and also allows the buyers to control the negotiation process.

Both buyers and suppliers are provided with analytical support (e.g. construction and generation of alternative offers), communication support (e.g. construction of messages) and visualization support (e.g. offer-history graph). In addition, taking into account the buyers' effort in processing offers and messages from more than one supplier, additional support has been provided to present the most recent offers and messages from each supplier in one place. This dynamically and simultaneously updates the negotiation status with all suppliers. Once the buyer decides to reply to one supplier, the system navigates to another screen but keeps the selected supplier information. This has been considered useful in tracing the negotiation process.

Similar to Imaras, an information-based design was followed in Imbins. The main screen shown in Figure 4-7 contains the recent offers and/or messages for making counter-offers or sending messages with argumentation. The negotiation history page was initially focused on the exchanged offers, while the content of messages was only partially displayed. Based on users' suggestions, an additional table was added to show the full messages.

In addition to the testing and improvement on the above three layers, the systems have been tested with different cases and different numbers of suppliers in each transaction for the consideration of usability and scalability. A dynamic calculator was added in the preparation stage to represent the participants' preferences. A stress test also resulted in replacing the database server and decomposing several modules into smaller components.

Furthermore, users also suggested providing: (1) more detailed and clear instructions to guide them in using the system and conducting the transaction; and (2) a demonstration of the system and process to familiarize users with the systems and tasks. Thus, a video demonstration was created to present the key system features and the procurement process (see the demo at Imaras 2011; Imbins 2011). The demo illustrates the systems and their use within different scenarios. A short quiz was also added to help users in reviewing the system and tasks. The results indicate positive effects of these improvements and the users provided positive comments on the system, process and experience.

4.6 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 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. Following the design science approach, a set of mechanisms are designed with the process model and information rules, and then implemented in a software platform with auxiliary models and user interface design. The mechanisms were tested in different settings and then improved based on the results.

4.6.1 Implications for mechanism design and implementation

Auctions and negotiations are two different classes of mechanisms and the advancement of ICTs 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 auction and MBMN from multi-attribute bilateral negotiation. Such extensions 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 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, cautions should be given 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 (Kersten, Pontrandolfo 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 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 able to make their decisions in bidding 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).

In mechanism implementation, the user interface is separated from the embedded process models. This allows researchers and practitioners to focus on the mechanism design and validation and controlling the effect of system user interface. The participants in e-procurement transactions are also users of such systems. They may be heterogeneous not only in their preferences but also in their technological competence. A system with a more user-friendly interface which is easier to use also helps reduce the obstacle for users and thus minimize their influence in mechanisms design and validation.

The mechanism design and implementation is an iterative process, which may require redesign and reimplementation to revise and improve the mechanisms based on the testing results. 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. This study considers both the laboratory environment which enables full control on the user side, and the online environment which provides a similar situation as e-procurement conducted in the real world. More realistic environments such as a trial use by procurement managers may provide a more comprehensive testing and validation of the mechanisms.

4.6.2 Extensions and future research

Currently, a series of experiments have been conducted, in which the two systems are used as test-beds implementing and validating these mechanisms. They are also used for the assessment of the systems with different auxiliary models and features, the construction of bidding behavioral models, and the observation of 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.

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

The information format and auxiliary models have been considered in mechanism design and implementation, while their effects need to be further examined or controlled in future studies. In particular, studies in decision support systems (DSSs) have noticed the effects of information format (e.g. Kamis, Koufaris et al. 2008), while its joint effects with the number of attributes and different information types are important in multi-attribute transactions. This will help address not only "*what*" information but also "*how*" the information is managed during the process. Also, the auxiliary models are implemented in the system to facilitate the process and support decision making, while their roles in implementing different mechanisms may vary. For instance, analytic support may be useful in both auctions and negotiations, whereas communication support is more useful in negotiations. This is related to both the type and format of information exchanged in the process (e.g. Kersten, Chen et al. 2010).

This study focuses on the information aspect in mechanism design and implementation. Other rules can be considered together in future work, for example, different winner determination rules and closing rules. The auction mechanisms in this study are equivalent to first-price auctions with hard close or 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 (Roth and Ockenfels 2002; Kagel and Levin to appear). Future research may design and implement the mechanisms with different winter determination and closing rules, and investigate the effects on the process and outcomes.

5. Study 2: Effects of Information Revelation in Auctions

5.1 Introduction

E-procurement is a key component in B2B commerce, through which businesses obtain goods and services (Minahan 2005). With advanced information and communication technologies, e-procurement can improve the traditional procure-to-pay processes and as well as can increase efficiency and effectiveness (Brynjolfsson, Hu et al. 2003; Quinn 2005). Reverse auctions are an important e-procurement exchange mechanism. In these auctions the buyer organizes an auction and the sellers (or suppliers) submit bids. Reverse auctions have been shown to achieve an average gross savings of 5–20 percent (Cohn 2000).

Most auctions deal with single attribute goods or services—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 percent 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 negotiations, for example, when procurement managers negotiate with a few suppliers in order to select one supplier. Negotiation, however, is a difficult and costly process, in particular when one needs to negotiate with many counterparts.

Several approaches to extend auctions to multi-attribute transactions have been proposed (e.g. Che 1993; Bichler 2000; Teich, Wallenius et al. 2003). The two concerns in designing multi-attribute auctions are preference representation and information revelation (Bellosta, Kornman et al. 2008). Some methods aim at combining price with the total costs of all non-price attributes, others in aggregating all attributes into utility functions. The existing reverse auction mechanisms generally require the revelation of a buyer's preferences (e.g. Bichler 2000; Chen-Ritzo, Harrison et al. 2005).

Information revelation is an important aspect of mechanism design because it can be used to control bidders' knowledge about the buyer's preferences (Milgrom and Weber 1982; Farrell 1987).

Recent research has focused on examining the effects of different information rules (e.g. Arora, Greenwald et al. 2007; Greenwald, Kannan et al. 2009; Cason, Kannan et al. 2011), though only a few studies have investigated the effects of information on outcomes in multi-attribute auctions (Bellosta, Kornman et al. 2008; Strecker 2010; Adomavicius, Gupta et al. 2012; Kagel and Levin to appear).

The present study employs a multi-attribute reverse auction system, *Imaras* (Kersten and Wu 2012), for implementation and manipulation of different rules of information revelation (see Study 1 in Section 4). The effects of these different rules are examined, while the context, including the characteristics of transaction tasks and participants, is controlled. This allows the study of the influence of information revelation on the transaction process and outcomes.

This study addresses a challenging and important issue in multi-attribute auction design in terms of information revelation, *providing sufficient information for bidders to make progressive bids* (i.e., bids that are better for the buyer than the bids made previously). The study's contribution is the formulation and testing of a set of rules solely based on information about bids under the condition that the buyer's preferences are not disclosed. In addition, the proposed rules allow the simplification of the formulation of bidding strategies in multi-attribute auctions.

Three different information revelation rules were tested in two experiments: *Rule 1*, information on admissible bids only; *Rule 2*, information on both admissible bids and winning bids; and *Rule 3*, information on admissible bids and all bidders' bids. Their effects on the process and outcomes of auctions are examined with both behavioral and perceptual measures.

The rest of this paper is organized in the following manner. Section 5.2 identifies various types of information used in auction design and presents a literature review that focuses on information types, their implementation, and their effects. Section 5.3 describes a research model and hypotheses to address the effects of dynamic information in multi-attribute auctions. Section 5.4 describes the experimental design and data collection for testing such effects. Section 5.5 presents the data analysis and Section 5.6 discusses the results. The paper concludes with discussions on the effects of different types of information and the implications for practice and future research.

5.2 Background and motivation

In market exchanges, information revelation is crucial as it affects participants' behavior and outcomes. The choice of information revelation rules has become an important issue in procurement (Jap 2002; Arora, Greenwald et al. 2007; Adomavicius, Gupta et al. 2012). This section first identifies information used in auction design. The rules of revealing different types of information and their effects are then reviewed.

5.2.1 Information revelation in auctions

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

In auctions, the type of information that the mechanism accepts from and returns to bidders is structured and known to them. Also, it is made available to all bidders at the same time (McAfee and McMillan 1987).

Furthermore, the mechanism provides information that pertains to the bid-taker (i.e., the buyer in reverse auctions). The main role of information revelation in auctions is to ensure the bidders are making progressive bids. Bidders may obtain information on the bid-taker's preferences prior to or during the auction (Koppius and Heck 2003; Strecker 2010).

In single-attribute auctions, this is easier as the bidders know the bidding direction (e.g., the lower the price the better for the buyer). Thus, it is often sufficient to inform bidders about the winning bid because this bid is the best one for the bid-taker. In multi-attribute auctions, 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 or their rankings. Thus, the winning bid may not produce sufficient information for bidders to make subsequent bids. If the bidders are given the buyer's utility function, it is still difficult for the bidders to optimize their bidding strategies as the utility function may be very complex and non-linear (David, Azoulay-Schwartz et al. 2006).

Different types of information have been considered in auction design, and they can be used to formulate a set of rules of information revelation (e.g. Bichler 2000; Koppius and Heck 2003; Strecker and Seifert 2004; Chen-Ritzo, Harrison et al. 2005; Strecker 2010). The following types of information which can be revealed to the bidders are considered here:

Type A. Buyer's preferences: The preferences may be fully or partially revealed, and this information may be revealed before auction and/or updated during auction.

Type B. Admissible bidding set (ABS): This type gives bidders the directions for allowable bids. It typically takes a form of constraints that are based on individual attributes and/or their combinations. Information of this type is revealed and updated dynamically during auction.

Type C. Bounds on attribute values: Similarly to Type B, this type provides directions for allowable attribute values. The two differences are: (1) constraints for a selected attributes may be given; and (2) information about the constraint is fixed and revealed before auction.

Type D. Actual bids: The buyer may reveal all or selective bids submitted by the bidders and their status (e.g., winning or losing bids, first or second ranked bids).

In multi-attribute auctions, information about either Type A or Type B is mandatory because the absence of such information would make it impossible to know how to make bids that are better for the buyer than the bids made earlier. In that case, the auction may be able to proceed while it requires bidders to "bid in the dark" and/or "bid with trial and error" in order to make admissible bids. Type A 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 or attributes (two or more); the type of utility (scoring) functions; and the accuracy of disclosure (Bichler 2000; Chen-Ritzo, Harrison et al. 2005; David, Azoulay-Schwartz et al. 2006). Type B tells the bidders what bid they can make so that their subsequent bids are better than the bids made earlier.

Type C and Type D are optional and can be included when information of Type A or Type B is used in auctions. This information provides the bidders with the bidding status and/or direction and helps them in making progressive bids.

In terms of the dynamics, Type A and Type C are both static as the information is announced at the beginning of the auctions and is kept constant. Information given in Type B and Type D is dynamic because it is generated or updated during the auction process.

5.2.2 Rules and effects of information revelation

Existing studies have implemented various rules of information revelation with different types of information. For instance, revealing buyer's preferences (Type A) (Bichler 2000; Chen-Ritzo, Harrison et al. 2005), revealing the buyer's preferences and winning bids (Type A + Type D) (Bellosta, Kornman et al. 2008), revealing buyer's preferences and bids (Type A + Type D) (Koppius and Heck 2003; Strecker and Seifert 2004), and revealing bidding constraints and winning bids (Type C + Type D) (Strecker 2010). Experimental studies on the rules of information revelation have shown that configurations of the types have different effects on the bidders' strategies, competition, and the outcomes for both buyers and bidders.

Bichler (2000) conducted several experiments in which the bidders were given the buyer's value function (i.e. Type A). The results show that in this setting, multi-attribute auctions do not provide substantial benefits over comparable single-attribute auctions in terms of efficiency. In other words, even with fully revealed utilities the additional complexity may outweigh the gains. While this may be the case, multi-attribute auctions allow for the exchange of goods that single-attribute auctions do not. Also, it should be noted that there may be other reasons (e.g., the assumption that bidders in both auctions have the same utility function) which caused single-attribute and multi-attribute auctions to have similar efficiency.

Koppius and van Heck (2003) conducted experimental studies on the impact of information availability on efficiency. The information availability specifies the type of information that is given and when, how and to whom it becomes available during the auction. They studied two types of multi-attribute English auctions (i.e. Type A + Type D): (1) auctions with unrestricted information availability, in which suppliers are provided with the winning bid, the corresponding bidder and the rating of losing bids; and (2) auctions with restricted information availability, in which the bidders are informed only about the winning bid and corresponding bidder. Their experiments showed that auctions with unrestricted information availability yield higher efficiencies than auctions with restricted information availability.

Strecker and Seifert (2004) analyzed the impact of preference revelation schemes on the efficiency of multi-attribute English and Vickrey auctions. They concluded that English auctions with revealed preferences of the buyer are more efficient than Vickrey auctions and also, English auctions with hidden preferences (i.e. Type A + Type D). In a recent study (Strecker 2010), the bidders were provided with restricted information regarding the buyer’s utility function: (1) indicative verbal information on the monotonicity constraints of the buyer’s scoring rule (i.e. Type C); and (2) the attribute values of winning bids (i.e. Type D). The results show that revealing the buyer’s preferences increases allocative efficiency and the bidders make more profits while the buyer’s utility increases slightly. In B2B commerce, however, preference disclosure is problematic because buyers often consider it confidential information (Burmeister, Ihde et al. 2002; Parkes and Kalagnanam 2005).

Chen-Ritzo et al. (2005) introduced a multi-attribute English auction where only partial information about the buyer's utility function was revealed. They showed that this variant performs better in terms of efficiency than single-attribute auction. The outperforming of the multi-attribute over the single-attribute auction holds even though the bids in the multi-attribute auction were far away from solutions predicted by theory. Notably, complexity in the auction mechanism consumes some of the efficiency gains over price-only auctions. This observation however, contradicts the findings reported by Bichler (2000).

In the framework proposed by Bellosta et al. (2008), the information imparted by the buyer depends 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 passes the attribute value bounds. This dependency is difficult to implement when the buyer does not make her preference model public (Burmeister, Ihde et al. 2002; Parkes and Kalagnanam 2005).

Teich et al. (1999) suggest an information revelation rule in which the buyer prescribes a preference path i.e., an ordered set of combinations of prices 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.

5.2.3 Motivation and objectives

Review of earlier studies indicates that every auction mechanism requires the disclosure of the buyer's preferences in order to provide sufficient information to 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. The existing rules of information revelation also require certain information be disclosed before auctions, such as buyer's preferences (Type A) and bidding constraints (Type C). This is helpful in initiating and automating auctions, particularly for simple situations such as single-attribute auctions. In such settings, the buyers have little control on information revelation during the auction process to dynamically guide bidders for efficient biding (e.g., Type B). Also, without other supplementary information (e.g., Type D), it is challenging for the bidders to make progressive bids in difficult situations such as multi-attribute auctions.

Sole disclosure of dynamic information (e.g., Type B) has not been studied yet because only recently an admissible bidding set (ABS) protocol for multi-attribute auctions has been designed (Kersten and Wu 2012). This protocol was implemented in the Imaras system, which supports multi-attribute auctions with dynamic information revelation (see Section 4). The system served as a test bed in this experimental study.

In the ABS protocol, the bidding set serves as a vehicle to transform information between the buyer and the bidders as well as between the utility value space and the attribute value space. The buyer constructs space in which alternatives can be evaluated. Using this space the buyer can, for every alternative, determine sets that dominate this alternative, sets which are dominated by it, and sets that are indifferent. In an auction, the system determines the sets which dominate the current winning bid from the buyer's perspective.

Giving the bidders full information about the dominating sets would disclose the buyer's preferences partially (when utility is a non-linear function) or fully (when it is linear). Therefore, the degree of disclosure is controlled by the buyer so that it is possible to prevent bidders from re-constructing the buyer's preferences. This is achieved by selecting several alternatives with equal utility to the current winning bid and modifying every alternative value of different attributes. The size of the change may be fixed or dynamic (e.g., bigger when there are many bidders and smaller when the number of bidders drops), and the attributes of which values are changed may be selected randomly or decided by the buyer prior the auction. Each of these selected alternatives with modified attribute values is used as the point of origin for one set of admissible bids. These sets are given to bidders and limit the bidding space so that bidders make bids with a utility that exceeds the winning bid.

The present study considers the practical needs of organizations in which the buyers are not required to disclose information before the auctions and are able to control information revealed during auctions. To this end, the present study addresses two questions: (1) *without disclosure of buyer's preferences, what information should be given to the bidders for efficient bidding?* and, (2) *what are the effects of revealing the different types of information?*

A conceptual model is proposed with a set of hypotheses concerning the effects of dynamic information revelation in multi-attribute auctions (Section 5.3). This study aims to fill the gaps in existing literature by: (1) formulating a set of rules that give bidders only dynamic information; (2) testing the effects of these rules in an e-procurement context; and, (3) verifying the impact of "more information" in multi-attribute auctions and extending the results reported in earlier studies. Specifically, the three sets of information revelation rules are considered: Type B only, Type B and Type D_{win}, where Type D_{win} is limited to winning bids, and Type B and Type D_{all}, where Type D_{all} covers all bids. The different types of information and their combinations are implemented in Imaras, and their effects on auction process and outcomes are experimentally examined (Section 5.4).

5.3 Research model and hypotheses

This study examines the effects of information revelation on the auction process and outcomes. In addition, the subject evaluation is also considered based on the participants' assessment. The conceptual model is presented in Figure 5-1. The model will be discussed in more detail in the following sections.

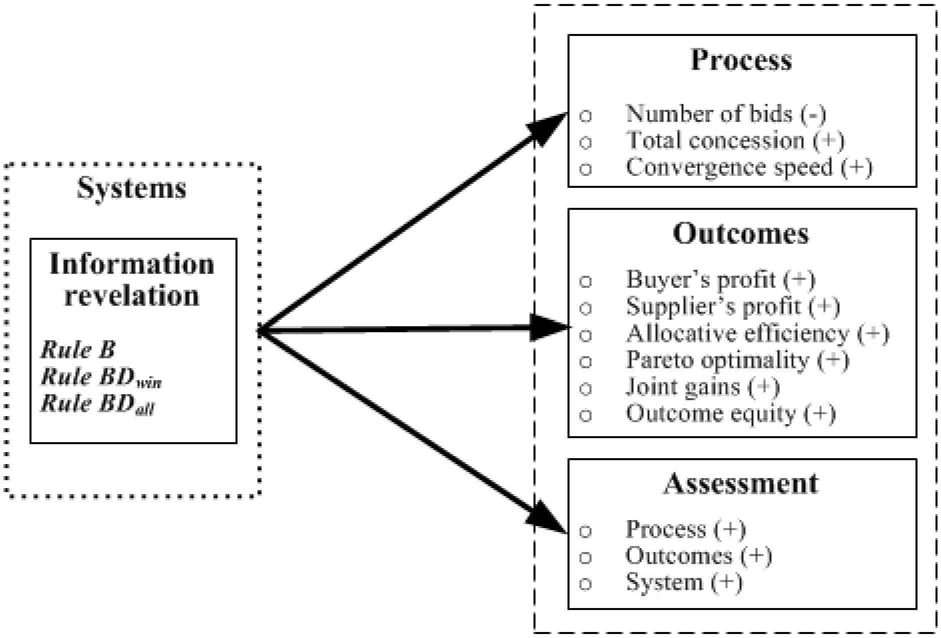


Figure 5-1. Research model

Note: "+" indicates a positive effect and "-" indicates a negative effect, when revealing more information revelation.

5.3.1 Variables and measurement

As shown in Figure 5-1, the independent variable is the rules of information revelation. Three rules of information revelation are examined:

Rule B: Admissible bidding set only (Type B).

Rule BD$_{win}$: Admissible bidding set with winning bids (Type B and D$_{win}$), where the current winning bids are revealed.

Rule BD$_{all}$: Admissible bidding set with all bidders' bids (Type B and D$_{all}$), where all bidders' bids are revealed.

Note that the three rules reveal different set of information, and *Rule B* $\subset$ *Rule BD$_{win}$* $\subset$ *Rule BD$_{all}$*. Also, information about the bidders' own bids is not included in the rule-sets—bidders know their own bids.

These rules are implemented in the Imaras system, which controls the information shown on the system screens. The admissible bidding sets (Type B) are available in all the three rules (Figure C-1 in Appendix C), while the suppliers' views of the bids and bidding process are different, respectively shown as Table C-1, C-2 and C-3 in Appendix C.

Both behavioral and perceptual measures are used to examine the effects of information disclosed to the bidders. Economic indicators have been mainly used to measure individual and market performance in experimental and behavioral economics (Roth 1995; Smith 2003). Recent studies have also considered the participants' subjective responses (Manski 2000; Kagel and Levin to appear). In particular, the economic measures listed in Appendix H are used to analyze the process and outcomes of auctions (Bichler 2000; Koppius and Heck 2003; Strecker and Seifert 2004; Strecker 2010).

Note that the present study considers situations in e-procurement practice, wherein a set of discrete alternatives are given and the buyer and suppliers' preferences are formulated with additive non-decreasing utility functions. The underlying assumptions in this scenario are thus more realistic than those in standard auction theory, particularly the quasi-linearity and risk-neutrality assumptions (Krishna 2010).

Quasi-linearity has been considered as a strong assumption but not practically realistic (e.g. Ausubel and Milgrom 2006; Varian 2010). Under this assumption, the efficient winning bids are also allocative efficient, providing the allocative efficiency is measured with sum of utility; however, in the situations that do not conform quasi-linear utility, the efficient bids may not be allocative efficient (neither measured with sum nor product).

The present study follows an approach in decision and negotiation analysis (Sebenius 1992; Raiffa, Richardson et al. 2002) that relies neither on quasi-linearity nor risk-neutrality. This implies that the utility functions are additive and non-decreasing and that there may be only one, out of many, efficient solution which is allocative efficient. Therefore, in addition to measuring solution or Pareto efficiency, which is done here with the number of alternatives that dominate the achieved contract or exist between the contract and the efficient frontier, a measurement of the allocative efficiency is also required. The standard economic measure, i.e. the sum of utilities, is less useful here because the value computed in this way would be different for different efficient solutions (this is not the case when the utilities are quasi-linear). Therefore, another well-known measure is used here: the distance between the winning bid (the achieved contract) and the Nash solution (i.e. the contract which maximizes the product value of the buyers' and the winning supplier's utilities).

Auction mechanisms are implemented in e-procurement systems. Bidders, as participants of the auctions, are also the users of such systems. Users' perceptions of the auction process and outcomes may affect their evaluation of the mechanisms. Satisfaction has been a surrogate of the effectiveness of information systems (Thong and Yap 1996), and has been used in the assessment of various types of systems, including e-auctions (Oörni 2003; Thomas and Robin 2004). A multi-dimensional scale for participants' assessment of e-markets has been developed based on extant literature, including: process, outcomes, and system (Wu and Yu 2009). The scale is adapted to procurement auctions in this study. As no human buyers are involved in auctions, the scale is used to measure the bidders' assessment.

In addition, several control variables are considered, including: number of bidders, participants' demographics and their expectations. The number of suppliers in procurement (i.e., bidders) has been considered in mechanism design and selection (Handfield and Straight 2003; Kaufmann and Carter 2004; Subramanian and Zeckhauser 2004; Subramanian 2009). 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 (Bichler 2000; Jap 2002; Suter and Hardesty 2005), a higher buyer's surplus (Engelbrecht-Wiggans 1987; Klafft and Spiekermann 2006; Carter and Stevens 2007), and directly and indirectly an effect on the buyer-supplier relationship (Jap 2007; Jap and Haruvy 2008). Moreover, research indicates that a competitive market with a large number of bidders may prevent disclosure of buyer's preferences and require a lower level of information revelation (Jap 2007; Cason, Kannan et al. 2011). Also, participants may behave differently in the auctions and thus affect the process and outcomes (Park and Wang 2009; Hou and Kevin 2010). Their demographics and expectations may also influence their assessment with the outcomes and system (Koeszegi, Vetschera et al. 2004; Koeszegi, Pesendorfer et al. 2006; Vetschera, Kersten et al. 2006).

5.3.2 Hypotheses

Information about bids is not explicitly related to the buyer's preferences. However, bidders may be able to discover the buyer's value function by comparing their own bids and other available information (e.g., winning bids and other bidders' bids). In theory, the more information that is disclosed in an auction, the better the market efficiency will be (Farrell 1987; Klemperer 1999). Empirical results have shown that a higher level of information revelation led to more efficient process in terms of number of bids, number of rounds, and convergence speed (Koppius and Heck 2003; Strecker and Seifert 2004).

Some studies found that the buyers gained better outcomes when more information was disclosed (Bichler 2000; Koppius and Heck 2003; Strecker and Seifert 2004; Chen-Ritzo, Harrison et al. 2005; Strecker 2010). Their findings also indicate that more information had no negative effect on the bidders' outcomes and allocative efficiency. Studies on information transparency have also found that available market information on offers from different suppliers increase market competition and thus lead to cost savings (Soh, Markus et al. 2006; Granados, Gupta et al. 2008; Granados, Gupta et al. 2010). A few studies, however, found that too much information generates noise signals for bidders to make appropriate decisions and leads to information saturation and collusion that reduce market efficiency (Dufwenberg and Gneezy 2000; Dufwenberg and Gneezy 2002; Koppius and Heck 2003).

Taking into account both sides, revealing more information during the auction process may help the bidders learn about the buyer's preferences and make trade-offs between different attributes, which may lead to better joint outcomes and more balanced contracts (Koppius and Heck 2003; Strecker and Seifert 2004; Chen-Ritzo, Harrison et al. 2005). Thus, we expect that:

H1 The more information that is revealed the greater the process efficiency in terms of smaller number of bids, larger concessions and faster convergence.

H2 The more information that is revealed the better the economic outcomes in terms of the profit, allocative efficiency, Pareto optimality, joint gain and outcome equity.

Moreover, additional information revealed by the buyer may also increase the transparency of the process along with, consequently, the trust of the bidders (Gattiker, Huang et al. 2007). Information about winning bids and other bidders' bids is valuable during the auction process; revealing such information may lead to better relational outcomes (Lösch and Lambert 2007). Users' evaluation of systems is affected by their performance and outcomes (Venkatesh, Morris et al. 2003; Vetschera, Kersten et al. 2006). A higher level of information revelation reduces the participants' efforts during the process, leads to better outcomes, and thus positively affects their perceptions and evaluations. Hence, we also expect that:

H3 An increase in the level of information revelation will lead to bidders' more positive assessment with the process, outcomes and system.

5.4 Experimental design and data collection

The purpose of this study is to provide insights into the effects of information revelation on the process and outcomes of auctions. The Imaras system is served as a test bed to manipulate different rules of information revelation and the proposed hypotheses are then tested with an experimental approach. The experimental design, tasks and procedure for data collection are described in the following sections.

5.4.1 Experimental design

The study was carried out in two experiments: A controlled laboratory experiment and an online experiment. The former helps establish the causality between independent variables and dependent variables and ensures the internal validity of the study (Colquitt and Gainesville 2008), while the latter provides a more natural environment in order to increase the external validity of the study and strengthen the findings (Kerlinger and Lee 2000).

Table 5-1 shows the experimental design with the treatments on information rules in the two experiments.

Table 5-1. Experimental design and treatments (Study 2)

Information revelation			Experiment 1 (Laboratory)	Experiment 2 (Online)
Rules	Types	Information		
Rule B	Type B	ABS only	Treatment B	
Rule BD$_{win}$	Type B + D$_{win}$	ABS + winning bids	Treatment BD$_{win}$	Treatment BD$_{win}$
Rule BD$_{all}$	Type B + D$_{all}$	ABS + all bidders' bids		Treatment BD$_{all}$

Experiment 1 was conducted in the laboratory environment with a number of sessions. Each session lasted one hour and 40 minutes, including the time for preparation and questionnaires. The auction in each session lasted 50 minutes; it could end earlier if no bidders submitted bids or no more better bids available for the buyer. It was multi-round auction; each round took five minutes. The bidders obtained the auction updates on the rounds and the revealed information immediately from their computer screen.

Experiment 2 was conducted in an online setting, in which the auctions were running on the Internet and lasted 10 days. Each round was set as one day. The bidders could log on and off at any time during the auction. They were informed by emails about any auction updates, but they were required to log on to access the revealed information.

5.4.2 Experimental tasks

The experimental tasks were role-play with a business case that involved contracting between a milk producer and several transportation service providers. Three attributes of the transportation service were concerned: (1) *standard rate*; (2) *rush rate*; and (3) *penalty for delay*. There were a number of option values for each attribute, and the possible ranges were known to each participant.

The bidders played the role of a sales manager for the service providers. They were competing with each other to win the contract. Each contract could be awarded to only one supplier. The service providers wanted to get the contract; however, the contract should bring their business profits rather than losses. Therefore, the bidders were given break-even points of the company they represented.

The context and background provided the public information that was known to every supplier, while the preferences were explained in the private information that was not known to the other suppliers. The reservation and aspiration levels of each company were also stated in their private information. A financial calculator is implemented in the system, and it could be used by the participants to calculate the revenue and profit for each contract alternative. Appendix D summarizes the business profiles and preferences of the companies involved in the transaction.

In both experiments, the utility function, reservation and aspiration levels, and the break-even point were kept unchanged for the buyer and the suppliers. The only difference was the number of alternatives due to the number of option values for each attribute. In Experiment 1, each attribute consisted of six option values, resulting in 216 alternatives in total; in Experiment 2, each attribute had 15 possible values; there were 3,375 alternatives.

5.4.3 Experimental procedure

The experiments involve several steps and a series of activities (Table E-1 in Appendix E). Before the experiment, the participants first signed up online and their demographical information was gathered via a registration form. The participants were then randomly matched up with different roles and assigned to one of the treatments.

During the experiment, the participants first read the case for the preparation, including the public information and the private information. This was followed by a case quiz and pre-questionnaire before the auction started. Table F-1 in Appendix F shows a sample case quiz for one supplier, which was used to improve the participants' understanding of the tasks. The participants were then asked to provide their perceptions of the transaction task as well as their aspiration and reservation levels. These measures were used to examine their understanding of the task, their expected bidding space (the alternatives they may bid), and the contract to achieve.

During the auction process, the participants constructed and submitted bids on behalf of the companies they represented. Once the auction was closed, they were asked to fill out a post-questionnaire that collected subjective responses of the process and outcomes. The participants reported their evaluation of the auction process in terms of performance, effort, and experience.

The participants' activities during the transaction process were recorded in a database, which was used to analyze the transaction process and outcomes.

In the experiments, there was no change in the experimental procedure, except for the participants in Experiment 2 being provided with a video demonstration of the system before the participants actually used it. This was introduced following the feedback from the participants in Experiment 1. In addition, because Experiment 2 was conducted online, the participants could be neither given instructions similar to those in Experiment 1, nor explanations during the process. The purpose of introducing the video demonstration was to improve the participants' knowledge and understanding of the system and the bidding process, which was similar to the business training for new technologies in the real world and also ensured that the participants had the same baseline experience in order to test the effects due to treated conditions (Kumar and Benbasat 2006; Kamis, Koufaris et al. 2008).

5.5 Data analysis and instrument testing

A descriptive analysis was first conducted. The instrument for bidders' assessment was tested with an exploratory factor analysis (EFA) using the data from Experiment 1, and it was then improved upon and validated with a confirmatory factor analysis (CFA) using the data from Experiment 2.

5.5.1 Descriptive analysis

There were a total 298 undergraduate students who participated in the experiments. They were recruited from the business school of a large Canadian university. The students were taking an introductory course on management information systems. The experiment was part of their course work on e-procurement and was worth 6 percent of each student's total mark, with both participation and performance being considered. The descriptive analysis are shown in Table 5-2.

Table 5-2. Descriptive analysis of the two experiments

	Experiment 1		Experiment 2	
	Treatment B	Treatment BD_{win}	Treatment BD_{win}	Treatment BD_{all}
Number of auctions	26	21	17	13
Number of bidders	98	77	66	45
Age (25 or younger, %)	96	92	91	93
Gender (female, %)	45	49	48	43
Knowledge (novice-1, expert-7)	2.92	3.30	2.90	3.34
Experience with system (low or no, %)	77	84	79	84
Task complexity (easy-1, difficult-7)	3.88	4.08	3.82	3.85

There were 179 participants in Experiment 1; among these participants four were removed from the data set as their auctions were terminated accidently. There were 26 auctions for Treatment B and 21 auctions for Treatment BD_{win}. On average, each auction involved 3.72 bidders. In Experiment 2, there were 119 participants and eight were excluded for the reason stated above. There were 30 auctions in total: 17 auctions for Treatment BD_{win} and 13 auctions for Treatment BD_{all}. On average, each auction involved 3.70 bidders. No significant differences were found between the treatments in terms of the number of bidders in each auction.

In both experiments, most of the participants were between 20 and 25 years old as they were undergraduate students. About 45 percent of the participants were female; gender does not differ across the treatments. The participants perceived their knowledge about auctions to be lower than average, and over 77 percent of the participants had low or no past experience in using an auction system. On average, the participants perceived the task would be relatively difficult. An ANOVA test showed no significant difference in their perceived task complexity between the treatments.

5.5.2 Instrument testing and factor analysis

The participants' responses to the post-questionnaire were used to examine their assessment of the auction process, outcomes, and system. All questions used a 7-point Likert scale that ranged from "Strongly disagree" to "Strongly agree." The instrument contains nine questions. Table 5-3 lists the items for each type of assessment used in Experiment 1 and Experiment 2.

Table 5-3. Instrument for bidders' assessment

Factors	Items
In Experiment 1	
Assessment of process	AP1. It was easy to keep track of the process. AP2. The organization of process was useful. AP3. This process was stimulating.
Assessment of outcomes	AO1. I am satisfied with the results that I achieved. AO2. I am satisfied with the results as compared to my expectations. AO3. The outcome is better for Milika than it is for the provider.
Assessment of system	AS1. The system was helpful in achieving my objectives. AS2. The system was helpful in improving my performance. AS3. The system was helpful in managing the transaction.
In Experiment 2	
Assessment of process	AP1. It was easy to keep track of the process. *AP2. The organization of process in phases and steps was useful.* AP3. This process was stimulating.
Assessment of outcomes	AO1. I am satisfied with the results that I achieved. AO2. I am satisfied with the results as compared to my expectations. *AO3. I think I obtained the best results for the company that I represent.*
Assessment of system	AS1. The system was helpful in achieving my objectives. AS2. The system was helpful in improving my performance. *AS3. The system was helpful in managing the process.*

An EFA was conducted with the data from Experiment 1 in order to obtain fewer measures that could be aggregated from the items and could be used to compare bidders' assessment. A correlation analysis indicated that the items were correlated. Thus, the maximum likelihood analysis was used with the Oblimin rotation method to identify the factors.

The results of EFA are shown in Table 5-4. The three factors extracted over 79 percent variance, and the factor loadings for all items were above 0.62. The eigenvalue for one factor was below one as suggested for EFA while it was able to explain over 10 percent of the variance. The result indicates that three factors may exist, corresponding to bidders' assessment of process, outcomes, and system.

Table 5-4. EFA for bidders' assessment

Item	Process	Outcomes	System
AP1	**0.84**	0.06	0.03
AP2	**0.62**	0.03	0.29
AP3	**0.80**	0.14	0.09
AO1	0.02	**0.87**	0.03
AO2	0.04	**0.87**	0.01
AS1	0.16	0.20	**0.75**
AS2	0.08	0.15	**0.80**
AS3	0.13	0.04	**0.66**
Eigenvalue	4.3	1.3	0.8
Explained variance	53.5%	16.1%	10.3%

One item for assessment of outcomes (AO3) did not load on any of these three factors and it was excluded from the final factor model. After reviewing the item, its wording was changed as there was concern that participants might become confused in evaluating their outcomes in comparison with the buyer's outcomes. Minor wording changes were also made to items AP2 and AS3 to improve their clarity and consistency with other items. The revised items are shown in italic in Table 5-3, and the instrument was then used in Experiment 2.

To validate the instrument, a CFA was conducted with EQS 6.1. The dataset contained 90 bidders that participated in Experiment 2 and completed the questionnaire. A robust analysis was conducted, which is not restricted by the normality and sample size of the dataset. Figure 5-2 shows the factor model and CFA results.

The factor model provided a good fit for the data. The result of chi-square test statistics is $\chi^2=49.79$ and the probability value is significant ($p=0.01$). This is acceptable as the sample size is relatively small and the model is not complex, which is consistent with a relative fit index independent from sample size (*IFI=0.98*) (Bollen 1990). Moreover, both CFI and NNFI are above 0.95, and RMSEA is located between zero and one (*CFI=0.98; NNFI=0.96; RMSEA=0.07).* These noncentrality-based indices meet the suggested cut-off criteria and indicate a valid factor model (Hu and Bentler 1999).

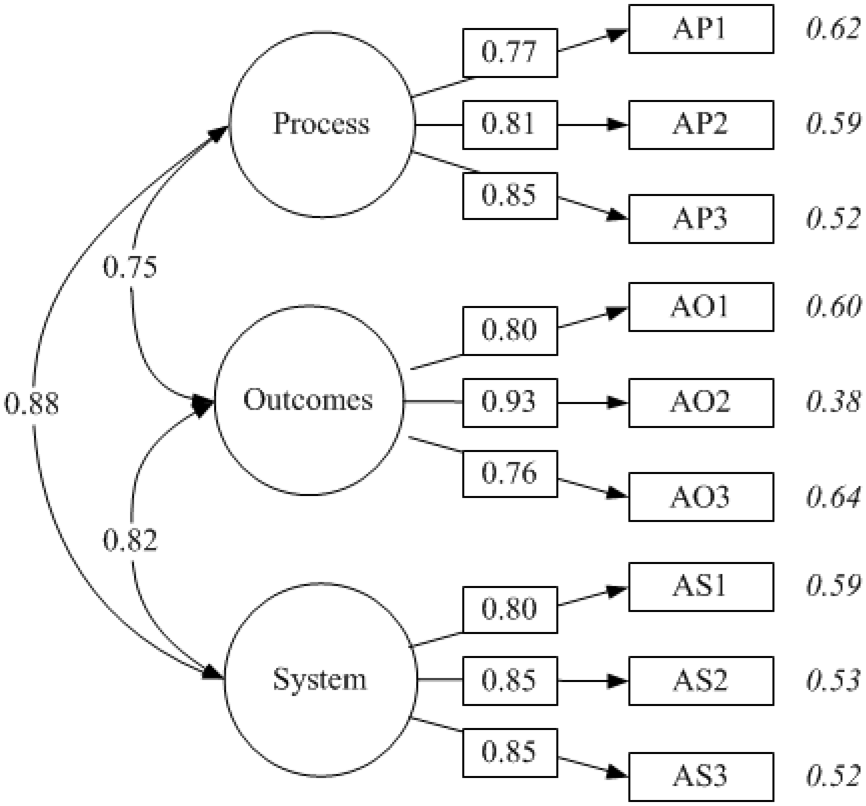


Figure 5-2. CFA for bidders' assessment

The values of Cronbach's α for all factors are above 0.82 (*AP=0.82, AO=0.88, AS=0.85*), exceeding the recommended cut-off criteria ($\alpha>0.70$) and indicating an adequate internal consistency reliability of the instrument (Nunnally and Berstein 1994). Moreover, all factor loadings are above 0.75, which shows significant improvement from the EFA result and a good convergent validity. The lowest average variance extracted (AVE) for the three factors is 0.73 for assessment of process, which satisfies the reliability criteria for all single factors ($AVE>0.50$). It also exceeds the shared variances between the factors, except the assessment of process and system (0.77). Thus, the discriminant validity is partially satisfied (Fornell and Larcker 1981). Note that the correlations between the three types of assessment are all above 0.5, which indicates that when bidders evaluate certain aspects of the auctions they may also consider other aspects. In particular, a high correlation exists between assessment of process and system (0.88), which failed the discriminant validity for these two factors. This may be due to that fact that the auction process is governed by the rules that are implemented in the system and thus the bidders might not distinguish their experience and feeling in the process from using the system. Further testing may be required with a larger sample. Considering the exploratory nature of this study is in the field, the three factors were all used to assess the process, outcomes and system in the auctions.

A weighted sum for each factor was calculated using the factor loadings and then used to compare the bidders' assessment in subsequent analysis (Section 5.6). As the same dataset should not be used to conduct both EFA and CFA analysis, the calculation of the weighted sum for Experiment 1 was based on the factor loadings obtained from EFA (Table 5-4), and the calculation for Experiment 2 was based on the factor loadings from CFA (Figure 5-2).

5.6 Results

Following these analyses, the effects of information revelation on the process, outcomes and bidders' assessment are examined.

5.6.1 Experiment 1: Rule B vs. Rule BD_{win}

The effects of different rules of information revelation on the process and outcomes of auctions are compared between the two treatments, i.e., Rule B and Rule BD_{win}. An ANOVA test was used to compare the number of bids and the convergence speed between the treatments. The bidders' assessment was also compared using ANOVA. These variables conformed normal distribution from the descriptive analysis. Nonparametric tests have been suggested by previous studies to compare variables based on utility, considering the normality of their distribution (Koppius and Heck 2003; Strecker and Seifert 2004). The Mann-Whitney test with independent samples was used to compare the distribution of the outcomes variables. Table 5-5 shows the results of process, outcomes and assessment between the treatments.

The result shows significant improvement in process efficiency when, in addition to the limit sets, the winning bids were revealed. The bidders who were given only the admissible bidding set made more bids and took more time to close the auctions. The result indicates that the bidders were able to make efficient bids when given merely the admissible bidding set, and, consequently, the auctions proceeded in a direction that favored the buyer. From the bidders' perspective, such information seemed to be opaque with a consequence of hiding the buyer's preferences. The result was that greater effort was required of the bidders to explore and learn the buyer's preferences and the other bidders' strategies. In Treatment BD_{win}, the winning-bid information may provide more clues about the buyer's and other bidders' preferences and thus the bidders could bid more efficiently that benefit buyers. Such information also indicates the existence of other bidders that may contribute to increased competition. This is shown in the larger concession the bidders made in Treatment BD_{win}. Lacking this additional information on winning bids, the bidders in Treatment B might be more uncertain about the process and may make smaller concessions which, as a result, lead to a slower convergence.

Table 5-5. Process, outcomes, and assessment (Rule B vs. Rule BD_{win})

		Rule B	Rule BD_{win}	Sig.
Process	Number of bids	6.44	5.65	***.05***
	Total concession	52.40	60.71	**.00**
	Convergence speed	57%	45%	***.03***
Outcomes	Buyer's profit	72.48	80.48	**.01**
	Supplier's profit	-2.12	-9.52	.34
	Joint gain	861	461	.32
	Outcome equity	0.12	0.10	.37
	Pareto optimality	1.15	0.05	***.04***
	Allocative efficiency	59.82	68.04	.09
Assessment	Process	3.01	2.94	.65
	Outcomes	2.96	2.94	.90
	System	3.68	3.69	.93

The outcomes were also significantly different when revealing the winning bids in addition to the admissible bidding set. Overall, the buyers' profit was significantly increased from 72.48 in Treatment B to 80.48 in Treatment BD_{win}. The supplier's profit was dropped from -2.12 to -9.52, which is not statistically significant. This seems to be surprising as generally the gain of buyers comes from the loss of suppliers, which is true in single-attribute auctions. In multi-attribute auctions, however, the trade-offs between attributes and the indifference of alternatives may result in different situations. Prior studies have found significant gain on one side with no difference on the other (e.g. Strecker 2010). The decrease in the supplier's profit may be partially due to the fact that more bidders were overbidding in Treatment BD_{win}. This indicates that either the participants were not aware enough about the break-even point for the company they represented, or that they were emotionally involved in the auctions. This would constitute a departure from auction theories based on rational behavior. The revelation of winning bids may lead to tough bids and increase the competition among the suppliers, taking into account the quicker convergence and their bigger losses in the auctions.

The Pareto optimality and allocative efficiency were also calculated to examine auction performance. The contracts reached in Treatment BD_{win} were, on average, very close to the Pareto optimality frontier. There were more better deals left on the table in Treatment B, i.e., both sides could gain more with better contracts. Note that optimal contracts are not necessarily better solutions; in fact, the supplier's profit was decreased in Treatment BD_{win} rather than in Treatment B. The result indicates that the bidders who were only provided with the admissible bids might be more uncertain about the auction and more risk-averse in their bidding behavior. Also, the fact that more bidders were overbidding in Treatment BD_{win} resulted in contracts that excessively benefited the buyer, which left less room to improve for Pareto optimality.

Considering the contract value for both the buyer and the supplier who won the contract, the joint gain and outcome equity were compared between the two treatments. The results show little difference in their distribution in the auctions.

In terms of the bidders' assessment of the process, outcomes and system, the results show that there was little difference between the bidders in the two treatments. Taking into account the difference between winners and non-winners, a further investigation was conducted to compare the bidders' assessment between these two groups across the treatments. The winners in Treatment B had more positive assessment with outcomes than non-winners. While it's marginally significant in Treatment $\mathrm{BD}_{\mathrm{win}}$, these results indicate that the participants might have focused only on the different information revealed during the process and through the system; however, they did not consider that the different rules of information revelation would make differences in the process and system. Another possible explanation is that the participants might not be aware of the fact that information revelation might change their actual process and the capability of the system.

5.6.2 Experiment 2: Rule $\mathrm{BD}_{\mathrm{win}}$ vs. Rule $\mathrm{BD}_{\mathrm{all}}$

In Experiment 2, the effects of information revelation on Rule $\mathrm{BD}_{\mathrm{win}}$ and Rule $\mathrm{BD}_{\mathrm{all}}$ were examined. Similar to Experiment 1, ANOVA and Mann-Whitney tests were used to compare their effects. The results are summarized in Table 5-6.

Table 5-6. Process, outcomes, and assessment (Rule $\mathrm{BD}_{\mathrm{win}}$ vs. Rule $\mathrm{BD}_{\mathrm{all}}$)

		Rule $\mathrm{BD}_{\mathrm{win}}$	Rule $\mathrm{BD}_{\mathrm{all}}$	Sig.
Process	Number of bids	4.38	2.93	**.00**
	Total concession	41.86	25.03	**.00**
	Convergence speed	36%	22%	**.01**
Outcomes	Buyer's profit	66.94	45.31	**.01**
	Supplier's profit	3.94	30	**.01**
	Joint gain	218	855.6	***.02***
	Outcome equity	0.35	1.53	**.01**
	Pareto optimality	0.76	0.92	.48
	Allocative efficiency	50.71	33.52	***.03***
Assessment	Process	3.65	3.88	.29
	Outcomes	3.26	3.77	***.04***
	System	3.95	3.74	.14

Similarly to Experiment 1, the results show that revealing more information led to higher process efficiency in terms of number of bids and convergence speed. The bidders who were provided with all bidders' bids made significantly fewer bids than those who were given the admissible bidding set and winning bids (2.93 vs. 4.38). The auctions in Treatment $\mathrm{BD}_{\mathrm{all}}$ converged faster than those in Treatment $\mathrm{BD}_{\mathrm{win}}$ (22 percent vs. 36 percent). However, the bidders made much smaller concessions in Treatment $\mathrm{BD}_{\mathrm{all}}$ than in Treatment $\mathrm{BD}_{\mathrm{win}}$. These results indicate that the revelation of all bidders' bids (both winning and losing bids) reduced the bidders' interest in bidding, i.e., the revelation of the losing bids might hinder the competition between suppliers.

The results in Table 5-6 also show that revelation of information led to different outcomes for the suppliers and the buyers. On average, the suppliers reached significantly higher profit (greater than 25 out of 100) when they were provided with all bids than suppliers who were given only winning bids. The buyers' outcomes were decreased when disclosing all bidders' bids during the auction. The substantive increase of sellers' profit led to the significant increase of the joint gains and outcome equity. These results indicate that more balanced contracts were reached when more information was disclosed.

Taking into account both process and outcomes, the results indicate that the information about other bidders' bids in Treatment BD_{all} led to the lack of interest in bidding and the decrease of competition in addition to a quicker auction termination. This is different from the results in Experiment 1, where the higher process efficiency may be partially due to the greater competition and compromise when revealing more information (i.e., winning bids). It should be noted, however, that the experiment settings and the revelation rules were different.

The Pareto optimality was not different between the treatments, indicating that the contracts reached in both treatments were equally efficient. However, the allocative efficiency was significantly higher in Treatment BD_{all} than in Treatment BD_{win} (33.52 vs. 50.71), i.e., there was smaller distance from the maximum achievable solution when revealing all bidders' bids. This indicates that the auctions with revelation of both winning bids and losing bids outperformed those auctions with revelation of only winning bids.

Next, the bidders' assessment of process, outcomes and system in the two treatments were compared. The results given in Table 5-6 show that only the outcomes were perceived to be significantly different between the two treatments. The bidders who were able to view other bidders' bids showed better assessment of the outcomes.

Moreover, a comparison between winners and non-winners across the treatments was conducted.

The result shows no significant differences in the winners' assessment between the treatments; however, the non-winners provided more positive evaluations on the outcomes and system in Treatment BD_{all} than those in Treatment BD_{win}. This indicates that the bidders might consider that the outcomes were fair due to the higher level of transparency in auctions, even though they did not win the contract. Also, they perceived that the system was more useful when more information was provided. Nonetheless, neither the winners nor the non-winners considered the process differently. These results again indicate that the bidders may not consider information revelation as a component in the process.

5.6.3 Summary of findings

Two experiments were carried out to compare three rules of information revelation, which consisted of the admissible bidding set, winning bids and/or losing bids. The effects of disclosing winning bids in the two experiments (i.e. Rule BD_{win}) cannot be directly compared because they were tested in different settings (laboratory vs. online); however, we expected that the results from Experiment 2 would strengthen the results from Experiment 1, considering the higher level of control and smaller decision space of the auction problem in the laboratory setting. Also, the participants in the two experiments were recruited from the same population and had similar characteristics, which allowed this study to exclude individual differences and to focus on the effects of information revelation. The findings from the two experiments are summarized in Table 5-7.

Overall, Hypothesis 1 on auction process efficiency was fully supported in Experiment 1 but partially supported in Experiment 2. The results show that revealing more information led to fewer bids and faster convergence. Note that the shorter auction length may be partially due to the greater competition (in Experiment 1) and due to the unwillingness of bidding (in Experiment 2). This is also indicated by the concessions made by the bidders in the auctions. Revealing the winning bids only led to greater concessions from the bidders, whereas disclosure of the losing bids led to smaller concessions.

Table 5-7. Summary of findings from two experiments

	Experiment 1		Experiment 2	
	(Rule B=> Rule BD_{win})	Hypotheses	(Rule BD_{win} => Rule BD_{all})	Hypotheses
H1: Process				
Number of bids	-	Supported	-	Supported
Total concession	+	Supported	-	Not supported
Convergence speed	+	Supported	+	Supported
H2: Outcomes				
Buyer's profit	+	Supported	-	Not supported
Supplier's profit	o	Not supported	+	Supported
Joint gain	o	Not supported	+	Supported
Outcome equity	o	Not supported	+	Supported
Pareto optimality	+	Supported	o	Not supported
Allocative efficiency	-	Not supported	+	Supported
H3: Assessment				
Process	o	Not supported	o	Not supported
Outcomes	o/+	Partially supported	o/+	Partially supported
System	o	Not supported	o/+	Partially supported

Note: "+"indicates positive effect; "-"indicates negative effect; "o" indicates no difference.

The results for Hypothesis 2 are mixed between the experiments. The suppliers' outcomes were significantly increased only when they were given all bidders' bids (Rule BD_{all}). There was no significant difference if the winning bids, but not the losing bids, were shown (Rule B vs. Rule BD_{win}). The buyers' outcomes were increased with Rule BD_{win} and decreased in the treatments with either Rule B or Rule BD_{all}. While the result is tentative, Rule BDwin outperformed other rules in both experiments in terms of buyer's gains.

The joint gain, outcome equity and allocative efficiency were all increased when all bidders' bids were disclosed, indicating more balanced contracts were reached. Revealing only the winning bids did not make a significant improvement in contract balance, but the Pareto optimality was increased. These results indicate that revealing more information in auctions leads to equivalent or better performance in terms of social welfare and market efficiency.

The bidders' assessment was concerned with three aspects: process, outcomes, and system. It was expected that information revelation as a component of these aspects would affect the bidders' assessment. Nonetheless, when more information was revealed, their assessment was only improved with outcomes. No significant differences were found on assessment of process and system in both experiments. A group comparison between winners and non-winners was also conducted. The results show that the winners were more satisfied with outcomes in both Treatment B and Treatment BD_{win} than the non-winners, and the non-winners were more satisfied with both outcomes and system in Treatment BD_{all} than those in Treatment BD_{win}. This indicates that the participants might not consider that information revealed during auctions would affect the process, whereas their assessment of outcomes and system was partially affected by their final achievement.

5.7 Discussion

This study considers situations wherein B2B transactions involve multiple attributes of goods or services rather than price only and wherein the buyers do not wish to explicitly reveal their preferences. In single-attribute auctions, the bidders can figure out what to bid even without giving the buyer's preferences. In multi-attribute auctions, it is important and challenging to determine what information is sufficient for the bidders to make progressive bids.

5.7.1 Information types and their effects

In Imaras auctions the minimum information disclosure is admissible bidding set; it tells the seller what the buyer accepts but does not disclose the preferences. The winning and losing bids are optional information that indicate the bidding status and provide information about the competitors' actions. All these types are feedback-type given during the auction and provided by the mechanism that allows the bidders to learn the buyer's preferences. Prior studies suggest disclosing more information to improve the efficiency of auction process and outcomes (e.g. Koppius and Heck 2003; Greenwald, Kannan et al. 2009).

The findings from the two experiments imply that the suppliers using multi-attribute reverse auctions should not favor the information revelation policy that stresses the winning bids (Rule

BD_{win}); instead, the revelation of either admissible bidding set only or all bidders' bids (Rule B or Rule BD_{all}) should benefit the bidders. The buyers, in comparison, should prefer mechanisms in which winning bids are revealed but not with the losing bids (Rule BD_{win} but not Rule BD_{all}). Thus, the effects of information revelation in multi-attribute auctions not only depend on the level or amount of information revealed but, more importantly, the types and combinations of information disclosed. For instance, Experiment 1 shows that revealing more information (the winning bids in addition to the admissible bidding set) is beneficial to the buyers and worse for the suppliers as the additional information increases the competition among the bidders. In Experiment 2, however, it shows a different situation as more information revelation (losing bids) hinders competition in this particular setting.

Information about winning bids may create an anchor for the bidders (Tversky and Kahneman 1974). Focusing on this anchor, these bidders might not explore the admissible bidding set and search for the best feasible alternatives. The bidders provided with the winning bids but without losing bids might make greater compromises when they are comparing their bid with the winning bid. Under this interpretation, bidders who focused on the winning bid used the difference between revenue yielded by their bid and by the winning bid to decide on their next bid. The other bidders may rely on their own bid, others' bids and/or admissible bids.

The revelation of losing bids may be double edged. On the one hand, they provide information about the buyer's preferences (these bids do not meet the buyer's needs) as well as about other bidders' preferences and strategies (these bids are submitted by competitors). This may lead the bidders to explore better solutions by making trade-offs between the multiple attributes and by making an appropriate but not necessarily greater compromise. On the other hand, they may also either generate noise signals which weaken the anchoring effects of winning bids or lead to an information saturation point where extra information does not improve the market efficiency (Dufwenberg and Gneezy 2000; Dufwenberg and Gneezy 2002; Koppius and Heck 2003; Kumar

2013). Information about losing bids may create additional signals (e.g., reference points with lower bonds) which diminish competition. As Dufwenberg (2002 , p. 442) wrote "the following piece of advice to auctioneers: you may announce winning bids, but keep the losing bids secret!"

Previous studies have also shown the complementary effects between the process efficiency and the level of information revelation (e.g. Koppius and Heck 2003). Auctions converge faster when more information is provided, and more information is revealed when auction lasts longer. This assumes that all the information is constructive for the bidders to learn the buyer's preferences without considering any noise signals. The present study shows that the number of bids and amount of time, indeed, can be reduced when revealing the additional information. Nonetheless, on a cautionary note, the quicker convergence of auction may not lead to efficient solutions due to noise signals that can cause a lack of participation and competition.

5.7.2 Implications for practice and future research

The contributions of this study are threefold: (1) identifying different types of information and formulating a set of rules without disclosure of buyer's preferences; (2) experimentally testing the effects of different rules that consist of different types of dynamic information; and (3) providing guidelines for suppliers, buyers and mechanism designers to appropriately and strategically use different information.

The findings imply that appropriate design of information rules in multi-attribute auctions enable bidders to operate efficiently in such complex situations. The rules formulated in this study are solely based on dynamic information about bids (admissible and submitted), which may benefit not only the buyers (no need to disclose their preferences) but also the suppliers (simplified bidding problem). The admissible bidding set may be opaque but the bidders need to make more effective use of such information to discover buyer's preferences. The winning and losing bids may provide extra value with their anchoring, learning, and signaling effects.

Due to the different interests among the buyers and bidders, specific controls on information revelation should be considered. For instance, if the anchoring effect indeed exists, then the buyers may consider creating anchors with simpler and clearer information so that they can obtain better outcomes. The buyers may also need to pay attention to the extra information that is revealed to bidders as it may lead to information saturation or even a worse situation that affects bidders' willingness to bid.

Several limitations of this study should be addressed for future research. In the experiments, a system was used by university students to conduct a simulated auction task. Research in e-business has discussed both advantages and disadvantages of this setting. The second experiment was conducted in an online setting which is closer to the real world situations. Nonetheless, one of the reasons that revealing more information with all bids (Rule BD_{all}) was not helping may be that these bidders were students and they had no vested interest in winning. They might want to win but it was not most important to them. When they saw that there were other "non-winners", many of them were satisfied and thus stopped bidding. Future research may validate the findings with a field study where the systems are used by business professionals for real life transactions. Also, the transaction is relatively complex and the number of bidders in each auction was small. This may limit the findings to those transactions that involve business contracts with only a few potential and important suppliers. Future work may consider transactions with a larger number of suppliers for simpler transactions, which may require different information policies.

6. Study 3: Comparison of Auctions and Negotiations

6.1 Introduction

Successful management of purchasing activities requires not only selecting the right product or service but also choosing the best method of buying them (Handfield and Straight 2003). Typical methods include reverse auctions and negotiations for business to business transactions. 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 negotiations; procurement managers negotiated with several suppliers in order to select one of them. E-commerce now allows for the search of suppliers anywhere in the world. This is particularly valuable in situations where there may be many potential suppliers, some in close proximity to the business's location others—far away. More advanced and suitable mechanisms than traditional single-attribute auctions and bilateral negotiations are needed in order to determine the best one from among many dispersed suppliers.

A number of multi-attribute auction mechanisms have been proposed (e.g. Bichler 2000; Teich, Wallenius et al. 2003). They may be used in solving problems in which formerly, only negotiations could have been employed, thus increasing procurement efficiency. To-date, however, there have been no studies in which such auctions and negotiations are compared.

Sequential bilateral negotiations with one supplier at a time or several suppliers simultaneously over multiple attributes are both complex and costly. Negotiations with multiple suppliers simultaneously, i.e., multi-bilateral negotiations, may not be possible or may require the engagement of several procurement managers. Such processes would benefit from ICT support; few studies, however, have modeled and examined multi-bilateral negotiations in an e-procurement context.

Organizations need to select and possibly adapt market mechanisms to suit their particular procurement situation. Models and guidelines have been proposed to aid the mechanism selection in procurement practice (e.g. Kraljic 1983; Handfield and Straight 2003). Most of them are based on normative theories (e.g. transaction cost theory by Williamson 1979). They consider general sourcing strategies (e.g. outsourcing, integration, spot buying or reverse auctions) rather than the specifications describing the marketplace and organization with its procurement process. In contrast, research in experimental economics and market design (Milgrom 2000; Smith 2003) empirically study mechanisms with different design characteristics. These studies are limited to single-attribute auctions; only a few studies examined multi-attribute auctions, while the results are mixed and even contradictory (e.g. Bichler 2000; Lewis and Bajari 2011). There is a dearth of empirical studies to compare multi-attribute auction mechanisms (Kagel and Levin to appear).

The present research thus aims to address this gap in the literature and to empirically examine and compare multi-attribute reverse auctions and multi-bilateral negotiations. This will help us gain an understanding of their roles in procurement process and outcomes. In order to carry out these goals, two systems have been developed: in one system, *Imaras*, a multi-attribute auction mechanism was implemented and in the second system, *Imbins*, a multi-bilateral negotiation mechanism was implemented. These systems are used in experiments to address the following main question: *How will the different mechanisms affect the process, outcomes and users' assessment of e-procurement?*

In this study, the two mechanisms are compared to investigate their effects on process efficiency, outcomes and suppliers' assessment. In order to enhance the validity and generalizability of the study, two experiments were conducted in laboratory and online environment respectively. The potential contributions of this research include:

(1) An interdisciplinary approach to study auctions and negotiations in e-procurement;

(2) The insights into the similarities and differences between auctions and negotiations, and

(3) The formulation of guidelines for strategic use of different mechanisms in various procurement

contexts.

The rest of this paper is organized as follows. Section 6.2 provides the background and motivation of this research, particularly comparative studies on auctions and negotiations. Section 6.3 formulates the research hypotheses to compare auctions and negotiations. Section 6.4 describes the two experiments for data collection, and Section 6.5 presents the data analysis and results. Section 6.6 discusses the findings and implications for practice and future research.

6.2 Background and motivation

E-procurement can be fulfilled through online auctions and negotiations. The relevant literature on comparisons of multi-attribute auctions and negotiations are briefly reviewed, providing the background and motivation of this study.

6.2.1 Auctions and negotiations

Multi-attribute auctions are designed to deal with transaction problems that involve multiple attributes. There are two main concerns when designing multi-attribute auctions: (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.

Several scoring methods have been proposed to represent buyer's preferences in multi-attribute auctions (e.g. Bichler 2001; Beil and Wein 2003; Engel and Wellman 2010). One such type of methods is the attribute monetization method; it expresses non-price attributes in monetary terms and then considers only two items in the valuation: price and monetized attributes. This method is discussed in Section 2.3; it has been implemented and tested in several auction mechanisms (Che 1993; Bichler and Kalagnanam 2005; Strecker 2010). The method is limited to auctions with risk-neutral bidders (i.e. those who do not differ among themselves and who offer goods fully described by price and costs). Another limitation is the limited ability for the sellers to trade-off attribute values.

Bellosta et al. (2008) proposed the use of reservation levels to represent the buyer's preferences. The non-compensatory character of this method allowed the authors to suggest a feedback rule based on attribute values. The sellers 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.

In multi-attribute auctions, the minimum requirement for information revelation is that the information be sufficient for the bidders to make progressive bids, i.e., consecutive bids that are increasingly better for the buyer. The revealed information may be directly or indirectly related to the buyer's preferences in one or a combination of these three forms: buyer's preferences, bids and constraints (Wu and Kersten 2013). Existing auction mechanism requires the disclosure of the buyer's preferences in order to provide sufficient information to 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. A novel auction procedure has been designed and implemented that allows for the separation of preference representation and information revelation and the control of disclosure (Kersten and Wu 2012).

Negotiation is a different class of mechanism used in procurement. It allows the participants to have more flexibility than auctions because the negotiation mechanism may be modified at any point in time while auction mechanisms have to stay fixed during the whole process. Typically, the mechanisms are designed and implemented with three types of models (Kersten and Lai 2007): model of the negotiation problem, model of the negotiator, and model of the negotiation process. Negotiations differ from auctions in that they allow both the buyers and sellers to exchange various types of information (e.g. offers, free-text messages) (Kersten and Noronha 1999; Ströbel and Weinhard 2003).

Negotiators, as participants in e-negotiations, are also the users of e-negotiation systems. Research has empirically investigated the use and assessment of e-negotiation systems and processes. Vetschera et al. (2006) presented an integrated model to analyze factors that affect users' assessment of systems on the process and outcomes. Wang et al. (2010) investigated user's satisfaction in e-negotiations and show that it is affected by their objective confirmation and their experience and feelings in the process.

6.2.2 Comparison of auctions and negotiations

Formal comparisons of market mechanisms have been of interest to economists (Manelli and Vincent 1995; Bulow and Klemperer 1996; Kirkegaard 2004). The underlying assumptions are the rationality and self-interests of market participants, which limit their implications to practical situations. It has been pointed out that the effects of mechanisms would vary according to the situation and it is difficult to judge their effects without the consideration of the overall context (e.g. products, participants and market) (Manelli and Vincent 1995). The comparison becomes even more difficult when the underlying assumptions significantly differ from each other, for instance, as in auctions and negotiations. Auctions assume that bidders have certain knowledge about the buyer's valuation and follow a strict and fixed procedure. Negotiations have significantly weaker assumptions; the key assumption is that the parties negotiate in good faith and that they have preferences allowing each to compare the alternatives. There are no limitations on communication and no assumptions about the sellers' knowledge of the buyer's valuation.

The development of experimental economics and behavioral economics (Roth 2002; Smith 2003) has made it possible to empirically test and compare different mechanisms within various contexts. This approach allows the validation of theoretical predications with empirical results from simulations and experiments. The economic assumptions are also extended to bounded-rationality and include social and psychological variables, through which more practical implications can be provided (Milgrom 2000; Maskin 2007).

Experimental studies have compared different auction mechanisms (e.g. Bichler 2000; Chen-Ritzo, Harrison et al. 2005; Sherstyuk 2009; Lewis and Bajari 2011; Scheffel, Pikovsky et al. 2011).

They analyzed the aggregate performance metrics (e.g. efficiency and revenue) and individual bidding behavior in different auctions. A few studies also compared auctions and negotiations (Thomas and Wilson 2002; Thomas and Wilson 2005; Gerke and Stiller 2006; Gattiker, Huang et al. 2007; Yu, Kersten et al. 2008).

Gerke and Stiller (2006) compared bilateral negotiations and reverse auctions in service procurement situations, based on the achieved welfare maximization, the fairness of welfare distribution between service consumer and service provider, and the effort of carrying out the procurement mechanism. The results showed that reverse auctions outperformed bilateral negotiations for all three evaluation criteria. They concluded that a reverse auction is the better procurement mechanism in such a service market.

Gattiker et al. (2007) experimentally compared face-to-face negotiations, email negotiations and reverse auctions and investigated their impact on buyer-supplier relationship. The information richness, depending on the medium and type of interaction was considered as a mediating variable, through which face-to-face negotiations led to the highest level of trust of the sellers in their buyer counterpart. The reverse auctions led to the lowest level of trust while email negotiations performed in between. They also found that task complexity played a moderating role. When reverse auctions are utilized, the greater the complexity of the purchase, the seller's trust level is lowered. However, when email is used, greater procurement complexity is associated with increased seller trust. The level of task complexity does not make differences in trust between the email and face-to-face negotiations.

The negotiations in above empirical studies are bilateral, which reduce or even remove the competition among sellers. Multi-bilateral negotiations have been rarely studied. Thomas and Wilson (2002; 2005) conducted two lab experiments to compare auction and negotiation mechanisms. In their first study, first-price auctions and multi-bilateral negotiations were compared in a procurement scenario. They found that with four sellers there was no significant difference between the two mechanisms in terms of the transaction prices. When the number of sellers was reduced from four to two, the transaction prices in multi-bilateral negotiations were higher than in first-price auctions. Moreover, no difference in outcome efficiency was found between these two mechanisms. In their second study, they compared second-price auctions and multi-bilateral negotiations with verifiable offers. The results showed that prices were lower in verifiable multi-bilateral negotiations than in second-price auctions, whereas they were equal in terms of efficiency. 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.

Yu and his colleagues (2008) compared English auctions and multi-bilateral negotiations in laboratory experiments. The results show that mechanisms had no significant effect on the buyer's and seller's outcomes in terms of their utility and joint gain. Their economic outcomes, however, affected the bidders' satisfaction with the process, outcome and their performance.

In addition, several field studies were carried out to compare and examine various conditions of using auctions or negotiations. Bajari and his colleagues (2003; 2009) conducted an empirical analysis of auctions and negotiations in the construction industry. They observed that the use of different mechanisms depends on the knowledge and complexity of the tasks. It suggests a number of possible limitations in the use of auctions; for instance, auctions may perform poorly with complex projects, incomplete contractual design and few available bidders. Negotiations have advantages if the specifications of the product to be traded are not well-defined a priori, which is often the case in this industry. Negotiations, unlike auctions, allow for the discussion and clarification of the specifications.

Kaufmann and Carter (2004) conducted a large scale field study to examine the feasible conditions for using reverse auctions or face-to-face negotiations. They identified the differences between these two modes on four dimensions: (1) the number of negotiable parameters (i.e. number of attributes), which is usually small and fixed in auctions but often larger and open in negotiations; (2) the human factor, which is significant in negotiations involving interpersonal interactions but very restricted in auctions where there is little room for personal interventions; (3) the visibility among suppliers, which is higher in auctions with its process and information transparency leading to higher level of competition; and (4) the time span or length of the process, which is normally longer in negotiations than in auctions.

The above study also addressed the limitations of cognitive processing in negotiations when exchanging information with large number of attributes and suppliers (Kagel 1995). The feasible conditions for using auctions or negotiations include the specifications of the purchasing items, the market and the participants (buyer, suppliers). Auctions can and should be used under the following conditions: when purchasing items with high specificity and attractiveness, when there are a large number of suppliers having a high degree of rivalry, and when there is a higher level of trust in the process/system (both technical and legal) and a lower level of unethical activities.

6.2.3 Motivation and objectives

Auction and negotiation differ in both theory and practice. Empirical validation of their difference and effects can guide the practice and lead to effective procurement. It has been noted that auctions often outperform negotiations for economic gains from the buyer's perspective (e.g. Bulow and Klemperer 1996; Beam and Segev 1997; Kirkegaard 2004; Gerke and Stiller 2006). However, studies have also shown negotiations, in many situations, outperform auctions (e.g. when the problem is ill-defined or relationship building is required) (e.g. Leffler, Rucker et al. 2006; Gattiker, Huang et al. 2007; Bajari, McMillan et al. 2009). In fact, many existing comparisons were either conducted in different settings or for different tasks, leading to inconclusive results, i.e. some studies found no differences in outcomes while others found that one mechanism produced better results than another (e.g. Thomas and Wilson 2002; 2005; Kugler, Neeman et al. 2006; Leffler, Rucker et al. 2006; Fluck, John et al. 2007). This indicates that the context matters when comparing and assessing these mechanisms. It thus requires further consideration and examination of auctions and negotiations: (1) *which (if at all) mechanism outperforms the other*; and, (2) *under what conditions will one mechanism outperform the other*.

Existing comparative studies on auctions and negotiations relied on single-attribute auctions, and only bilateral negotiations were compared to the auctions (except for Thomas and Wilson (2002; 2005). This may be due to the lack of comparable mechanisms for multi-attribute auctions and multi-bilateral negotiations. When such mechanisms are designed or become available, their experimental comparison needs to be considered for validation and selection purposes. In a laboratory setting, Chen-Ritzo et al. (2005) compared three-attribute auctions and price-only auctions; in a field study, Lewis and Bajari (2011) compared two-attribute auctions with price-only auctions. The results of both studies were encouraging, showing that multi-attribute auctions led to better outcomes for both buyers and sellers.

Moreover, the comparisons made by (Thomas and Wilson 2002; Thomas and Wilson 2005; Sherstyuk 2009; Scheffel, Pikovsky et al. 2011) were based on the presentation of mechanisms to users as an abstract model or a rudimentary system. Other comparisons (Gerke and Stiller 2006; Gattiker, Huang et al. 2007) were based on experiments in which subjects used very different systems, including their user interface. When human subjects are involved in such experimental comparison, the effects of user interface and system features are of concern. In order to empirically compare different mechanisms, one approach to prevent, separate or control such effects is to implement them in the same system environment. In real-life situations, the system that is used has multiple features and options and often provides process and decision support tools. If one seeks insights that may have practical relevance, then systems that could be deployed in real-life situations should be used.

All of the above indicates a need for experimental comparison of multi-attribute auction and multi-bilateral negotiation mechanisms in order to understand their differences and guide their selection in e-procurement. Two types of mechanisms have been designed and implemented (Study 1 in Section 4): multi-attribute reverse auction (MARA) and multi-attribute multi-bilateral negotiation (MBMN). They can be used in the same types of procurement transactions, for instance, B2B involving multiple suppliers and multiple attributes. There are however, important differences, which are due to differences in the implemented mechanisms, namely: (1) the buyer's active participation; and (2) the flexibility of information exchange. The two mechanisms are illustrated in Figure 4-1 (Section 4.3.1), each involving one buyer and three suppliers.

In MARA, the buyer does not make bids or counter-bids; instead, the buyer initiates the auction with required information (e.g. preferences, constraints and reservations) and specifies the rules that are followed by the auction mechanism to respond to the suppliers, including the feedback about their submitted bids and for their prospective bids (e.g. current winning bid, updated constraints). The suppliers in neither system communicate with each other, and they only obtain feedback from the buyer through the mechanism.

Differently, in MBMN both the buyer and suppliers can make offer and exchange messages. Through those offers and/or messages, the buyer can selectively bargain with one or more suppliers and may implicitly or explicitly convey her preferences, constraints and reservations to the suppliers. There is no restriction or constraints on the suppliers' offers, while the buyer may refer to the current outstanding offer as a constraint in order to request better offers from the suppliers.

The two mechanisms are implemented in the Invite platform to build two e-procurement systems (Study 1 in Section 4). MARA was implemented in the Imaras system while MBMN was implemented in the Imbins system. The implementation and use of these two mechanisms are supported with the auxiliary models and system features, including: analytical support for bid/offer comparison and analysis, communication support with messaging function, and visualization support with graphical display of bids/offers through auction/negotiation process. The systems can be used for different transaction problems and in various contexts. Also, as they are implemented with similar user interface and the same tools, it enables to employ the capabilities of information technologies but also to separate and control the effects of user interface or system features.

This makes it possible to fill the gap and meet the need for empirical comparison of auctions and negotiations. The present research conducts experiments to examine the effects of these two mechanisms using the two systems. The purpose is to investigate the advantages and disadvantages of different mechanisms in e-procurement context.

6.3 Research model and hypotheses

This study compares auctions and negotiations by examining their effects on the transaction process and outcomes. In addition, the subjective evaluation is also considered based on the participants' assessment. The conceptual model is presented in Figure 6-2. The variables and their hypothesized relationships are described in Section 6.3.1 and 6.3.2, respectively.

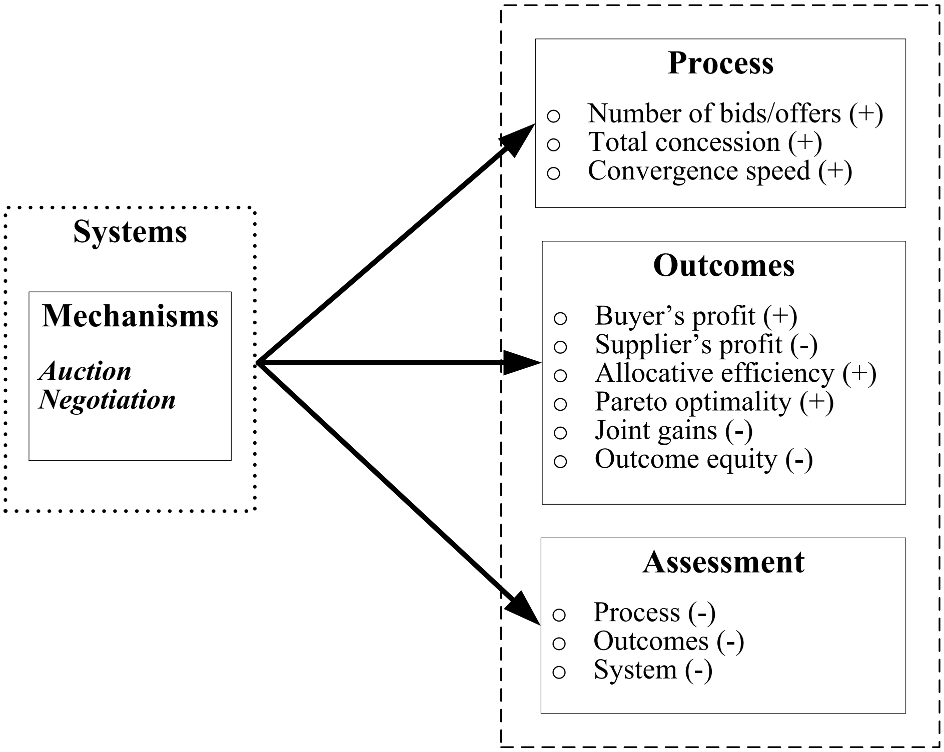


Figure 6-1. Research model

Note: "+"indicates a positive effect and "-"indicates a negative effect, when comparing auction to negotiation.

6.3.1 Variables and measurement

The independent variable is the mechanism that is implemented in the system. This study focuses on the different mechanisms with information revelation and exchange during the procurement process. Two particular mechanisms are examined:

> ***Auction***: Multi-attribute reverse auction in which the buyer reveals the admissible bids and current winning bid;
>
> ***Negotiation***: Multi-attribute multi-bilateral negotiation in which the buyer exchange offers and messages with each supplier.

The two mechanisms are implemented in Imaras and Imbins respectively. In both mechanisms, the suppliers have full access to their own bids or offers/messages through the process. The two mechanisms mainly differ in terms of the types of information conveyed from buyer to suppliers.

In the auctions, the buyer is not involved in the transaction process; rather, the buyer defines the rules prior to the auctions and the mechanism then follows the rules to evaluate the suppliers' bids, identify the winning bid, state the admissible bids, and finally announce the winner. The feedback information about the admissible bids and the bid status (wining or not) is provided to the suppliers via the Imaras system that implements the mechanism (Figure A-1 and Table A-2 in Appendix A). Such information is public and creditable, i.e. all the suppliers receive the same information at the same time and based on which, they can make appropriate decisions.

In the negotiations, the buyer may disclose any constraints on subsequent offers (equivalent to admissible bids in the auctions) and other suppliers' offers (e.g. the current outstanding offer and/or non-preferable offers) (Figure B-1 and Table B-1 in Appendix B). While the buyer may not disclose the offers submitted from all suppliers, she may want to provide clues to the suppliers so that they can make better offers for her, and also explicitly or implicitly refer to the outstanding offer to increase bargaining power. This will make the negotiations become similar to the auctions. Nonetheless, such information is private and non-verifiable. Each supplier can only communicate with the buyer and has to rely on the information they obtain from the buyer (Table B-2 in Appendix B). The suppliers cannot completely trust this information and the buyers do not necessarily disclose the current best offer—even if they mention that they have a better offer, the suppliers may view it as a tactic.

In this study, both economic and subjective measures are used to examine and compare the two mechanisms. Economic indicators have been mainly used to measure individual and market performance in experimental and behavioral economics (Roth 1995; Smith 2003). Appendix H lists the behavioral and economic measures from prior studies on auctions and negotiations (incl. Kersten and Noronha 1999; Bichler 2000; Koppius and Heck 2003; Chen-Ritzo, Harrison et al. 2005; Gerke and Stiller 2006; Vetschera, Kersten et al. 2006; Jap and Haruvy 2008; Strecker 2010; Whitford, Bottom et al. 2011; Kersten, Vahidov et al. 2013).

Similar to the assumptions mentioned in Study 2 (Section 5.3.1), this study also takes into account realistic situations in e-procurement and thus do not rely on quasi-linearity and risk-neutrality assumptions. It follows the approach in decision and negotiation analysis to assess the quality of contracts, including: allocative efficiency, Pareto optimality, joint gains and outcome equity.

Transaction process can be analyzed using the number of bids/offers, total concession and convergence speed, which together indicate the process efficiency. Because buyer is not directly involved in auctions, the number of bids/offers and concessions are concerned with the suppliers only. The convergence speed is considered at the transactional level.

The outcomes are measured using potential profit from a contract, which is the difference between the company's revenue from the contract and its break-even point. This was operationalized in the business case to establish a realistic situation where the participants perform a role-play in the experiments; instead of directly using utilities, the notions of revenue, cost and profit help enhance the realistic context. In the process and outcome analysis, the measures are calculated in the way similar to use utilities. This allows comparing the outcomes between the suppliers who have different break-even points. Also, the outcomes are based on the achieved agreement between the two sides; thus, the variables are calculated with the profit for the buyer and the supplier who won the contract.

Mechanisms are implemented in e-procurement systems. The participants of the transactions are also the users of such systems. Users' perceptions of the process and outcomes may affect their assessment of the mechanisms. Satisfaction has been a surrogate of the effectiveness of information systems (Thong and Yap 1996), and has been used in the acceptance and assessment of various types of systems, including e-markets and e-negotiation systems (Oörni 2003; Thomas and Robin 2004; Wang, Lim et al. 2010). Existing literature indicates satisfaction involves outcomes (Geyskens and Steenkamp 2000; Staples, Wong et al. 2002), own performance (Etezadi and Farhoomand 1996; Gelderman 1998), and process (Rangaswamy and Shell 1997; Davey and Olson 1998). A multi-dimensional scale of participants' assessment in e-markets has been developed and tested (Wu and Yu 2009). The instrument has been adapted and used in previous study for auctions (Wu and Kersten 2013), and the improved version was used for comparing auctions and negotiations in this study (see also Table 5-3 in Section 5.5.2). For the purpose of this study, the scale is used to measure the suppliers' assessment.

6.3.2 Hypotheses

Formal and empirical studies on mechanism comparisons have shown that the performance of different mechanisms may vary in terms of process efficiency and outcomes (Koppius and Heck 2003; Kaufmann and Carter 2004; Thomas and Wilson 2005; Gerke and Stiller 2006; Mithas and Jones 2007; Kersten, Vahidov et al. 2013).

Auctions provide the same feedback information to all the suppliers, whereas this is private and more implicit in negotiations. The explicit feedback information about bids in auctions can be used by the suppliers to discover buyer's preferences, which can lead to better performance in requesting and receiving bids and thus to converge faster towards an agreement (Koppius and Heck 2003; Thomas and Wilson 2005; Strecker 2010). In negotiations, buyers often customize and exchange private information with suppliers that requires longer time and more effort (Kaufmann and Carter 2004; Subramanian 2009). Public information provided in auctions also indicates the existence and participation of other suppliers, which increases the competition and thus requires the suppliers to make larger concessions in their bids (Jap and Haruvy 2008; Granados, Gupta et al. 2010; Kersten, Vahidov et al. 2013). It should be noted that the concessions made by the bidders may also depend on their reservation levels based on the supplier's profile (e.g. resource, competency). The comparisons are based on average concessions made by the suppliers who use the same mechanisms. Thus, we expect that:

H1 Suppliers will make a greater number of bids in auctions than in negotiations.

H2 Suppliers will make larger concessions in auctions than in negotiations.

H3 Auctions will converge in a shorter time than negotiations.

Auctions have also been found to increase the buyer's economic gains more than negotiations (Thomas and Wilson 2002; Kaufmann and Carter 2004; Jap and Haruvy 2008; Kersten, Vahidov et al. 2013). This is partially due to the higher competition among suppliers in auctions. Auctions reveal information about winning bids from other suppliers, and thus the suppliers know that they are competing with others. This can be completely concealed in negotiations, if the buyer does not announce any information about other suppliers and/or outstanding offers. Studies on information transparency have also found that available market information on offers from different suppliers increases market competition and thus leads to cost savings for buyers (Soh, Markus et al. 2006; Granados, Gupta et al. 2008; Granados, Gupta et al. 2010).

Experimental studies on auctions have shown mixed results on supplier's outcomes, particularly in multi-attribute transactions (Bichler 2000; Koppius and Heck 2003; Chen-Ritzo, Harrison et al. 2005). In negotiations, the lower level of competition may lead to smaller concessions from the suppliers and thus improve their gains (Kersten, Vahidov et al. 2013). In addition, the buyer can also make offers and counter-offers in negotiation, which often requires reciprocity and obligations and thus decreases their gains (Esser and Komorita 1975). It should be also noted that the profit is measured based on the contract reached between the buyer and one of the suppliers (i.e. winning supplier). Since the value and cost functions vary across suppliers, the larger concessions may not always lead to lower profit and the profit may also be different for different winning suppliers. Hence, we expect that:

H4 Buyer's profit will be higher in auctions than in negotiations.

H5 Supplier's profit will be lower in auctions than in negotiations.

Taking into account both the buyer and the supplier side, four indicators are used to measure their joint performance and the contract quality: allocative efficiency, Pareto optimality, joint gains and outcome equity. Revealing the buyer's preferences and other valuable information such as winning bids helps the suppliers make trade-offs between different attributes and seek joint improvements (Koppius and Heck 2003; Chen-Ritzo, Harrison et al. 2005; Strecker 2010). The previous study also shows more balanced contracts were reached when more information was revealed in multi-attribute reverse auctions (Study 2 in Section 5). In negotiations, additional information exchanged during the process may help them gain more knowledge about each other and thus achieve better joint outcomes (Kersten and Noronha 1999; Vetschera, Kersten et al. 2006; Kersten and Lai 2008).

The evidence on joint performance, nonetheless, is mixed in the few empirical comparisons of auctions and negotiations. It has shown no difference between the two mechanisms (Thomas and Wilson 2002; Thomas and Wilson 2005), superiority of auctions (Thomas and Wilson 2002; Kaufmann and Carter 2004; Gerke and Stiller 2006) and advantages of negotiations (Bajari, McMillan et al. 2003; Gattiker, Huang et al. 2007; Bajari, McMillan et al. 2009). This may be partially due to the specifications of mechanisms (e.g. bilateral negotiations), information revelation (see Section 5) and the characteristics of transactions (e.g. task complexity). In this study, the two mechanisms are compared within the same context, i.e. an e-procurement contract with multiple attributes and multiple suppliers. While auctions may focus on economic goals (i.e. the buyer will achieve the best possible contract), negotiations as social-economic process also involve relational concerns. When both sides consider each other and make reciprocal offers, they will be able to reach more balanced contract. Thus, we also expect that:

H6 Auctions will outperform negotiations in terms of the allocative efficiency and Pareto optimality.

H7 Negotiations will outperform auctions in terms of joint gains and outcome equity.

Moreover, additional information revealed by the buyer may also increase the transparency of the process along with, consequently, the trust of the suppliers and a better relationship (Gattiker, Huang et al. 2007; Lösch and Lambert 2007). Reciprocity can be a vehicle for conveying sentiments and developing relationship in social exchange (Molm, Schaefer et al. 2007). Buyers in negotiations may make reciprocal offers and counter-offers, which increase the suppliers' actual gains and thus improve their feelings and assessment of the process and outcomes. Suppliers in e-procurement are also users of such systems, and the evaluation of systems is often affected by their performance and outcomes (Venkatesh, Morris et al. 2003; Vetschera, Kersten et al. 2006). Hence, we expect that:

H8 Negotiations will lead to more positive assessment of process, outcomes and system than auctions.

6.4 Experiments and data collection

The purpose of this study is to investigate the different mechanisms in terms of their impact on the procurement process and outcomes. The two systems (Imaras and Imbins) are developed to implement the mechanisms and are used to conduct the transactions. The proposed hypotheses are tested with an experimental approach. The experimental design, tasks and procedure for data collection are described in the following sections.

6.4.1 Experimental design

This study adopts an experimental approach that combined laboratory and online settings to test the research hypotheses. Laboratory experiments have been considered to better establish and test causal relationships by manipulating the independent variables, controlling the environment and procedure, and observing the effects on the dependent variables (Croson 2005; Kagel and Levin to appear). Online experiments have been widely conducted in e-commerce research, which replicate the natural environment and increase the external validity (Kerlinger and Lee 2000; Jap 2003; Bapna, Jank et al. 2008).

Table 6-1 presents the experimental design with two mechanisms in two settings, and thus four treatments were managed in this study.

Table 6-1. Experimental design and treatments (Study 3)

Mechanisms	Experiment 1 (Laboratory setting)	Experiment 2 (Online setting)
Auction	Treatment 1 (T1)	Treatment 3 (T3)
Negotiation	Treatment 2 (T2)	Treatment 4 (T4)

In Experiment 1, the auctions and negotiations were conducted in the laboratory environment with a number of sessions. Each session lasted two and half hour, including the time for preparation and questionnaires. The buyers in negotiations and the suppliers were set up in different lab rooms, where the facilitators gave instructions and guided them through the experiment. The time slot for bidding and negotiating was also controlled, which lasted 50 minutes. The auctions were in a multi-round setting; each round took five minutes. The bidders obtained the auction updates on the rounds and the revealed information immediately from their computer screen. The buyers and suppliers in negotiations were exchanging offers and/or messages through the system; and, the system automatically sent a notice to their screen for any updates on their negotiations.

In Experiment 2, the auctions and negotiations were running online and lasted 10 days. In auctions, each round was set as one day and thus results in maximum ten rounds. The participants could log on and off at any time during the auction or negotiation. They were informed by emails about any updates from the ongoing auctions and negotiations, and they were required to log on to access the updates and make offers or bids within the systems.

6.4.2 Experimental tasks

The experimental task was a business case that involved contracting between a milk producer and several transportation service providers. Three attributes of the transportation service were concerned: (1) *standard rate*; (2) *rush rate*; and (3) *penalty for delay*. There were a number of values for each attribute, and the possible ranges were known to each participant. To maintain a relatively complex problem, there were 3,375 alternatives for the contract.

The buyer participants in negotiations represented a procurement officer for the milk producer. The supplier participants played the role of a sales manager for one of the service providers. They were competing with each other to win the contract. Each contract could be awarded to only one supplier. In auctions, the one who made the best bid for the milk producer would be the winner. In negotiations, they were negotiating with the buyer in order to reach an agreement. The service providers wanted to get the contract, while the contract should bring their business profits rather than losses. The participants were given the break-even points of the contract for their company.

The context and background provided in the general information document that was known to every supplier, while the preferences were explained in the confidential information document that was not known to the other suppliers. The reservation and aspiration levels of each company were also indicated in their confidential information, indicating the worst and best deals respectively. A financial calculator is implemented in the system, which can be used by the participants to calculate the revenue and profit for each contract alternative. Appendix D summarizes the business profiles and preferences of the companies involved in the transaction. Based on the preferences of the buyer and each supplier, the utility distribution of alternatives can be identified and used for calculating the outcome measures.

6.4.3 Experimental procedure

The experimental procedure and the main activities are listed in Table E-1 in Appendix E, which involves several phases: registration, matchup, preparation, interaction and conclusion. Demographics, self-reported data and transaction process and outcomes were collected in different phases.

Before the experiment, the participants first signed up online and their demographical information was gathered via a registration form. The participants were then randomly matched up with different roles and assigned to one of the treatments. In Experiment 1, the participants were also asked to select the session based on their availability, and they were assigned into the chosen session during the experiment.

The participants were also required to watch a video demonstration of the system before they actually used it in the experiment. This was suggested from the participants' feedback in previous study (Wu and Kersten 2013). It also ensured that the participants had the same baseline knowledge and experience with the system in order to test the effects due to treated conditions (Kumar and Benbasat 2006; Kamis, Koufaris et al. 2008).

During the experiment, the participants first read the general and confidential information for the preparation. This was followed by a case quiz and pre-questionnaire before the auction or negotiation started. Table F-1 in Appendix F shows a sample case quiz for one supplier, which was used to improve the participants' understanding of the tasks. The participants were then asked to provide their perceptions of the task as well as their expected aspiration and reservation levels (Table G-1 in Appendix G). These measures were used to examine their understanding of the task and their expectations on the contract.

The participants could access and review the general and confidential information anytime during the transaction. In the interaction phase, the participants constructed and submitted bids or offers on behalf of the companies they represented. In negotiations, they may also send messages with or without offer. Once the transaction was closed, they were asked to fill out a post-questionnaire to report their perceptions and evaluation of the process, outcomes and system (Table G-2 in Appendix G).

The participants' activities during the transaction process were recorded in a database, which was used to analyze the transaction process and outcomes.

6.5 Data analysis and results

The data sample and a descriptive analysis of the experiments were first conducted. The hypotheses were then tested, followed by group comparisons to further examine the differences between the two mechanisms.

6.5.1 Data sample and descriptive analysis

The experiments involved over five hundred business students from North America, Europe and Eastern Asia. The majority of suppliers were undergraduate students who were studying business courses related to information technologies; graduate students in business programs played the role of buyers in negotiations. The experiments were part of their course work and worth more than six percent of the total mark, with both participation and performance being considered.

In the two experiments, there were total 257 students registered for auctions and 262 registered in negotiations as suppliers matched with 67 buyers. After review and validation of the transactions, 82 records in the supplier dataset were removed from the auction dataset and 64 from the negotiation dataset. The criteria for dropping those records were: (1) not participating at all (i.e. no bids or offers made through the experiment); (2) inactive (only one bid or offer made at the beginning); or, (3) no other suppliers in the transaction. Consequently, the data records with 373 suppliers and 61 buyers were used in the subsequent analysis: Experiment 1 includes 28 auctions and 23 negotiations with total 181 suppliers, and Experiment 2 includes 17 auctions and 38 negotiations with total 202 suppliers. Table 6-2 shows the data sample and demographic portrait of the participants.

Most of the participants were between 20 and 25 years old as they were undergraduate students. About 48 to 57 percent of the participants were female; gender does not significantly differ across the treatments. Most of the participants perceived their knowledge about auction or negotiation lower than average, and majority of the participants had low or no past experience in using an auction or negotiation system for e-procurement transactions. They also perceived the task relatively difficult. An ANOVA test showed no significant difference in their experience and perceived task complexity between the treatments.

Table 6-2. Descriptive analysis of the experiment and participants

	Experiment 1		Experiment 2	
	T1	T2	T3	T4
No. of transactions	28	23	17	38
No. of suppliers	109	72	66	126
Age group (25 or younger, %)	84.9	88.9	90.9	91.3
Gender (female, %)	50.5	48.6	47.9	56.7
Knowledge (novice-1, expert-7)	2.53	2.66	2.90	2.85
Experience with system (low or no, %)	83.2	80.6	78.8	76.1
Task complexity (easy-1, difficult-7)	3.55	3.72	3.82	3.79

6.5.2 Instrument testing and factor analysis

The participants' responses to the post-questionnaire were used to examine their assessment of the process, outcomes and system. The instrument that was developed in Study 2 (see Section 5.5.2) was adapted for both auctions and negotiations in this study.

Considering the differences between auctions and negotiations, the instrument was validated with a CFA for negations. Due to the small sample size of the negotiation dataset with completed questionnaires in Experiment 1 (*N=60*), the dataset in Experiment 2 was first used for the CFA (*N=102*) and followed by a group analysis with the two samples.

A robust analysis was conducted, which is not restrictively limited by normality and sample size. The factor model provided a good fit for the data. The result of chi-square test statistics is

$\chi2=37.42$ with acceptable significance ($p=0.04$). The Bollen's IFI is 0.97 that indicates a valid model independent from the sample size (Bollen 1990). Both CFI and NNFI are above 0.95 and RMSEA is located between zero and one ($CFI=0.98; NNFI = 0.97; RMSEA=0.06$), indicating a good fit of the factor model (Hu and Bentler 1999). The results confirm the three types of suppliers' assessment exist in the negotiations.

In terms of reliability, the values of Cronbach's α for all factors are above the recommended criteria with a cut-off of 0.70 ($AP=0.81, AO=0.90, AS=0.86$), indicating a high internal consistency (Nunnally and Berstein 1994). Moreover, the factor loadings are in an acceptable range (from 0.77 to 0.93), indicating a good convergent validity. Average variance extracted (AVE) has been recommended to indicate reliability and discriminant validity (Fornell and Larcker 1981). The AVEs for the three factors are all greater than 0.72, which satisfies the reliability criteria ($AVE>0.50$) and indicates adequate discriminant validity (the highest shared variance with 0.70 between AP and AS).

Figure 6-3 shows the factor model and CFA results for negotiations. The model was further validated with a group analysis between two samples: one with online negotiations ($N=102$) and one with both laboratory and online negotiations ($N=162$).

The result shows no differences in two factors: assessment of outcomes and assessment of system. However, the AVE for assessment of process was lower in the combined sample (0.64), which is acceptable for reliability but fails to discriminate from assessment of system. This again may be due to the high correlation between the two factors (0.84). It indicates that when the suppliers evaluate certain aspects of the negotiations they may also consider other aspects. In particular, the suppliers who are satisfied with the process are most likely also satisfied with the system. A weighted sum for each factor was calculated using the factor loadings, and then used to compare suppliers' assessment in subsequent analysis. It needs, nonetheless, to be cautioned in using them for comparisons and in interpreting the results.

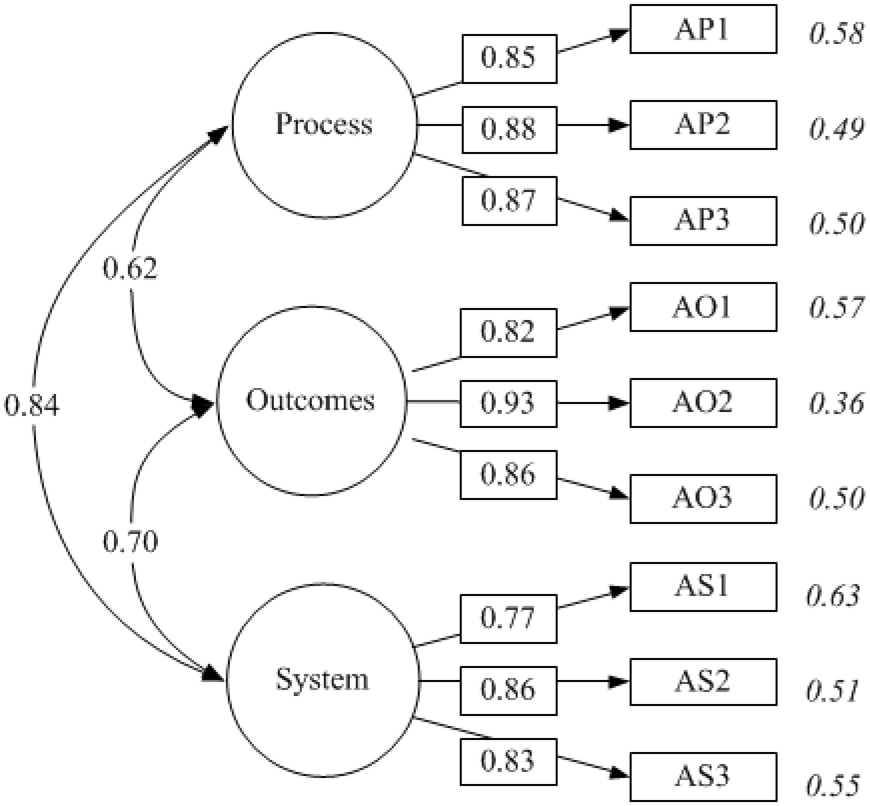


Figure 6-2. CFA for suppliers' assessment in negotiations

6.5.3 Hypotheses testing

The hypotheses were tested with the datasets from the two experiments. Prior studies have noted that utility based variables such as concessions and outcomes may not necessarily conform to a normal distribution, thus nonparametric analysis such as Mann-Whitney U-test with independent samples has been suggested (Koppius and Heck 2003; Lösch and Lambert 2007). In this study, ANOVA tests were used to compare the mean values of number of bids/offers, convergence speed and assessment, which conformed normal distribution from the descriptive analysis. Mann-Whitney U-tests were used to compare the distribution of concessions and outcome variables with independent samples from each treatment. Table 6-3 shows the results that compare the process, outcomes and the suppliers' assessment.

Effects on process

In Experiment 1 (laboratory setting), the suppliers made a significantly greater number of bids in auctions than their offers in negotiations (6.61 vs. 3.57, $p \leq 0.01$). They also made significantly larger concessions in auctions than in negotiations (60.89 vs. 23.08). In Experiment 2 (online setting), the differences remained but were not as significant as in Experiment 1 (4.72 vs. 3.40, $p \leq 0.05$). Thus, hypotheses H1 and H2 are supported in both laboratory and online settings.

Table 6-3. Comparison on process, outcomes and assessment

	Experiment 1		Experiment 2	
	T1	T2	T3	T4
Process				
No. of bids/offers	$6.61^{*\#}$	3.57	$4.72^{\wedge}$	3.40
Total concession	$60.89^{*\#}$	23.08	46.05^{*}	25.91
Convergence speed	21.97^{-}	19.15^{+}	47.76	53.67
Outcomes				
Buyer's profit	75.82^{*-}	47.13	66.94^{*}	52.61
Supplier's profit	-7.82^{*+}	23.39	3.94^{*}	19.92
Allocative efficiency	62.26^{*+}	30.94	50.71^{*}	33.25
Pareto optimality	0.50^{*}	13.57	0.76^{*}	11.58
Joint gain	-763.50^{*+}	916.57	-218.06^{*}	935.74
Outcome equity	-0.06^{*+}	0.68	0.35	0.45
Assessment				
Process	3.52^{*-}	4.19	3.83	3.95
Outcomes	$2.93^{*\#}$	3.73	3.68	3.39
System	3.63	3.88	3.84	4.06

*Note: (1) numbers are mean values; (2) significance when comparing auction to negotiation (T1 vs. T2, T3 vs. T4): * $p < 0.01$, ^ $p < 0.05$; and, (3) significance when comparing laboratory setting to online setting (T1 vs. T3, T2 vs. T4): #* $p < 0.01$, + $p < 0.05$, - $p < 0.1$.

The result shows that the suppliers were more active in auctions, which might be due to the revealed public information that provided clearer directions and the same decision space for their bidding. Such information may also have increased the competition between the bidders that motivated them in bidding. In negotiations, each buyer was bargaining with two or more suppliers. Taking into account the average number of offers made by each supplier (3.57 in laboratory and 3.40 online), the buyer might need to review, evaluate and compare more than seven offers and then make decision to reject offers or make counter-offers. Thus, the task load might be shifted from the system to the buyers, which may decrease the process efficiency in requesting new proposals.

The convergence speed was not significantly different between the two mechanisms, neither in Experiment 1 nor in Experiment 2. Thus, hypothesis H3 is not supported. This may be due to the fact that the auction was multi-round with a fixed round duration (five minutes in Experiment 1 and one day in Experiment 2), which could lead to slow convergence if the suppliers submitted more bids and stayed in more rounds. In negotiations, the information exchange was two-way through which both sides could make offers with certain concessions and thus could reach agreement in a shorter time period. This together may undermine the difference in convergence speed between the two mechanisms.

Effects on outcomes

In terms of the outcomes, the buyers in Experiment 1 gained much higher profit in auctions than in negotiations (75.82 vs. 47.13), while the suppliers reached better deals in negotiations than in auctions (23.39 vs. -7.82). The same happened in Experiment 2, though the differences were smaller (Table 6-3). Thus, hypotheses H4 and H5 are both fully supported in the two experiments.

This may be due to the differences in concession-making between auctions and negotiations. In auctions, the suppliers had to continuously make concessions to compete against others, which increased the buyer's gains but decreased their own profit. In fact, the suppliers were overbidding in the laboratory setting due to the highly competitive environment and time pressure. As a result, they won the contract, which however would not produce profit. In negotiations, the buyer made concessions with reciprocal offers from which the suppliers gained a higher profit.

The allocative efficiency was significantly higher in negotiations than in auctions, whereas the Pareto optimality was higher in auctions. In both Experiment 1 and Experiment 2, the buyer and supplier in negotiations reached an agreement that was closer to the best achievable contract (i.e. the contract that maximizes the sum of utilities for both sides). This was not expected because auctions would result in higher competitions between the suppliers and thus lead to more efficient contracts. Nonetheless, the suppliers were making large concessions and even overbidding in order to win the contract, which did not produce profit and were inefficient. In negotiations, even though the buyer made concessions that reduced their profit from the contract, the gains for both the buyer and supplier ultimately increased the value of the contract and thus led to more efficient allocations.

Note that an efficient contract may not be Pareto optimal, i.e. there may be alternatives that can improve the deal to increase the profit for buyer, supplier or both sides without decreasing the value for any side. In the two experiments, auctions led to better solutions or contracts than negotiations in terms of Pareto optimality (i.e. the solutions from auctions were closer to the efficient frontier). This was mainly due to the fact that the suppliers had to submit admissible bids in auctions and often had to make larger concessions to win the round. The concessions merely from the supplier side would lead to contracts that favor only the buyer, resulting little room for improvement for both parties. Thus, hypothesis H6 is partially supported in terms of Pareto optimality.

In terms of joint gains and outcome equity, the results also show a higher contract quality for both buyer and supplier in negotiations than in auctions. In Experiment 1, the joint gains were positive and larger in negotiations than in auctions (916.57 vs. -763.50). The negative value in auctions was due to the suppliers' overbidding and thus reaching non-profitable contracts. The joint gains in Experiment 2 were improved for the contracts through auctions but still worse than the ones through negotiations. The outcome equity was significantly better from negotiations than from auctions in Experiment 1 (0.68 vs. -0.06). The buyer and supplier in negotiations were able to achieve more balanced contracts, which may be due to the concessions from both sides. In auctions, the suppliers were provided with admissible bids that may have lacked directions towards better solutions for both buyer and supplier. Also, the winning bids might have misled the suppliers to compete with extreme values on certain attributes and thus leading to more imbalanced contracts. The situation was improved in Experiment 2, where the difference between auctions and negotiations in terms of outcome equity was not significant. Thus, hypothesis H7 is fully supported in the laboratory setting (i.e. both joint gains and outcome equity), while it is partially supported in the online setting (only joint gains).

Effects on suppliers' assessment

In comparing the subjective assessment, the suppliers who used the negotiation mechanism in Experiment 1 were more satisfied with the process and outcomes than the suppliers who used the auction mechanism (Table 6-3). The suppliers did not significantly differ in the system assessment. In Experiment 2, there were no significant differences in the suppliers' assessment of the process, outcomes and system. Thus, hypothesis H8 is partially supported in the laboratory setting and not supported in the online setting.

It was expected that the suppliers would evaluate the systems differently since they reported different feelings about the process and outcomes. It is possible that suppliers did not "blame" the system because of their outcomes. The results show that the systems were neither considered very good nor very bad. This suggests that there was no difference in their perception of the systems (e.g. user interface, features, tools), which confirms the experimental setting that prevent effects due to different systems. However, it is also possible that the suppliers provided positive or negative assessments solely based on their own outcomes, which may undermine the differences in system evaluation. Prior studies have shown the differences between winners and non-winners in their assessment. Thus, a further analysis is conducted to compare the winning suppliers and the non-winning suppliers.

6.5.4 Group comparisons

The analysis and results of hypotheses testing also indicate potential impacts from: (1) the experimental setting (laboratory vs. online), (2) the outcomes (winners vs. non-winners), and (3) the buyer's role and behavior in exchanging different types of information. Thus, further analyses were conducted to examine their effects.

Comparison 1: laboratory setting vs. online setting

The results on experimental setting comparison are also shown in Table 6-3. It shows that the bidders made significantly more bids and greater concessions in the laboratory than online (T1 vs. T3). The suppliers in negotiations did not behave differently between the two settings (T2 vs. T4) in terms of number of offers and total concession. The transactions were converged significantly faster in the laboratory than online for both auctions and negotiations ($p \leq 0.01$). On average, it took two times longer when the transactions were conducted online.

In terms of the outcomes, there was no significant difference in negotiations between the two settings (T2 vs. T4). In auctions, the buyer's profit was slightly decreased from the online setting than in the laboratory (66.94 vs. 75.82, $p \leq 0.1$), while the supplier's profit was significantly improved when they played online (3.94 vs. -7.82, $p \leq 0.05$). On average, the suppliers were able to reach profitable contracts when they were given a longer time in round duration and total transaction length. They also achieved more efficient contracts with higher joint gains and outcome equity ($p \leq 0.05$), though the Pareto optimality did not differ from the laboratory setting.

It was also found that the suppliers in auctions reported a higher level of assessment of the process and outcomes when they were bidding online. There were no significant differences in their assessment of the systems between the experiments, neither in auctions nor in negotiations.

Overall, the results were consistent between the two experiments, whereas the effects of mechanisms on process, outcomes and assessment were weakened in the online setting. This was expected as stronger effects could be observed in a more controlled setting (i.e. laboratory experiment). It is also possible that the time pressure and competition level were higher in the laboratory setting, which caused larger concessions from the suppliers in auctions and thus led to worse contracts for them.

Comparison 2: winning suppliers vs. non-winning suppliers

The winning suppliers were awarded with the contract and they may perceive themselves to be more successful than other suppliers (i.e. non-winners). Since the convergence speed and the outcome variables are measured at the transaction level (i.e. an agreement was reached between buyer and supplier), they are not applicable to those who did not reach a contract. Thus, the comparison was performed on the suppliers' behavior in the process and their assessment of the process, outcomes and system. Table 6-4 shows the results of a group comparison between winners and non-winners.

Table 6-4. Comparison between winning suppliers and non-winning suppliers

	Experiment 1				Experiment 2			
	T1		T2		T3		T4	
Groups	WS	NWS	WS	NWS	WS	NWS	WS	NWS
No. of suppliers	28	81	23	49	17	49	38	88
Process								
No. of bids/offers	8.50^{*}	5.41	3.09	3.16	$5.35^{\wedge}$	4.04	3.58^{*}	2.75
Total concession	70.64^{*}	51.51	16.70	20.43	$49.65^{\wedge}$	39.16	$29.61^{\wedge}$	18.14
Assessment								
Process	3.60	3.40	4.52	4.13	4.26^{*}	3.41	4.23^{*}	3.66
Outcomes	3.26^{*}	2.52	3.99^{*}	2.79	4.56^{*}	2.75	4.18^{*}	2.57
System	3.89^{*}	3.33	4.42^{*}	3.55	4.37^{*}	3.29	4.41^{*}	3.71

Note: (1) "WS"–winning suppliers, "NWS"–non-winning suppliers; (2) numbers are mean values; (3) significance for comparison in each treatment: $* p < 0.01$, $^\wedge p < 0.05$.

The winning suppliers submitted greater number of bids/offers than the non-winning suppliers in three treatments: laboratory auction (8.50 vs. 5.41, $p<0.01$), online auction (5.35 vs. 4.04, $p<0.05$) and online negotiation (3.58 vs. 2.75, $p<0.01$). They also made larger concessions than the non-winners in those three treatments. This indicates that the winners were more actively participating in the transaction and competing against other suppliers.

Overall, the winners had significantly positive assessment of the process, outcomes and system than the non-winners ($p<0.01$). This suggests that it is the outcome (i.e. winning or losing the contract) and not the concession-making that affects their assessment. In turn, this may indicate the low payout from making large concessions that result in loses. The only exception was their assessment of process in the laboratory experiment, which might be due to the shorter time frame and faster convergence. The results indicate that the suppliers' outcomes indeed affected their perception and evaluation of the transaction process, outcomes and systems. When they won the competition and were awarded with the contract, they had more positive attitude towards their assessment.

Comparison 3: public information vs. private information

It was noted that one of the differences between the two mechanisms is the buyer's role and behavior. In auctions, the buyer does not participate during the process; thus, the suppliers receive only public information about the winning bids and admissible bids that are automatically generated and updated by the mechanism. There is no private information nor offers from the buyer to the suppliers.

In negotiations, the buyer can not only send messages to the suppliers but also make offers or counter-offers. If the buyer only sends messages, then her role is similar to the buyer in auctions; there is no explicit concession and obligation from the buyer side. However, when the buyer makes counter-offers, it often requires reciprocity and concessions and thus decreases their gains. Then, the concession-making pattern is different from auctions (two-way vs. one-way).

The buyer's different role and behavior, particularly in exchanging different types of information (e.g. message only, reciprocal offers), may affect the transaction process and outcomes. Thus, a further analysis on the transaction process was conducted to examine the effects of different information conveyed from buyer to suppliers. The result shows that different types of interactions could be identified based on the information types. Specifically, three types of information were identified:

1. *public information* in auction with winning bids and admissible bids;
2. *private information* in negotiation without buyer's offers (messages only); and,
3. *private information* in negotiation with buyer's offers (messages attached to offers).

The effects were examined by analyzing the suppliers' bids or offers that were followed or replied to the different information. Considering the differences between buyers (e.g. experience, strategies), the analysis was conducted at the transactional level, i.e. the suppliers' responses to the information from the same buyer in each auction or negotiation.

There were a total of 2,307 bids, offers and messages recorded from the 434 participants (373 suppliers and 61 buyers) in the two experiments. All the bids were included in the analysis as the bids were submitted following the public information announced by the buyer through the auction mechanism ($N_1=965$). The buyer's offers and messages in negotiations were only used to categorize the suppliers' subsequent offers. The opening offers made by suppliers were excluded as they were not replying to buyer's offer or message. The remaining records included 81 offers replying to buyer's message ($N_2=81$) and 372 offers replying to buyer's offer ($N_3=372$). Table 6-5 shows the results of a comparison between the different types of information.

The results confirm that different types of information provided by the buyer affected the transaction process in terms of number of bids/offers and concession-making. The buyer's concessions were calculated with the value change between the supplier's offers but based on the buyer's preferences. Thus, it increases the buyer's gains resulting from the concessions made by the suppliers.

Table 6-5. Comparison between different types of information

	Experiment 1			Experiment 2		
	Auction	Negotiation		Auction	Negotiation	
Information	Public	Private, no B-offer	Private, B-offer	Public	Private, no B-offer	Private, B-offer
No. of bids/offers per transaction	$24.14^{*\#}$	$1.19^{\#}$	6.48	$17.00^{*\#}$	$1.47^{\#}$	6.21
Supplier's concessions	$10.81^{\#}$	$9.36^{\#}$	3.76	$9.19^{\wedge}$	$5.47^{\#}$	11.42
Buyer's concessions	$11.21^{\#}$	$10.90^{\#}$	4.41	$10.39^{\wedge}$	7.08^{+}	11.92

Note: (1) numbers are mean values; (2) significance when comparing to private information without offer: $*\, p < 0.01$, $\wedge\, p < 0.05$*; (3) significance when comparing to private information with offer:* $\#\, p < 0.01$, $+\, p < 0.05$*; (4) three types of information: public information in auction (public), private information in negotiation without buyer's offers (Private, no B-offer), and private information in negotiation with buyer's offers (Private, B-offer).*

The public information revealed in auctions led to a greater number of bids submitted by the suppliers. The private messages without buyer's offer did not motivate the suppliers in making counter-offers, whereas the suppliers made more offers when responding to the buyer's offers. Similar results were found in the two experiments, though fewer bids and offers were made in the online setting.

The suppliers made significantly larger concessions in their bids following the public information in auctions. In negotiations, buyer's messages also led to greater concessions in supplier's subsequent offers, while buyer's offers resulted in smaller concessions in suppliers' counter-offers. There were no significant differences in suppliers' concession-making between the public information in auctions and the buyer's message in negotiations. However, different results were found in the negotiations in Experiment 2. The suppliers made much larger concessions when replying to buyer's offers and smaller concessions to buyer's messages. The suppliers' concessions led to an increase in the buyer's gains. In the laboratory setting, the buyers benefited from their public information in auctions and messages in negotiations; in the online setting, their gains were improved by making reciprocal offers to the suppliers.

This indicates that the private messages in negotiations had the same effect as the public information in auctions in the laboratory setting, which may be due to the similar environment with high time pressure. In the online setting, the suppliers had longer time to verify the information from the buyer. The public information in auctions is more transparent and valid for all suppliers than the private information in negotiations. In particular, a message without an explicit offer becomes difficult to verify. Thus, the suppliers may make their bids/offers based on the public information or buyer's offers, in which case they may feel it is worthwhile to make concessions.

6.6 Discussion

E-procurement has advanced with the adoption of information technologies and various market mechanisms, leading to cost savings, strategic advantages and enhanced business relationships. Effective procurement depends not only on the proper selection of products and/or services but also on the appropriate selection and use of market mechanisms. Despite the number of general guidelines that have been formulated, there is lack of empirical evidence that can assist and suggest strategic choices of various mechanisms.

Business procurement often involves multiple parties and multiple attributes, which requires advanced market mechanisms. Auctions and negotiations are traditionally two different classes of market mechanisms. With the advancement of information technologies, these two different mechanisms have recently been extended to facilitate and govern such procurement transactions: from single-attribute auctions to multi-attribute auctions and from bilateral negotiations to multi-bilateral negotiations. This study takes a further step to experimentally compare two such mechanisms in e-procurement: multi-attribute reverse auctions and multi-bilateral multi-attribute negotiations. Their differences in the process, outcomes and suppliers' assessment were investigated in two experiments, one in the laboratory and one on the Internet. Group comparisons were also conducted to further examine the effects of experimental setting, suppliers' outcomes and buyer's behavior.

6.6.1 Findings and implications

The results from the two experiments are consistent; however, there are some differences between the two mechanisms. The results show that auctions were more efficient and competitive than negotiations in terms of the process, including the number of bids or offers and the concessions made by the suppliers. Also, auctions outperformed negotiations in terms of the buyer's gains with the sacrifice of the supplier's profit. The contracts reached through auctions were more efficient than those through negotiations in terms of Pareto optimality. However, the buyers and suppliers reached more balanced contracts in negotiations than in auctions. The suppliers gained more profit in negotiations than in auctions, and they also showed higher assessment of the process and outcomes in negotiations.

The differences between auctions and negotiations are more significant in the laboratory setting than the online setting. The results show significant differences mainly in auctions. In the laboratory setting, the suppliers made a greater number of bids and larger concessions, and thus achieved worse contracts and showed a lower level of assessment of the process and outcomes.

It was suspected that the suppliers' behavior and assessment would differ between the winners and non-winners. Indeed, the results of a group comparison within each treatment show that the winning suppliers were more actively participating in the transaction and competing against others in making more bids/offers with larger concessions. The winners also had significantly more positive assessment of the process, outcomes and system than the non-winners

One of the major differences between auction and negotiation is the buyer's role, particularly with regard to the information conveyed from the buyer to the suppliers during the transactions. Three types of information were identified: *public information* (buyer's announcements in auction), *private information without buyer's offer* (buyer's messages in negotiation), and *private information with buyer's offer* (buyer's offers attached with messages in negotiation). They were found to affect suppliers' behavior in making bids/offers and concessions, which in turn affected buyer's gains. The public information consistently led to a greater number of bids and larger concessions than the private information, both in laboratory and online. However, the two types of private information showed different effects between the two settings. The buyer's messages led to reciprocal offers from the suppliers with larger concessions in laboratory only, while the buyer's offers had the same effect only in the online setting.

Several implications can be drawn from these findings. First, advanced auction and negotiation mechanisms can be used for the same e-procurement transactions while they may be superior to each other on different aspects. Auctions are more efficient and competitive, which can benefit buyers in requesting and receiving proposals from different suppliers, increasing the bargaining power, and thus reaching a better deal. When running in a shorter time period, the higher competition and time pressure may lead to overbidding and non-profitable contracts for the suppliers. This may hurt their incentives in participating in such transactions. In a longer time frame, nonetheless, auctions can still be efficient and lead to profitable contracts for both buyers and suppliers. Negotiations can benefit both sides with profitable and more balanced contracts. This may be of particular concern when the buyer's goal is not to maximize her profit but to improve social welfare (e.g. in public procurement) (Croom and Brandon-Jones 2005; Subramanian 2009).

Second, the buyer can make reciprocal offers with certain concessions in negotiations and thus lead to higher quality contracts. Another distinction between auctions and negotiations is that while auctions focus on economic value (e.g. cost savings, profit gains), negotiations have both economic and social aspects. In auctions, the competition is among suppliers as they bid against each other for favor of the buyer; thus, the concessions are made merely from the suppliers. In negotiations, the competition between suppliers is brought about through the buyer's involvement. It can be similar to auctions if the buyer does not make any concessions; however, the offers or counter-offers made by the buyer often require certain concessions and reciprocity that also benefit the suppliers (Kersten, Vahidov et al. 2013). Taking into account the counterpart's interests in the transactions, the two sides may exchange reciprocal offers and thus reach a more balanced agreement. Mechanism designers and practitioners should note such differences in concession-making between auctions and negotiations.

Moreover, the buyer's different roles can be distinguished and analyzed with respect to the types of information conveyed to the suppliers. In auctions, the information about admissible bids and winning bids is announced to all the suppliers. The information may be implicit in disclosing the buyer's preferences, but it provides sufficient guidance for the suppliers to make progressive bids. It may also lead to higher competition and thus more concessions by the suppliers as it indicates the existence of the competitors. Note that the winning bids in auctions provide anchors for suppliers' decision making in their subsequent bids, which may also direct their attention to inappropriate alternatives. Suppliers should note and avoid such risks by carefully analyzing the information obtained from the buyer through the mechanisms. Buyers may consider other choices in providing feedback information to the bidders, for instance, bid ranking and average value (Adomavicius, Gupta et al. 2012).

In negotiations, the information is private through the communication between the buyer and each supplier separately. The information with message only is not verifiable; the suppliers may hesitate to make offers and concessions based merely on such information. In order to motivate suppliers in submitting their proposals, buyers may need to provide more public and verifiable information (e.g. outstanding offers) (Thomas and Wilson 2005) and clearer guidance in directing the suppliers' offers such as preferences on different attributes in the auctions. The information with the buyer's offer is not only valid but also reciprocal, which motivates suppliers in making counter-offers. Note that the effects of buyer's offers and messages may vary in different situations. In a high time pressure situation, buyer's messages can play the same role as the public information in auctions, which leads to higher competition between suppliers and thus larger concessions in their offers. In a more relaxed environment, valid information such as buyer's offers may be expected when exchanging reciprocal offers. Thus, buyers should behave strategically to convey more influential information in different contexts.

Lastly, user's assessment has been well studied and widely used in assessing information systems and online transactions (Zviran and Erlich 2003; Chen, Rodgers et al. 2008). The results from this study confirm that assessment is a multi-facet instrument and can be used to assess e-procurement transaction from various aspects. E-procurement is a unique process that involves two sides and multiple parties. In such a collaborative environment, users' assessment may be influenced by their counterparts and competitors. Procurement mechanisms define the rules that prescribe participants' behavior and their interactions, which may affect their experience and thus assessment of the transactions. It is worthy to note that user's assessment is strongly affected by their performance and outcomes in such transactions. Suppliers who are awarded with the contracts through their efforts are more satisfied with the process, outcomes and systems.

6.6.2 Limitations and future research

Several limitations in this study should also be noted for future research. This study addresses multi-attribute transactions in e-procurement which allows exchanging only complete offers and awarding of a contract to one supplier. In practice, it may be feasible and required to have partial offers, multi-sourcing and nested transactions. Future research may extend the present study to compare the variants of mechanisms in those situations. For instance, research may consider the relative importance and interdependency of the attributes, which can be used to transform the partial offers to single-attribute or similar multi-attribute transactions.

This study examines and compares the effects of different types of information conveyed from buyer. Yet, this is a *post hoc* analysis using the suppliers' offers that responded to buyer's information. In future research, experiments with more controllable information may validate and extend this comparison. For example, buyers in negotiations can only send messages without making any offers, which allows for the control of buyer's behavior in the process. Moreover, the buyer's messages in negotiations were considered as one type of information. The content of the messages, however, actually conveys the information and meaning to suppliers. Future studies may conduct content analysis to verify the information and further examine the role of buyer's messages.

The transaction task in the experiment is relatively complex and the number of participants in each transaction is small. This may limit the findings to those transactions that involve business contracts with only a few potential and important suppliers. The number of suppliers involved in the process may affect the outcomes (Thomas and Wilson 2002). A comparison of the number of suppliers was not conducted due to the small sample size. Future work may replicate the experiments and control the number of suppliers in each transaction. It may also be worthwhile to test transactions with a large number of suppliers and simpler tasks, which may benefit from different mechanisms (Carter and Stevens 2007; Jap 2007; Cason, Kannan et al. 2011).

Two experiments were carried out to enhance the internal and external validity of this study. The main subjects were university students who study information systems in business programs. Research has discussed both advantages and disadvantages of this approach in e-business studies (Jiang and Benbasat 2007; Cenfetelli, Benbasat et al. 2008). Future research may validate the hypotheses and findings with a field study where business professionals use similar systems in real-life transactions.

7. Conclusion

The present research is carried out with three studies on multi-attribute market mechanisms in e-procurement. This section concludes the dissertation with a summary of the three studies and their contributions to research and practice. The limitations are also addressed for future directions.

7.1 Summary of three studies

Organizations often need to make decisions about where and how to obtain required goods or services. In-house production and procurement from the market are general solutions, which have been studied and applied to different situations. Organizations who choose to procure from external sources need specific and operational guidelines. E-procurement has advanced with the adoption of ICTs and various market mechanisms, leading to cost savings, strategic advantages and enhanced business relationships. Effective procurement requires the proper selection and utilization of existing mechanisms, and, if not feasible, then entails the design of advanced mechanisms or the adaptation to emergent variants.

The present research considers situations: (1) wherein B2B transactions involve multiple attributes of goods or services rather than price only, (2) wherein a number of suppliers participate and compete for the same contract, and (3) wherein the buyers do not wish to explicitly reveal their preferences. Existing procurement mechanisms meet one or two of these practical requirements; however, no such mechanism is available to support these transactions. There is a need to design and implement feasible mechanisms to solve this practical, yet challenging, problem.

Moreover, a number of normative guidelines have been proposed to help practitioners in selecting and using appropriate mechanisms, depending on the transaction characteristics. It has been widely accepted that auction is a good candidate for noncritical transactions and that negotiation is more appropriate to form strategic partnership. There are situations, however, wherein both auction and negotiation may apply (e.g. leverage procurement). Existing studies have focused on single-attribute auctions and bilateral negotiations. There is a dearth of comparative studies on multi-attribute mechanisms.

Thus, this research aims to: (1) design and implement feasible mechanisms that meet the above requirements in e-procurement, and (2) gain a better understanding of their use and impact in e-procurement. Towards these goals, three studies are carried out. They are relatively independent but closely connected with each other, following the research roadmap (Section 3) and guided by the research framework (Figure 3-1 in Section 3.1). They also study the multi-attribute mechanisms from an information lens. Information is key aspect in market mechanisms, system design and decision making. The three studies address the following questions respectively:

- *What information do the suppliers need to know? How to convey the information from the buyer to suppliers?* (Study 1 in Section 4)
- *How does information revelation affect the process, outcomes and bidders' assessment in multi-attribute reverse auctions?* (Study 2 in Section 5)
- *Which (if at all) mechanism outperforms the other? Under what conditions will one mechanism outperform the other?* (Study 3 in Section 6)

Study 1 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. It presents two feasible mechanisms for multi-attribute multi-supplier transactions. They allow buyers to control preference representation and information revelation, assuring that suppliers obtain sufficient information in making effective proposals while protecting confidential information. Following the design-science approach, the mechanisms are implemented to support multi-attribute reverse auctions and multi-bilateral negotiations.

Study 2 examines the revelation of information in multi-attribute reverse auctions. Three revelation rules are formulated with admissible bids, winning bids and all bidders' bids. Their effects on the process, outcomes and bidders' assessment are tested in two experiments. The results show that: (1) it is sufficient for suppliers making meaningful offers when solely revealing dynamic information in the transaction process without direct disclosure of buyer's preferences; (2) different types of information may lead to various effects such as anchoring, learning and signaling effects; (3) buyers and suppliers favor different rules of information revelation, considering the process efficiency and their gains (e.g. the suppliers reached better outcomes with either admissible bids only or all bidders' bids, while the buyers gained more when revealing the winning bids only); and, (4) information revelation during the process appears not affecting participants' assessment of the process and systems, whereas it is considered differently by the winners and non-winners in their perceptions of the outcomes and systems.

Study 3 compares multi-attribute reverse auctions and multi-bilateral negotiations in both laboratory and online experiments. The results show that auctions are more efficient than negotiations in terms of the process. Auctions led to greater gains for the buyers, whereas more balanced contracts were reached in negotiations. Suppliers' assessment was affected by their outcomes, and the winning suppliers were more satisfied with the process, outcomes and system. The buyer's role was also examined. Different types of information conveyed from buyer influence suppliers' behavior in making bids/offers and concessions, which in turn affected buyer's gains. In particular, the public information revealed in auctions increased the competition level and thus led to a greater number of bids and larger concessions. This then improved the buyer's gains but resulted into imbalanced contracts. The two types of private information in negotiations showed different effects in the laboratory and online settings. The buyer's messages led to reciprocal offers from the suppliers with larger concessions in the laboratory only, while the buyer's offers had the same effect only in the online setting.

7.2 Contributions

This research contributes to future studies and practices in e-procurement, in particular,

(1) The research formulates two process models and proposes two multi-attribute mechanisms in e-procurement.

Existing mechanisms either support single-attribute transactions or require disclosure of buyer's preferences, which has limited their adoption and application in e-procurement practice. The proposed process models address these practical needs and enable to design and implement effective and comparable mechanisms. In particular, two novel procurement mechanisms, multi-attribute reverse auction and multi-bilateral negotiation, are designed to support e-procurement transactions that involve multiple attributes and multiple suppliers and that allow buyers to control the revelation of their preferences. The approach also allows the design of hybrid and seamless mechanisms between classic auction and negotiation mechanisms.

(2) The research develops two innovative systems that enable to study and compare auction and negotiation processes in a similarly competitive context.

Many existing comparative studies were conducted in different settings or for different tasks, leading to inconclusive and even contradictory results. In order to empirically examine the similarities and differences between auctions and negotiations, the above two comparable multi-attribute procurement mechanisms are implemented with similar user interface and system features. The systems provide a test-bed to conduct experiments in which various contextual factors can be controlled and manipulated to validate and study different mechanism design and their impact. The systems are tested and deployed on the Internet; to-date, they have been used by over 2,000 users for research and education. The systems form a basis for two subsequent studies in this thesis (i.e. Study 2 and Study 3) and many other studies (e.g. human-agent negotiations by Vahidov and Kersten 2012a; 2012b). They can also be used for business training in e-procurement and contract design.

(3) The research provides insights into the similarities and differences between auctions and negotiations.

Auctions and negotiations are two classic market mechanisms. Discrepant definitions and mixed use of the two mechanisms exist in different disciplines. This research shows that they are capable to support the same procurement transactions with the advancement of information technologies, yet they are different in several aspects. Their convergence and distinction can and should be noted in terms of their design, implementation and impact on the transaction process and outcomes. The variants of auction and negotiation mechanisms proposed in Study 1 show that they are mainly different in terms of the buyer's role in the processes and the flexibility of information exchange, while technology convergence also makes it possible to design a series of mechanisms between the two classic mechanisms by defining and configuring a set of design parameters. From an information revelation lens, Study 2 compares three variants of mechanisms within the auction family. The results show that different information rules lead to various effects (e.g. anchoring, learning and signaling) that may benefit or harm the buyers and suppliers differently. Taking a further step, Study 3 compares the mechanisms between auctions and negotiations. The results show that auctions do outperform negotiations in terms of process and outcome efficiencies that favor the buyers, while negotiations lead to more balanced contracts. It also indicate that similar effects may be achieved with different mechanisms; for instance, the public announcement of winning bids in auctions and the buyer's public messages without making offer (and thus no concession-making) in negotiations both can add pressures on the suppliers, result in larger concessions from the suppliers and better outcomes for the buyers.

(4) The research formulates specific guidelines for strategic use of different mechanisms in certain procurement contexts.

This research carries out two experimental studies in which the proposed mechanisms are studied and compared. The findings indicate that auctions and negotiations outperform each other on different aspects in different situations, such as buyer's gains versus supplier's gains, process efficiency versus outcome efficiency, individual gains versus joint outcomes, and laboratory setting versus online setting. The results from Study 2 suggest that buyers should realize and distinguish the different types of information and the effects of their revelation in auctions. Insufficient information may increase the suppliers' learning effort that reduces the process efficiency, while revealing too much information can also harm the bidders' interests and thus lead to earlier terminations. The combination of admissible bids and winning bids may be the best candidate if buyers expect higher economic gains. In other situation such as public procurement, higher information transparency and social welfare with more balanced contracts may be given a higher priority. Also, even the same type of information may lead to different effects in different contexts. In Study 3, the private information (buyer's offers and messages) in negotiations show different effects in the laboratory and online settings. The buyer's messages led to reciprocal offers from the suppliers with larger concessions under a higher time pressure in the laboratory setting, while the buyer's offers had the same effect only in the online setting. The findings from this research help practitioners in the selection and utilization of these mechanisms based on business needs and situations.

(5) The research implicates that an interdisciplinary approach is required to empirically study and compare auction and negotiation mechanisms in e-procurement, which typically involves IS research, decision and negotiation analysis, and experimental economics.

E-procurement is an artifact or information system in which business process models are implemented with information technologies. Various mechanisms can be modeled and implemented in such systems through the design science approach, and the systems then provide test beds to experimentally examine and compare the implemented mechanisms. This interdisciplinary approach provides a new avenue to design, implement and assess market mechanisms in e-procurement.

7.3 Limitations and future directions

Several limitations should be mentioned and can be addressed in future research.

This research studies the multi-attribute transactions in e-procurement which allows exchanging only complete offers and awarding of a contract to one supplier. In practice, it may be feasible and required to have partial offers, multi-sourcing and nested transactions. Future research may extend the present research to compare the variants of mechanisms in those situations.

The transaction task in the experiment is relatively complex and the number of participants in each transaction is small. This may limit the findings to those transactions that involve business contracts with only a few potential and important suppliers. A comparison of the number of suppliers was not conducted due to the small sample size. Future work may replicate the experiments and manipulate the number of suppliers in each transaction. It may also be worthwhile to test transactions with a large number of suppliers and simpler tasks, which may benefit from different mechanisms. Moreover, the structure of the transactions are pre-defined (e.g. number of attributes, number of alternatives, preferences) in order to control the tasks in experiments. In practice, an open structure may be required to allow the parties exploring their decision and/or utility space, for instance, to add new attributes and alternatives, to introduce new suppliers in the process, to elicit and revise their preferences. These potential extensions and applications of the proposed mechanisms may be accomplished in future research.

The effects of different types of information conveyed from buyer were examined in both Study 2 and Study 3. It was only possible to conduct a *post hoc* analysis in the latter. Future experiments with more controllable information may validate and extend this study. For example, buyers in negotiations can only send messages without making any offers, which allows for the control of buyer's behavior in the process. Moreover, the buyer's messages in negotiations were considered as one type of information. The content of the messages, however, actually conveys the information and meaning to suppliers. Future studies may conduct content analysis to verify the information and further examine the role of buyer's messages. In addition, the effects of revealing other types of information may be examined and compared in future research, for instance, the identity of suppliers and the number of active suppliers.

Experiments in both laboratory and online settings were carried out to enhance the internal and external validity of the study. The main subjects were university students who study information systems in business programs. The experiment was part of their course work worth six marks in their final grade, which might not be sufficient to provide an incentive for their dedication and participation in this study. For instance, one of the reasons that revealing more information with all bids did not improve the outcomes may be that the students had other objectives and "winning" might not be the most important one (e.g. Kersten, Gimon et al. 2013). Future research may consider using monetary or other format of incentives to align with their motivations in the study. A field study will be preferred to validate the hypotheses and findings in which business professionals use similar systems in their real-life e-procurement transactions.

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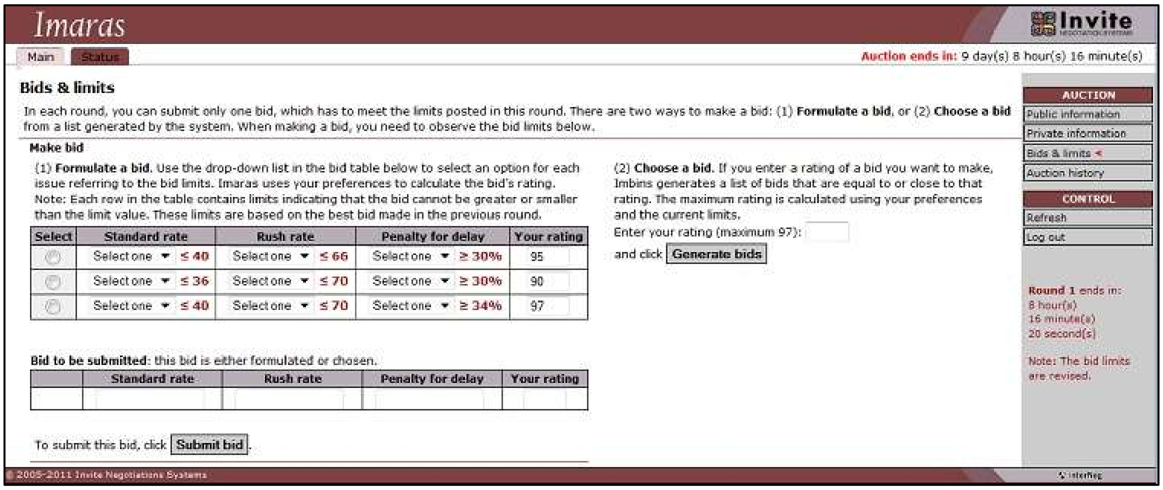
Appendix A: System screenshots of Imaras

The following is a series of main screenshots when using Imaras for multi-attribute auctions. The demonstrated auction was running in the online setting with ten days (one day per round), in which the admissible bids and winning bids were shown. The bidder was Nart who was representing one of the suppliers.

Bids & limits

This is the web page where you can make a bid and check the current limits for admissible bids. Other information may be also available on this page depending on the auction rules and settings, for instance, the bids in previous rounds, the winning bids and/or other bidders' bids.

Figure A-1 shows the initial screen at the beginning of an auction, where no bids have been made yet.



Auction ends in: 9 day(s) 8 hour(s) 16 minute(s)

Bids & limits

In each round, you can submit only one bid, which has to meet the limits posted in this round. There are two ways to make a bid: (1) **Formulate a bid**, or (2) **Choose a bid** from a list generated by the system. When making a bid, you need to observe the bid limits below.

Make bid

(1) **Formulate a bid.** Use the drop-down list in the bid table below to select an option for each issue referring to the bid limits. Imaras uses your preferences to calculate the bid's rating. Note: Each row in the table contains limits indicating that the bid cannot be greater or smaller than the limit value. These limits are based on the best bid made in the previous round.

Select	Standard rate	Rush rate	Penalty for delay	Your rating
○	Select one ≤ 40	Select one ≤ 66	Select one ≥ 30%	95
○	Select one ≤ 36	Select one ≤ 70	Select one ≥ 30%	90
○	Select one ≤ 40	Select one ≤ 70	Select one ≥ 34%	97

Bid to be submitted: this bid is either formulated or chosen.

	Standard rate	Rush rate	Penalty for delay	Your rating

To submit this bid, click Submit bid.

(2) **Choose a bid.** If you enter a rating of a bid you want to make, Imbins generates a list of bids that are equal to or close to that rating. The maximum rating is calculated using your preferences and the current limits.

Enter your rating (maximum 97):

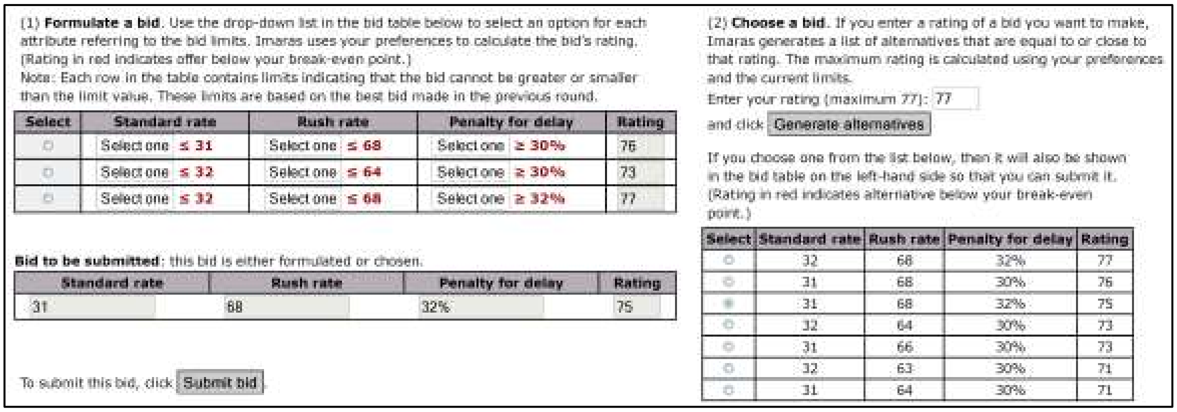
and click Generate bids

Round 1 ends in:
8 hour(s)
16 minute(s)
20 second(s)

Note: The bid limits are revised.

Figure A-1. Initial screen of "Bids & limits"

Figure A-2 shows the two ways to make a bid during the auction, either to formulate a bid on each attribute or to generate a list of bids and choose one based on the total rating value. In both ways, the bid needs to conform the limits, i.e. admissible bidding sets.



(1) **Formulate a bid**. Use the drop-down list in the bid table below to select an option for each attribute referring to the bid limits. Imaras uses your preferences to calculate the bid's rating. (Rating in red indicates offer below your break-even point.)

Note: Each row in the table contains limits indicating that the bid cannot be greater or smaller than the limit value. These limits are based on the best bid made in the previous round.

Select	Standard rate	Rush rate	Penalty for delay	Rating
○	Select one ≤ 31	Select one ≤ 68	Select one ≥ 30%	76
○	Select one ≤ 32	Select one ≤ 64	Select one ≥ 30%	73
○	Select one ≤ 32	Select one ≤ 68	Select one ≥ 32%	77

Bid to be submitted: this bid is either formulated or chosen.

Standard rate	Rush rate	Penalty for delay	Rating
31	68	32%	75

To submit this bid, click Submit bid.

(2) **Choose a bid**. If you enter a rating of a bid you want to make, Imaras generates a list of alternatives that are equal to or close to that rating. The maximum rating is calculated using your preferences and the current limits.

Enter your rating (maximum 77): 77

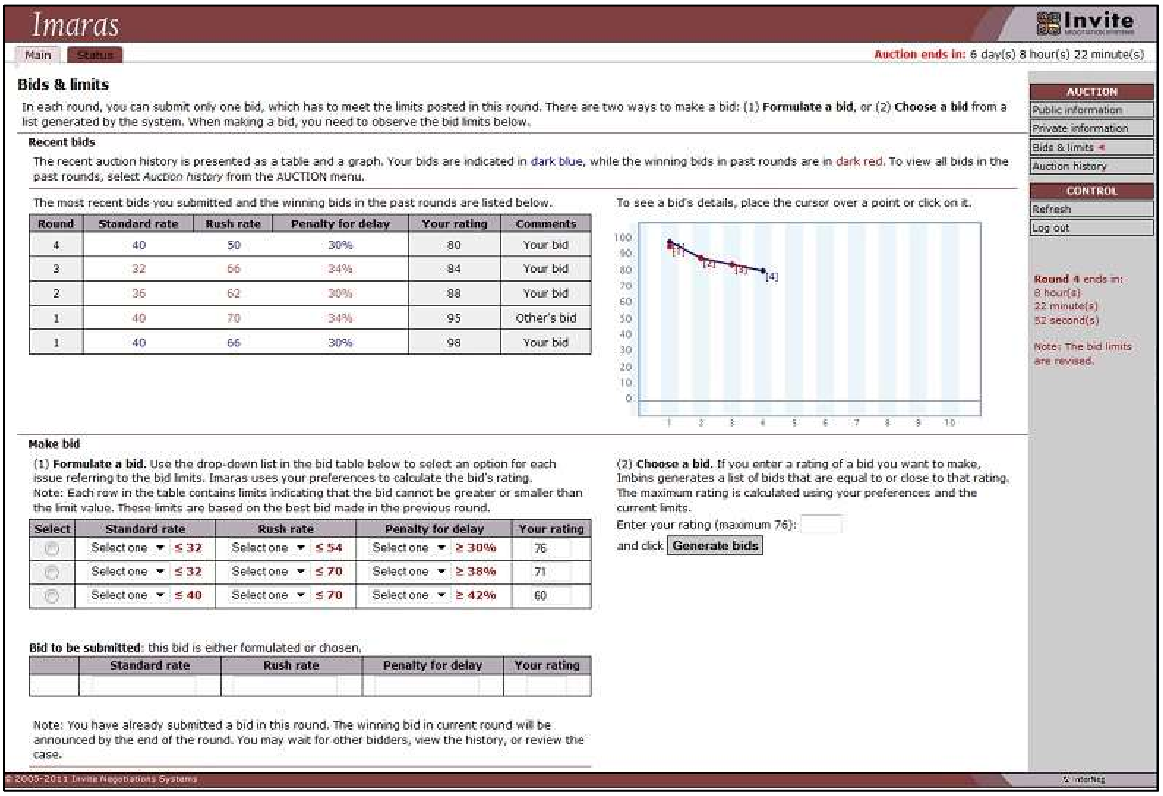
and click Generate alternatives

If you choose one from the list below, then it will also be shown in the bid table on the left-hand side so that you can submit it. (Rating in red indicates alternative below your break-even point.)

Select	Standard rate	Rush rate	Penalty for delay	Rating
○	32	68	32%	77
○	31	68	30%	76
●	31	68	32%	75
○	32	64	30%	73
○	31	66	30%	73
○	32	63	30%	71
○	31	64	30%	71

Figure A-2. Bid formulation and generation with admissible bidding sets

Figure A-3 shows the screen after the auction run several rounds, where bids from this bidder and other bidders have been made. The limits for admissible bids in current round have been updated, and the winning bids either from this bidder or other bidders are shown in the recent bids table and graph. The table lists the most recent bids with their specifications on each attribute and their total rating value.



Auction ends in: 6 day(s) 8 hour(s) 22 minute(s)

Bids & limits

In each round, you can submit only one bid, which has to meet the limits posted in this round. There are two ways to make a bid: (1) **Formulate a bid**, or (2) **Choose a bid** from a list generated by the system. When making a bid, you need to observe the bid limits below.

Recent bids

The recent auction history is presented as a table and a graph. Your bids are indicated in dark blue, while the winning bids in past rounds are in dark red. To view all bids in the past rounds, select *Auction history* from the AUCTION menu.

The most recent bids you submitted and the winning bids in the past rounds are listed below.

Round	Standard rate	Rush rate	Penalty for delay	Your rating	Comments
4	40	50	30%	80	Your bid
3	32	66	34%	84	Your bid
2	36	62	30%	88	Your bid
1	40	70	34%	95	Other's bid
1	40	66	30%	98	Your bid

To see a bid's details, place the cursor over a point or click on it.

Round 4 ends in:
8 hour(s)
22 minute(s)
52 second(s)

Note: The bid limits are revised.

Make bid

(1) **Formulate a bid.** Use the drop-down list in the bid table below to select an option for each issue referring to the bid limits. Imaras uses your preferences to calculate the bid's rating.
Note: Each row in the table contains limits indicating that the bid cannot be greater or smaller than the limit value. These limits are based on the best bid made in the previous round.

Select	Standard rate	Rush rate	Penalty for delay	Your rating
○	Select one ▼ ≤ 32	Select one ▼ ≤ 54	Select one ▼ ≥ 30%	76
○	Select one ▼ ≤ 32	Select one ▼ ≤ 70	Select one ▼ ≥ 38%	71
○	Select one ▼ ≤ 40	Select one ▼ ≤ 70	Select one ▼ ≥ 42%	60

(2) **Choose a bid.** If you enter a rating of a bid you want to make, Imbins generates a list of bids that are equal to or close to that rating. The maximum rating is calculated using your preferences and the current limits.
Enter your rating (maximum 76):
and click Generate bids

Bid to be submitted: this bid is either formulated or chosen.

	Standard rate	Rush rate	Penalty for delay	Your rating

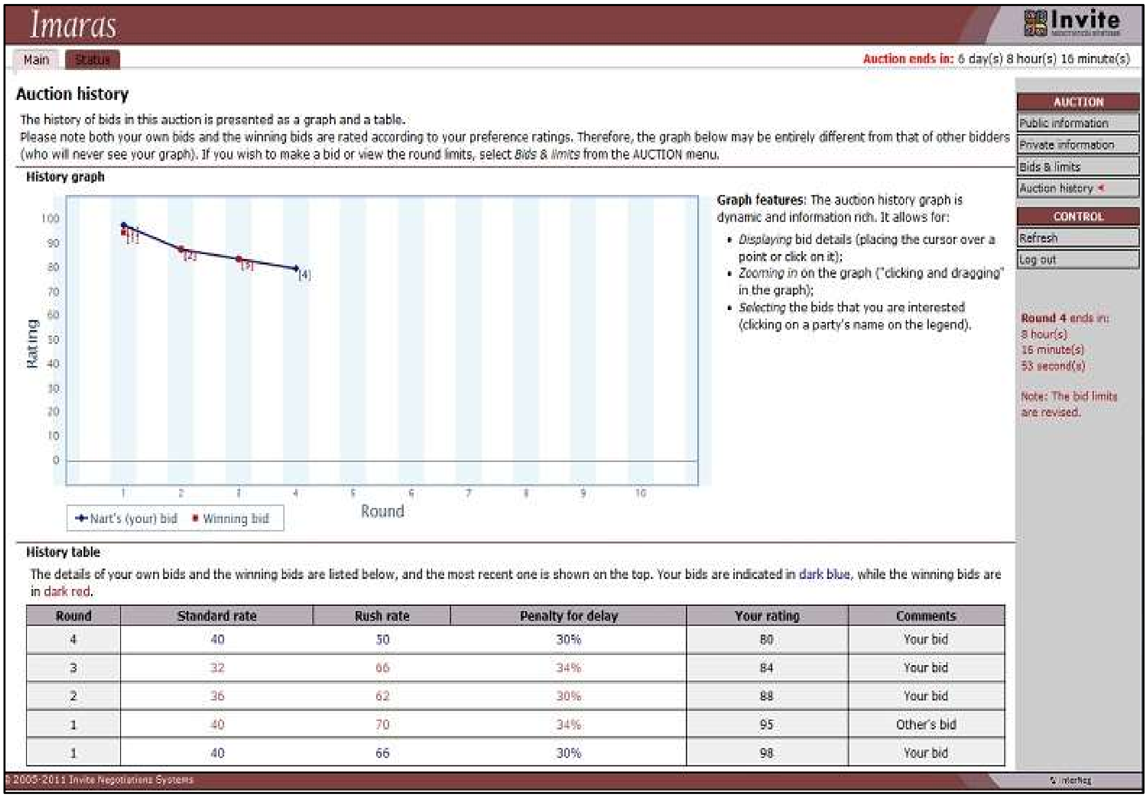
Note: You have already submitted a bid in this round. The winning bid in current round will be announced by the end of the round. You may wait for other bidders, view the history, or review the case.

Figure A-3. Screen of "Bids & Limits" after several rounds

Auction history

During the auction, the bidders can always review all the bids that have been submitted by themselves and other information depending on the rules (e.g. the winning bids and/or other's bids). The auction history is shown in both a table and a graph.

Figure A-4 shows the auction history during the fourth round. The bidder's own bids are shown in each round, and the winning bids in each round are highlighted. These bids are shown in both the history table and history graph; while the table shows the specifications of the bids, the graph depicts the bids based on their rating value and the round it was submitted.



Auction ends in: 6 day(s) 8 hour(s) 16 minute(s)

Auction history

The history of bids in this auction is presented as a graph and a table.
Please note both your own bids and the winning bids are rated according to your preference ratings. Therefore, the graph below may be entirely different from that of other bidders (who will never see your graph). If you wish to make a bid or view the round limits, select *Bids & limits* from the AUCTION menu.

History graph

Graph features: The auction history graph is dynamic and information rich. It allows for:

- *Displaying* bid details (placing the cursor over a point or click on it);
- *Zooming in* on the graph ("clicking and dragging" in the graph);
- *Selecting* the bids that you are interested (clicking on a party's name on the legend).

Round 4 ends in:
8 hour(s)
16 minute(s)
53 second(s)

Note: The bid limits are revised.

History table

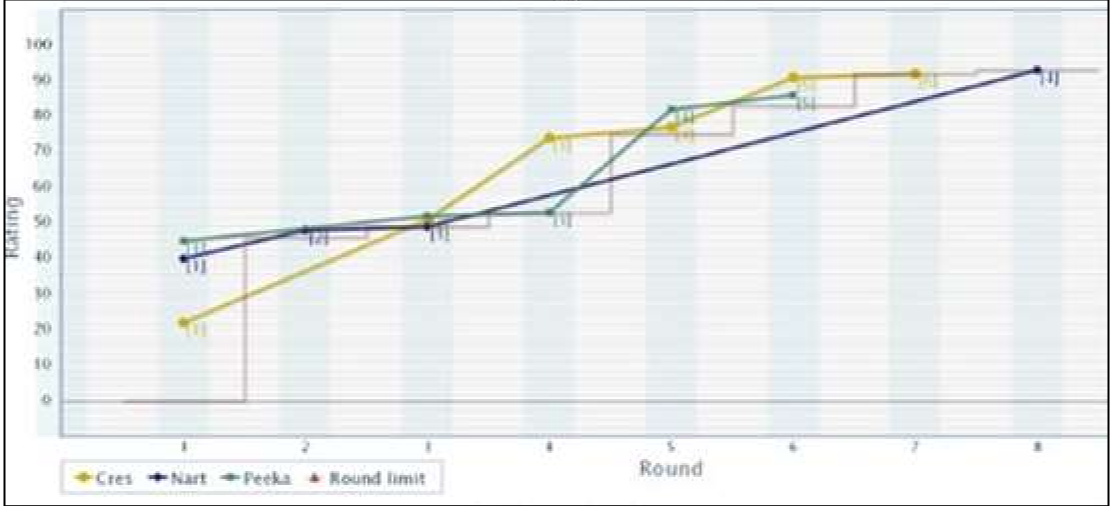
The details of your own bids and the winning bids are listed below, and the most recent one is shown on the top. Your bids are indicated in dark blue, while the winning bids are in dark red.

Round	Standard rate	Rush rate	Penalty for delay	Your rating	Comments
4	40	50	30%	80	Your bid
3	32	66	34%	84	Your bid
2	36	62	30%	88	Your bid
1	40	70	34%	95	Other's bid
1	40	66	30%	98	Your bid

Figure A-4. Screen of "Auction history" after several rounds

Figure A-5 shows a closer view of the visualization of the auction process in graphs. It also shows the different views of the process from the bidder's perspective (i.e. suppliers) and the auctioneer's perspective (i.e. buyer). The purple line in the buyer's view indicates the rating value of the limits or the admissible bidding sets in each round; thus, the actual bids submitted by each bidder are above the purple line, i.e. their rating value cannot be lower than the value of admissible bids.

a. Supplier's view



b. Buyer's view

Figure A-5. Visualization of bidding process: (a. Supplier's view; b. Buyer's view)

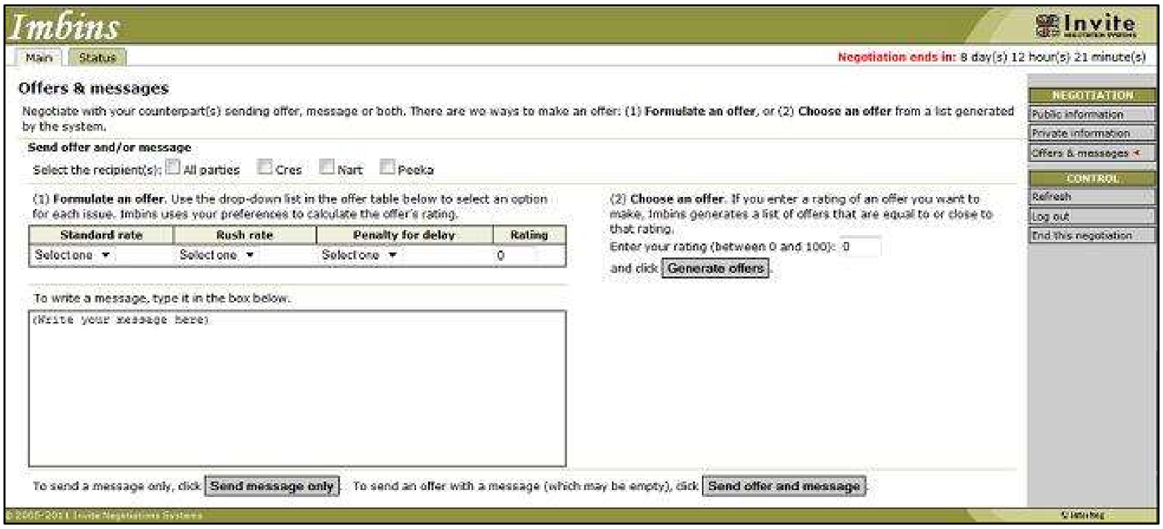
Appendix B: System screenshots of Imbins

The following is a series of main screenshots when using Imbins for multi-bilateral negotiations. The demonstrated negotiation was running in the online setting with a total time length of ten days. The screenshots show the views from one of the suppliers (represented by Cres) and the buyer (represented by Malk).

Offers & messages

This is the web page where the users (both the buyer and suppliers) can make an offer, send a message, and review the most recent offers/messages (if there are any). Note that there are differences between the buyer's screen and the supplier's screen, including: (1) the buyer can decide to whom the offer/message will be sent, which can one or more than one of the suppliers (e.g. Cres, Cres and Nart, or all parties). The buyer will also be able to view the offers/messages sent from all the suppliers and from the buyer herself. However, the supplier can only send offers/messages to the buyer, and she can only see the offers/messages from the buyer or herself.

Figure B-1 shows the initial screen of the buyer, where no offer/message has been made or exchanged yet. In the section "Send offer and/or message", the buyer can choose the receipt of the offer or message. The buyer can also choose to send an offer with message, an offer without message, or only a message. There are also two ways in making an offer, either to formulate an offer by specifying the values for each attribute or to generate and then choose an offer by giving certain rating values.



Negotiation ends in: 8 day(s) 12 hour(s) 21 minute(s)

Offers & messages

Negotiate with your counterpart(s) sending offer, message or both. There are wo ways to make an offer: (1) **Formulate an offer**, or (2) **Choose an offer** from a list generated by the system.

Send offer and/or message

Select the recipient(s): ☐ All parties ☐ Cres ☐ Nart ☐ Peeka

(1) **Formulate an offer.** Use the drop-down list in the offer table below to select an option for each issue. Imbins uses your preferences to calculate the offer's rating.

Standard rate	Rush rate	Penalty for delay	Rating
Select one ▼	Select one ▼	Select one ▼	0

To write a message, type it in the box below.

(Write your message here)

(2) **Choose an offer.** If you enter a rating of an offer you want to make, Imbins generates a list of offers that are equal to or close to that rating.

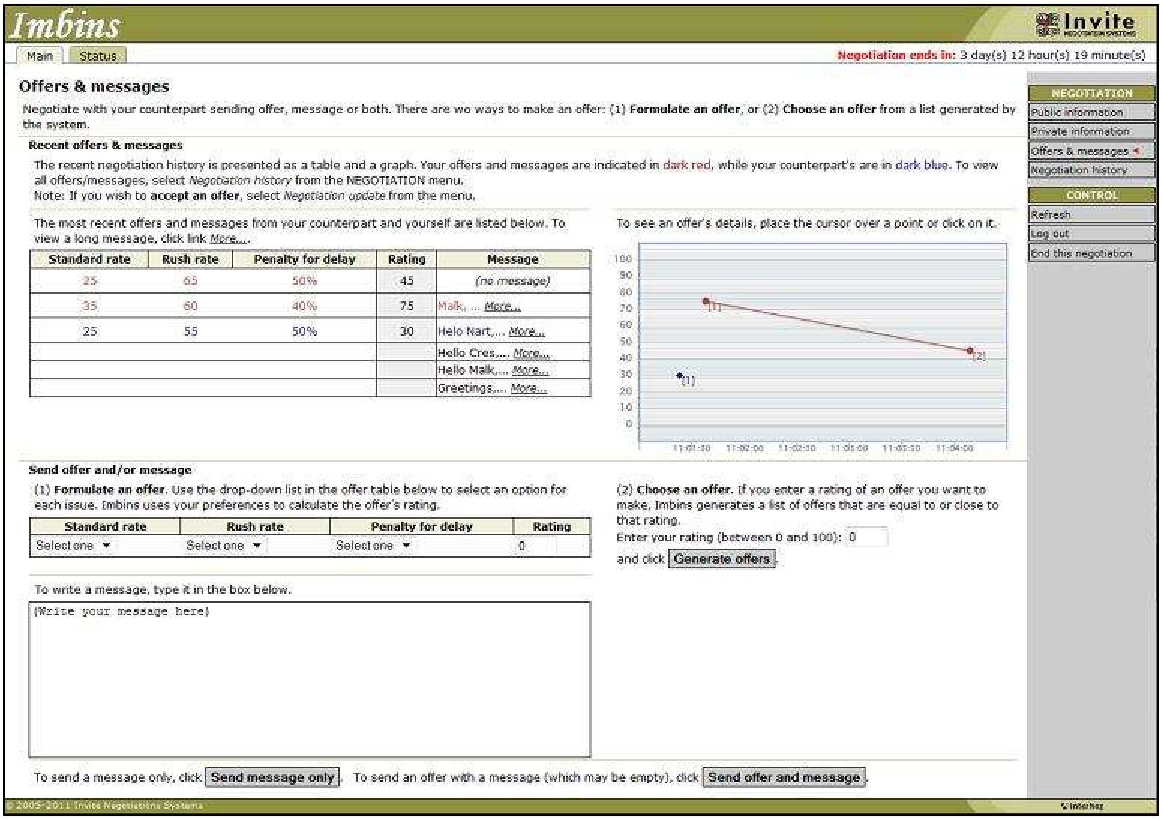
Enter your rating (between 0 and 100): 0

and click Generate offers.

To send a message only, click Send message only. To send an offer with a message (which may be empty), click Send offer and message.

Figure B-1. Initial screen of "Offers & messages" for the buyer

Figure B-2 shows the screen of the supplier, where a number of offers/messages have been made or exchanged with the buyer. Similar to the buyer, the supplier can also send an offer, a messages or an offer with message. There are also two ways for making offers. Note that the rating values are calculated based on the viewer's (i.e. the supplier here) preferences, for both her own offer and the buyer's offer.



Negotiation ends in: 3 day(s) 12 hour(s) 19 minute(s)

Offers & messages

Negotiate with your counterpart sending offer, message or both. There are wo ways to make an offer: (1) **Formulate an offer**, or (2) **Choose an offer** from a list generated by the system.

Recent offers & messages

The recent negotiation history is presented as a table and a graph. Your offers and messages are indicated in dark red, while your counterpart's are in dark blue. To view all offers/messages, select *Negotiation history* from the NEGOTIATION menu.
Note: If you wish to **accept an offer**, select *Negotiation update* from the menu.

The most recent offers and messages from your counterpart and yourself are listed below. To view a long message, click link *More...*.

Standard rate	Rush rate	Penalty for delay	Rating	Message
25	65	50%	45	*(no message)*
35	60	40%	75	Malk, ... More...
25	55	50%	30	Helo Nart,... More...
				Hello Cres,... More...
				Hello Malk,... More...
				Greetings,... More...

To see an offer's details, place the cursor over a point or click on it.

Send offer and/or message

(1) **Formulate an offer.** Use the drop-down list in the offer table below to select an option for each issue. Imbins uses your preferences to calculate the offer's rating.

Standard rate	Rush rate	Penalty for delay	Rating
Select one ▾	Select one ▾	Select one ▾	0

(2) **Choose an offer.** If you enter a rating of an offer you want to make, Imbins generates a list of offers that are equal to or close to that rating.
Enter your rating (between 0 and 100): 0
and click Generate offers.

To write a message, type it in the box below.

(Write your message here)

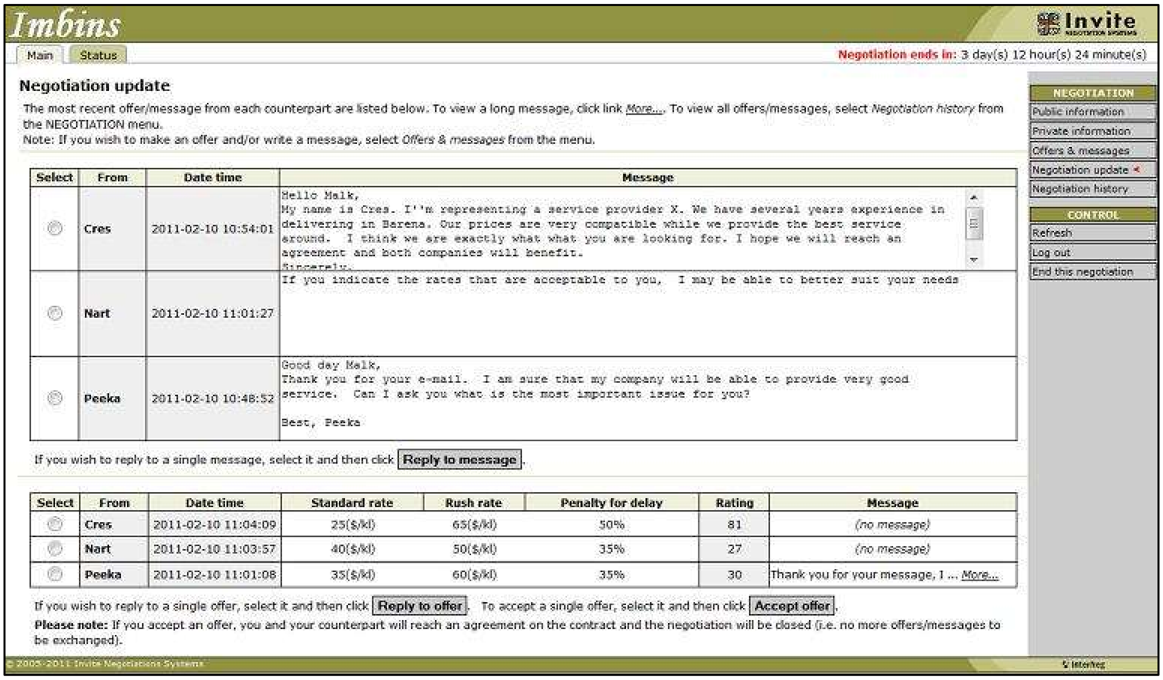
To send a message only, click Send message only. To send an offer with a message (which may be empty), click Send offer and message.

Figure B-2. Screen of "Offers & messages" for the supplier

Negotiation update

Once a new offer/message is received, the buyer and suppliers will be notified by the system via emails. Then, they can log into the system to check any updates for the negotiation. The suppliers will be forwarded to the "Offers & messages" screen (Figure B-2), while the buyer will be forwarded to the "Negotiation update" screen.

Figure B-3 shows the buyer's screen of "Negotiation update". The buyer can not only view the details of the offers/messages from all the suppliers but also decide how to react to those offers. If the buyer is not satisfied with all the offers from suppliers, then she may reply to one of the offers; otherwise, the buyer may accept the offer, which will then conclude the negotiation. Note that the rating value of the offers from each supplier is calculated based on the buyer's preferences. Thus, the offer with higher rating value would be more profitable for the buyer.



Negotiation ends in: 3 day(s) 12 hour(s) 24 minute(s)

Negotiation update

The most recent offer/message from each counterpart are listed below. To view a long message, click link *More...*. To view all offers/messages, select *Negotiation history* from the NEGOTIATION menu.
Note: If you wish to make an offer and/or write a message, select *Offers & messages* from the menu.

Select	From	Date time	Message
○	**Cres**	2011-02-10 10:54:01	Hello Malk, My name is Cres. I''m representing a service provider X. We have several years experience in delivering in Barena. Our prices are very compatible while we provide the best service around. I think we are exactly what what you are looking for. I hope we will reach an agreement and both companies will benefit. Sincerely,
○	**Nart**	2011-02-10 11:01:27	If you indicate the rates that are acceptable to you, I may be able to better suit your needs
○	**Peeka**	2011-02-10 10:48:52	Good day Malk, Thank you for your e-mail. I am sure that my company will be able to provide very good service. Can I ask you what is the most important issue for you? Best, Peeka

If you wish to reply to a single message, select it and then click **Reply to message**.

Select	From	Date time	Standard rate	Rush rate	Penalty for delay	Rating	Message
○	**Cres**	2011-02-10 11:04:09	25($/kl)	65($/kl)	50%	81	*(no message)*
○	**Nart**	2011-02-10 11:03:57	40($/kl)	50($/kl)	35%	27	*(no message)*
○	**Peeka**	2011-02-10 11:01:08	35($/kl)	60($/kl)	35%	30	Thank you for your message, I ... More...

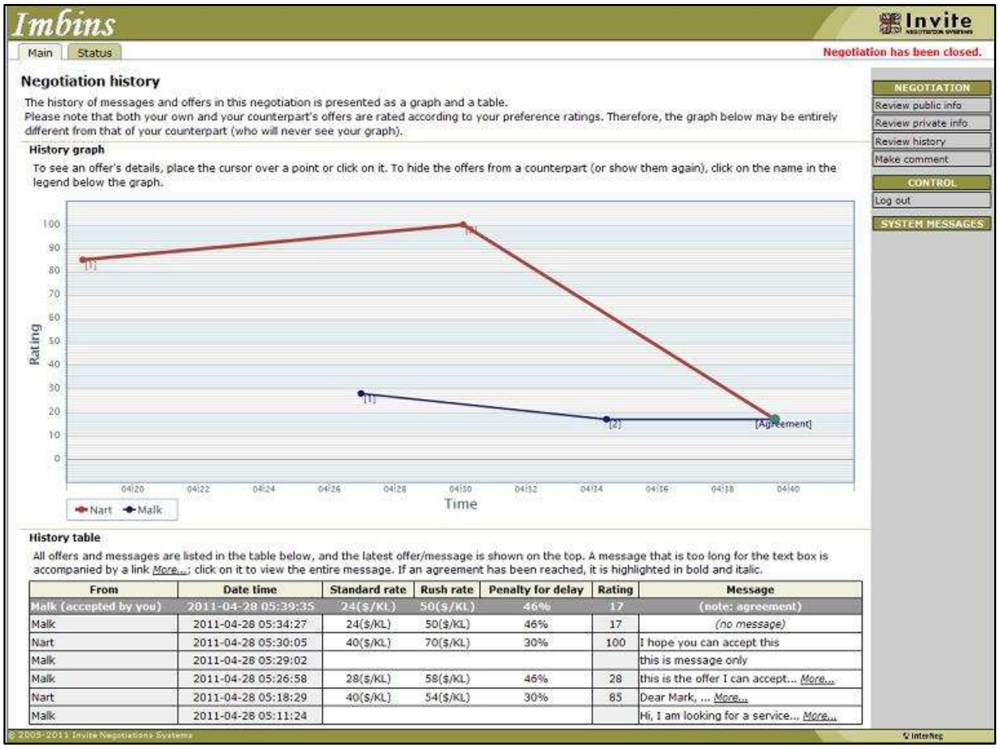
If you wish to reply to a single offer, select it and then click **Reply to offer**. To accept a single offer, select it and then click **Accept offer**.
Please note: If you accept an offer, you and your counterpart will reach an agreement on the contract and the negotiation will be closed (i.e. no more offers/messages to be exchanged).

Figure B-3. Screen of "Negotiation update" for the buyer

Negotiation history

During the negotiation, both the buyer and suppliers can review all the offers/messages that have been exchanged with the counterpart(s). The negotiation history web page shows the offers/messages in a table and a graph. If an agreement has been reached, it will be highlighted in the table and on the graph.

Figure B-4 and B-5 show the "Negotiation history" screens for the supplier and the buyer respectively. On the supplier's screen, she can view the offers/messages from the buyer and herself; on the buyer's screen, she can view the offers/messages that she exchanged with all the suppliers.



Negotiation history

The history of messages and offers in this negotiation is presented as a graph and a table.
Please note that both your own and your counterpart's offers are rated according to your preference ratings. Therefore, the graph below may be entirely different from that of your counterpart (who will never see your graph).

History graph

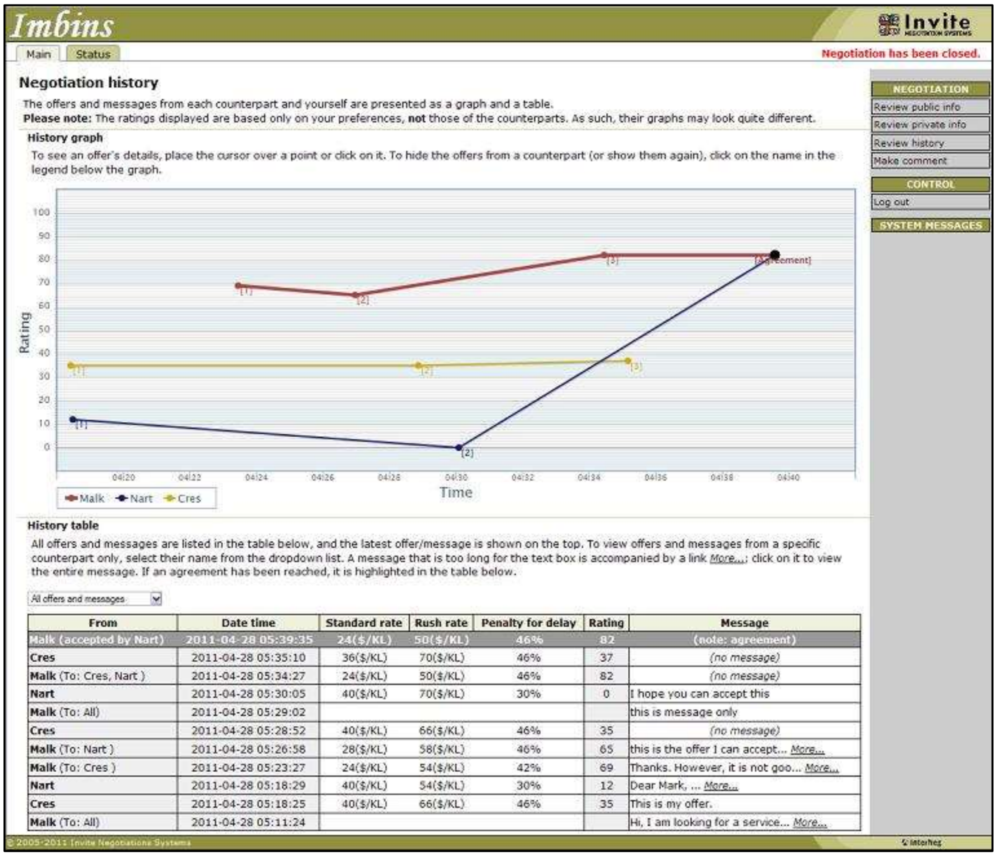
To see an offer's details, place the cursor over a point or click on it. To hide the offers from a counterpart (or show them again), click on the name in the legend below the graph.

History table

All offers and messages are listed in the table below, and the latest offer/message is shown on the top. A message that is too long for the text box is accompanied by a link More...; click on it to view the entire message. If an agreement has been reached, it is highlighted in bold and italic.

From	Date time	Standard rate	Rush rate	Penalty for delay	Rating	Message
Malk (accepted by you)	2011-04-28 05:39:35	24($/KL)	50($/KL)	46%	17	(note: agreement)
Malk	2011-04-28 05:34:27	24($/KL)	50($/KL)	46%	17	*(no message)*
Nart	2011-04-28 05:30:05	40($/KL)	70($/KL)	30%	100	I hope you can accept this
Malk	2011-04-28 05:29:02					this is message only
Malk	2011-04-28 05:26:58	28($/KL)	58($/KL)	46%	28	this is the offer I can accept... More...
Nart	2011-04-28 05:18:29	40($/KL)	54($/KL)	30%	85	Dear Mark, ... More...
Malk	2011-04-28 05:11:24					Hi, I am looking for a service... More...

Figure B-4. Screen of "Negotiation history" for the supplier



Negotiation history

The offers and messages from each counterpart and yourself are presented as a graph and a table.
Please note: The ratings displayed are based only on your preferences, **not** those of the counterparts. As such, their graphs may look quite different.

History graph

To see an offer's details, place the cursor over a point or click on it. To hide the offers from a counterpart (or show them again), click on the name in the legend below the graph.

History table

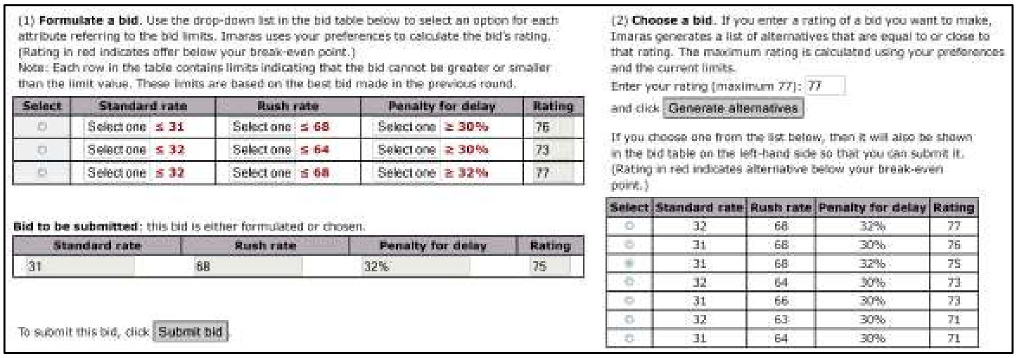
All offers and messages are listed in the table below, and the latest offer/message is shown on the top. To view offers and messages from a specific counterpart only, select their name from the dropdown list. A message that is too long for the text box is accompanied by a link More...; click on it to view the entire message. If an agreement has been reached, it is highlighted in the table below.

All offers and messages

From	Date time	Standard rate	Rush rate	Penalty for delay	Rating	Message
Malk (accepted by Nart)	2011-04-28 05:39:35	24($/KL)	50($/KL)	46%	82	(note: agreement)
Cres	2011-04-28 05:35:10	36($/KL)	70($/KL)	46%	37	*(no message)*
Malk (To: Cres, Nart)	2011-04-28 05:34:27	24($/KL)	50($/KL)	46%	82	*(no message)*
Nart	2011-04-28 05:30:05	40($/KL)	70($/KL)	30%	0	I hope you can accept this
Malk (To: All)	2011-04-28 05:29:02					this is message only
Cres	2011-04-28 05:28:52	40($/KL)	66($/KL)	46%	35	*(no message)*
Malk (To: Nart)	2011-04-28 05:26:58	28($/KL)	58($/KL)	46%	65	this is the offer I can accept... More...
Malk (To: Cres)	2011-04-28 05:23:27	24($/KL)	54($/KL)	42%	69	Thanks. However, it is not goo... More...
Nart	2011-04-28 05:18:29	40($/KL)	54($/KL)	30%	12	Dear Mark, ... More...
Cres	2011-04-28 05:18:25	40($/KL)	66($/KL)	46%	35	This is my offer.
Malk (To: All)	2011-04-28 05:11:24					Hi, I am looking for a service... More...

Figure B-5. Screen of "Negotiation history" for the buyer

Appendix C: Implementation of information rules in Imaras



(1) **Formulate a bid.** Use the drop-down list in the bid table below to select an option for each attribute referring to the bid limits. Imaras uses your preferences to calculate the bid's rating. (Rating in red indicates offer below your break-even point.)
Note: Each row in the table contains limits indicating that the bid cannot be greater or smaller than the limit value. These limits are based on the best bid made in the previous round.

Select	Standard rate	Rush rate	Penalty for delay	Rating
○	Select one ≤ 31	Select one ≤ 68	Select one ≥ 30%	76
○	Select one ≤ 32	Select one ≤ 64	Select one ≥ 30%	73
○	Select one ≤ 32	Select one ≤ 68	Select one ≥ 32%	77

Bid to be submitted: this bid is either formulated or chosen.

Standard rate	Rush rate	Penalty for delay	Rating
31	68	32%	75

To submit this bid, click Submit bid.

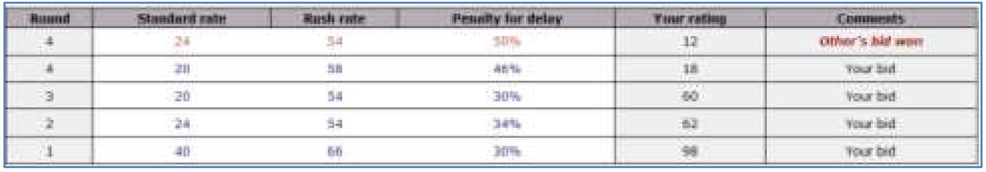
(2) **Choose a bid.** If you enter a rating of a bid you want to make, Imaras generates a list of alternatives that are equal to or close to that rating. The maximum rating is calculated using your preferences and the current limits.
Enter your rating (maximum 77): 77
and click Generate alternatives

If you choose one from the list below, then it will also be shown in the bid table on the left-hand side so that you can submit it. (Rating in red indicates alternative below your break-even point.)

Select	Standard rate	Rush rate	Penalty for delay	Rating
○	32	68	32%	77
○	31	68	30%	76
●	31	68	32%	75
○	32	64	30%	73
○	31	66	30%	73
○	32	63	30%	71
○	31	64	30%	71

Figure C-1. Supplier's view of admissible bidding sets (Type B)

Table C-1. Supplier's view (Rule B: revelation of own bids only)



Round	Standard rate	Rush rate	Penalty for delay	Your rating	Comments
4	24	54	50%	12	Other's bid won
4	20	58	46%	18	Your bid
3	20	54	30%	60	Your bid
2	24	54	34%	62	Your bid
1	40	66	30%	98	Your bid

Table C-2. Supplier's view (Rule BD$_{win}$: revelation of own bids and winning bids)

Round	Standard rate	Rush rate	Penalty for delay	Rating	Comments
9	20 ($/kl)	50 ($/kl)	50%	0	Your bid won
8	20 ($/kl)	52 ($/kl)	50%	5	Your bid
7	20 ($/kl)	54 ($/kl)	50%	15	Your bid
6	20 ($/kl)	56 ($/kl)	50%	18	Your bid
5	20 ($/kl)	52 ($/kl)	46%	11	Other's bid
5	20 ($/kl)	52 ($/kl)	36%	16	Your bid
4	22 ($/kl)	54 ($/kl)	39%	30	Other's bid
4	20 ($/kl)	62 ($/kl)	30%	45	Your bid
3	26 ($/kl)	60 ($/kl)	37%	47	Other's bid
3	26 ($/kl)	64 ($/kl)	30%	59	Your bid
2	31 ($/kl)	63 ($/kl)	32%	68	Your bid
2	30 ($/kl)	66 ($/kl)	36%	66	Other's bid
1	36 ($/kl)	70 ($/kl)	39%	85	Your bid

Table C-3. Supplier's view (Rule BD_{all}: revelation of all bids)

Round	Standard rate	Rush rate	Penalty for delay	Rating	Comments
8	20 ($/kl)	52 ($/kl)	48%	7	*Your bid won*
7	20 ($/kl)	59 ($/kl)	50%	9	Other's bid
6	20 ($/kl)	61 ($/kl)	48%	14	Other's bid
6	20 ($/kl)	61 ($/kl)	50%	11	Other's bid
5	20 ($/kl)	52 ($/kl)	43%	18	Other's bid
5	20 ($/kl)	56 ($/kl)	42%	23	Other's bid
4	20 ($/kl)	61 ($/kl)	32%	64	Other's bid
4	20 ($/kl)	68 ($/kl)	44%	31	Other's bid
3	20 ($/kl)	63 ($/kl)	30%	68	Your bid
3	20 ($/kl)	59 ($/kl)	20%	64	Other's bid
3	20 ($/kl)	63 ($/kl)	32%	66	Other's bid
2	20 ($/kl)	66 ($/kl)	30%	73	Your bid
1	24 ($/kl)	62 ($/kl)	30%	74	Your bid
1	32 ($/kl)	68 ($/kl)	34%	85	Other's bid
1	22 ($/kl)	66 ($/kl)	32%	76	Other's bid

Appendix D: Summary of profiles and preferences

Table D-1. Suppliers' representative and profile

Company	Representative	Profile	Attributes		
			Standard rate	Rush rate	Penalty for delay
Continental	Cres	High standard service; large enterprise customers; high rate; high reliability	High	High	Low
Universal	Nart	Large networks; low rate; average reliability	Low	Low	High
Worldwide	Peeka	High diversity service; small/medium business customers; low rush rate	High	Low	Medium
Global	Rito	High flexibility service; high responsiveness; low standard rate; high rush rate	Low	High	High
International	Swes	High customer satisfaction; high standard rate; average rush rate; high reliability	High	Medium	Low

Table D-2. Preferences of the buyer and suppliers

Attribute	Option	Milika	Continental	Universal	Worldwide	Global	International
		Malk	Cres	Nart	Peeka	Rito	Swes
Standard rate ($/kl)	20	45	0	0	0	0	0
	24	35	10	**7**	15	**4**	10
	28	**25**	15	10	20	8	15
	32	10	25	16	**35**	10	**20**
	36	5	**35**	21	45	12	30
	40	0	45	25	50	15	40
Rush rate ($/kl)	50	15	0	0	0	0	0
	54	**12**	15	5	**7**	15	6
	58	8	20	8	10	20	10
	62	6	30	**12**	13	30	15
	66	3	**35**	18	17	35	**25**
	70	0	40	20	20	**40**	35
Penalty for delay (%)	30	0	**15**	**55**	**30**	**45**	**25**
	34	8	12	50	22	40	20
	38	12	10	35	16	35	16
	42	22	8	15	11	10	10
	46	32	6	10	9	7	7
	50	**40**	0	0	0	0	0
Reservation		16	25	10	15	22	23
Aspiration		77	85	74	72	89	70

Note: the underlined numbers indicate the reservation level; the bolded numbers indicate aspiration level; the reservation point indicates the break-even point.

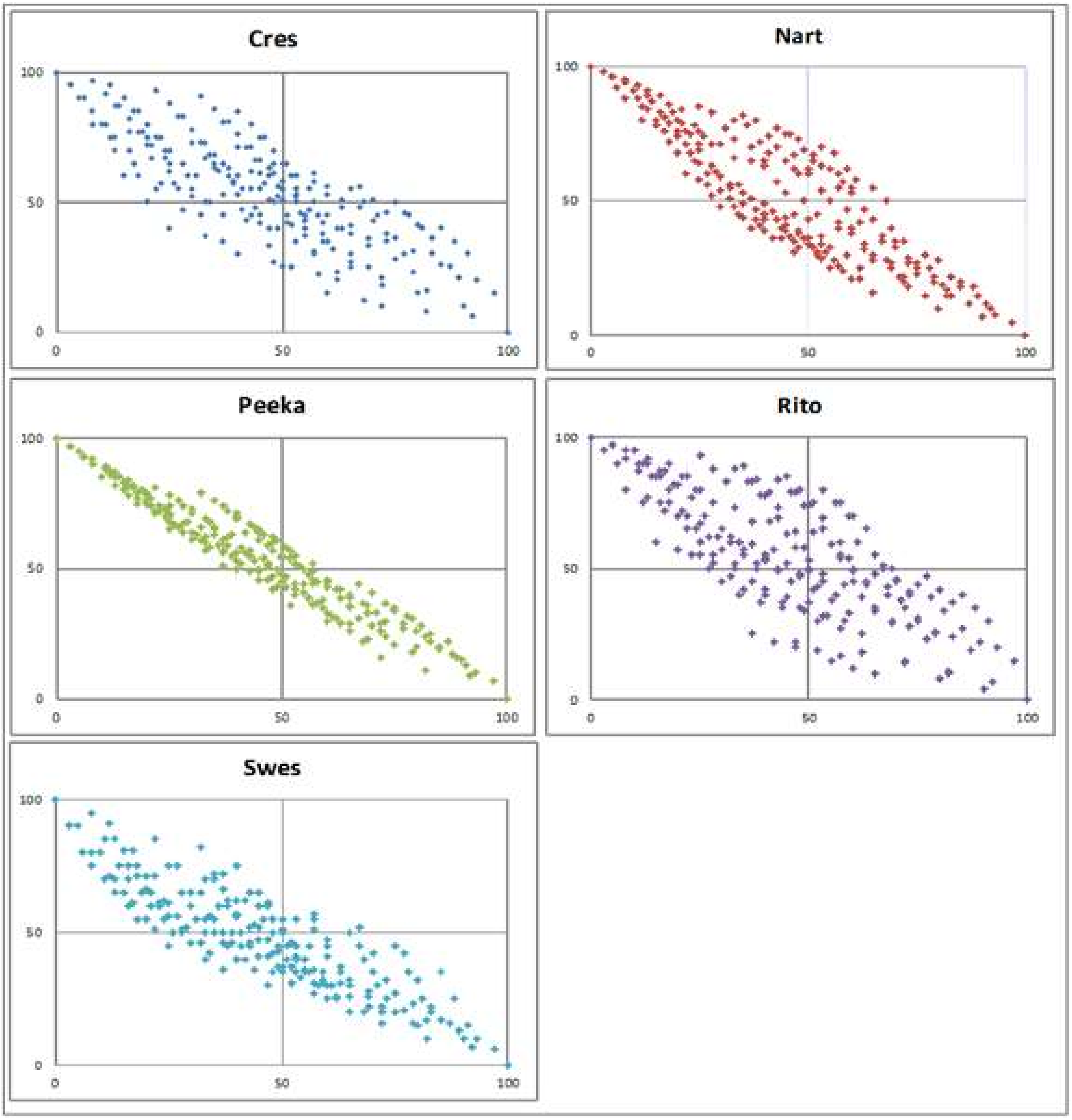


Figure D-1. Utility distribution of alternatives between the buyer and each supplier

Appendix E: Experimental procedure

Table E-1. Experimental procedure

	Activity	Description
1	Registration	Register online, sign consent form and answer questions with regard to demographics and relevant experiences; Choose session (date/time) for lab setting participation
2	Confirmation	Receive an automatic generated email confirmation of registration;
3	Reminder	Receive an email three days before the experiment; Lab setting: the email contains the system URL, log-in, session date/time and lab room number; Online setting: the email contains the system URL, log-in, starting date/time, and deadline
4	Match-up	Lab setting: Show up in lab 10 minutes before the session starting time, and then receive a seat number randomly from facilitator for match-up (assigned to auctions or negotiations); Online setting: Randomly matched up through the administration software
5	Instructions	Lab setting: Receive the printed instructions from facilitator; Online setting: Receive or download the instructions from the system website
6	Log-in	Log into the system with the assigned seat number
7	Case document	Read the case with both public and private information
8	Case quiz	Answer a quiz about the case
9	Pre-questionnaire	Answer questions before the auction or negotiation
10	Interaction	Auction: Bidding through Imaras after the bidding starting time; Negotiation: Negotiating through Imbins after the negotiation starting time
11	Conclusion	Reach an agreement or the deadline
12	Post-questionnaire	Answer post-questionnaire after the auction or negotiation
13	Feedback	Voluntarily write comments and provide feedback

Appendix F: Sample case quiz for one supplier (Continental Inc.)

Table F-1. Sample case quiz

1. Milika is ...	o a broker company. o a transportation company. o a milk producer.
2. Continental is ...	o an airline company. o a milk producer. o one of the logistics services providers to win the contract.
3. Cres is ...	o the sales manager for Continental. o the purchasing manager for Continental. o the purchasing manager for Milika.
4. Malk is...	o an independent agent for logistics service procurement. o the purchasing manager for Milika. o the sales manager for Milika.
5. The two issues to be negotiated in this contract are: standard rate and penalty for delay.	o True o False
6. Only one issue is important; other issues are not important at all.	o True o False
7. Milika has chosen an e-procurement system, thinking that it is a good way to select the most suitable provider and to assign the contract.	o True o False
8. The break-even point indicates that alternatives with a lower rating may cause losses.	o True o False
9. Regarding rating, which of the following statements is correct?	o The higher is the rating value the better is the alternative for the user (or the company represented). o Different companies may have different preferences or interests for the same issues and/or options. o Alternative with a rating of zero is the worst possible alternative. o All of the above.
10. The system provides a calculator that can be used to determine the ratings of offers you make and/or you receive.	o True o False

Appendix G: Questionnaires

Table G-1. Pre-questionnaire

	Items and scales	Relevant studies
Task complexity	Understanding of the case I just read was ... Based on the case description, I expect the contracting task to be ... (*7-point Liker scale, "Very difficult" to "Very easy")*	(Bellosta, Imene et al. 2004; Wang and Zionts 2005; Gattiker, Huang et al. 2007; Bellosta, Kornman et al. 2008; Kersten, Wu et al. 2011)
Aspirations levels	After reading the case, what agreement/contract do you think you will reach? (*list of values for each attribute*)	
Reservation levels	What is the worst offer that you think you may still accept? (*list of values for each attribute*)	

Table G-2. Final version of post-questionnaire

	Items	Questions and scales	Relevant studies
Assessment of process	AP1 AP2 AP3	It was easy to keep track of the process. The organization of process in phases and steps was useful. This process was stimulating. (*7-point Liker scale from "Strongly disagree" to "Strongly agree")*	(Curhan, Elfenbein et al. 2006; Wu and Yu 2009; Wang, Lim et al. 2010; Kersten, Wu et al. 2011)
Assessment of outcomes	AO1 AO2 AO3	I am satisfied with the results that I achieved. I am satisfied with the results as compared to my expectations. I think I obtained the best results for the company that I represent. (*7-point Liker scale from "Strongly disagree" to "Strongly agree"*)	(Suh 1999; Curhan, Elfenbein et al. 2006; Vetschera, Kersten et al. 2006; Wu and Yu 2009)
Assessment of system	AS1 AS2 AS3	The system was helpful in achieving my objectives. The system was helpful in improving my performance. The system was helpful in managing the process. (*7-point Liker scale from "Strongly disagree" to "Strongly agree"*)	(Davis 1989; Vetschera, Kersten et al. 2006; Wang, Lim et al. 2010; Kersten, Wu et al. 2011)

Table G-3. Changes of items in post-questionnaire after pilot study

	Items	Before changes	After changes
Assessment of process	AP2	The organization of the process was useful.	The organization of process in phases and steps was useful.
Assessment of outcomes	AO3	The outcome is better for Milika than it is for the provider.	I think I obtained the best results for the company that I represent.
Assessment of system	AS3	The system was helpful in managing the transaction.	The system was helpful in managing the process.

Appendix H: Measurement of process and outcomes

Table H-1. Variables and measurement of process

Variables	Measures and scales	Relevant studies
Number of bids	Individual level: The total number of bids submitted by each individual. Transaction level: The total number of bids submitted by all the participants in the same auction. (*Scale: integer number greater or equal to 0*)	(Bichler 2000; Koppius and Heck 2003; Strecker and Seifert 2004; Jap and Haruvy 2008)
Number of offers (with /without message)	Individual level: The total number of offers made by each individual. Transaction level: The total number of offers made by all the participants in the same negotiation. (*Scale: integer number greater or equal to 0*)	(Kersten and Noronha 1999; Lai, Doong et al. 2006; Vetschera, Kersten et al. 2006; Weber, Kersten et al. 2006)
Concessions	The value change between bids or offers made by the same party. The value is the revenue of the proposed contract with a rating scale of 0–100. The suppliers' total concession is the value change between their first bid/offer and their final bid/offer. This indicates how much value the suppliers have compromised through the transaction. (*Scale: integer number between 0 and 100*)	(Nastase 2006; Vetschera 2007; Johnson and Cooper 2009; Wachowicz and Wu 2010; Whitford, Bottom et al. 2011; Kersten, Vahidov et al. 2013)
Convergence speed	The amount of time to close the transaction with or without an agreement (i.e., actual interaction time) divided by the announced time length. It indicates how fast a transaction converged or reached a result. (*Scale: percentage between 0 and 100%)*	(Koppius, Kumar et al. 2000; Koppius and Heck 2003; Strecker and Seifert 2004)

Table H-2. Variables and measurement of outcomes

Variables	Descriptions and scales	Relevant studies
Buyer's profit	The difference between the buyer's revenue of the contract and her break-even point. (*Scale: integer number between -100 and 100*)	(Bichler 2000; Koppius and Heck 2003; Strecker and Seifert 2004; Chen-Ritzo, Harrison et al. 2005; Strecker 2010)
Supplier's profit	The difference between the winning supplier's revenue of the contract and her break-even point. (*integer number between -100 and 100*)	
Allocative efficiency	The deviation of the achieved contract from the Nash solution (i.e. alternative which maximizes the product value of the buyers' and winning supplier's profits). It is calculated with the Euclidean distance between the product value of an achieved contract and the Nash solution. It indicates the distance from the contract to the best possible deal in the utility space. The smaller the value, the more efficient the contract. (*Scale: real number between 0 and 100*)	(Koppius, Kumar et al. 2000; Koppius and Heck 2003; Strecker and Seifert 2004)
Pareto optimality	The number of alternatives that dominate the achieved contract to the Pareto frontier (i.e., number of solutions that are even better for both the buyer and supplier, comparing to the contract they reached). It indicates the possible decision space that the buyer and supplier may explore or improve to gain more value for both. The smaller the value, the higher efficient the contract and the smaller room for contract improvement. (*Scale: integer number between 0 and 3375*)	(Koppius, Kumar et al. 2000; Koppius and Heck 2003; Strecker and Seifert 2004)
Joint gains	The product of the buyer's profit and the winning supplier's profit based on the contract, which indicates the social welfare for both sides from the achieved contract. The larger the value, the greater the social welfare for both the buyer and supplier. (*Scale: integer number between -10000 and 10000*)	(Weingart, Bennett et al. 1993; Foroughi, Perkins et al. 1995; Gerke and Stiller 2006; Strecker 2010)
Outcome equity	The division of the winner's profit over the buyer's profit based on the contract, which indicates the contract balance between the two sides. The closer the value to one, the higher equity the contract. (*Scale: real number between -100 and 100*)	(Croson 1999; Foroughi, Perkins et al. 2001; Gerke and Stiller 2006; Whitford, Bottom et al. 2011)

Glossary

Alternative: A possible decision that may be selected in decision-making or proposed in negotiation. It comprises attribute values, such as price, color, weight, quantity, etc. An alternative that is proposed by a bidder/negotiator as a potential agreement is a bid or an offer.

Aspiration level: The maximum (or minimum) value of a single attribute that the bidder/negotiator intend to achieve or satisfactory with.

Attribute: A construct that is used to distinguish entities (e.g., objects, goods or individuals). It represents a characteristic or feature of an entity that is relevant for the decision maker. Attributes which are selected by the negotiators to agree on their values are also known as issues.

BATNA: Best Alternative to the Negotiated Agreement is a decision alternative, which the negotiator can achieve, if the negotiation in which she is engaged in fails. It is an alternative which is available, e.g., it has been offered by someone other than the person she negotiates with. The negotiator should not accept any agreement that is worse for her than BATNA.

Bid: A combination of options (a package or an alternative) that is submitted by one bidder. The bid may contain one option for each attribute under considerations or some attributes may not be present in the bid.

Concession: A decrease of value through a bid or an offer from the bidder/negotiator's perspective. In negotiation, an offer which, according to the negotiator who proposes it, should be considered better by her counterpart than the offer previously made by the negotiator. In multi-attribute auction/negotiation, the bidder/negotiator may think she made a concession when in fact she made a reverse concession.

Inefficient agreement: An agreement that is dominated by at least one other alternative, i.e., there is at least another alternative that is better for one party than the accepted agreement and not worse for any other party.

Issue: Attribute which is the subject of the negotiation and values (options) of which have to be agreed on by the participants. An option which is proposed is a partial offer, if one option for each issue is proposed, then we have a complete package (offer).

Offer: A combination of options (a package or an alternative) that is sent by one negotiator to the other. The offer may contain one option for each issue under considerations or some issues may not be present in the offer. In the latter case we have a partial offer which is typical for sequential negotiations.

Option: One of the values that an attribute or issue can take. For example, the attribute "Tolerable product failure rate" may have the options "3%", "5%" and "10%".

Package: Also called an alternative, the difference is that it includes only attribute or issue values. It is a particular bundle of options that has been selected across several or all the negotiated issues. If values for all issues are included, then it is a complete package; otherwise it is a partial package.

Rating: A simplified form of the preference representation used to compare alternatives (offers). Often rating values are scaled between 0 and 100 (or o and 10); the higher the rating is the better the offer.

Reservation level: The maximum (or minimum) value of a single attribute that the negotiator cannot violate for a specific reason.

Trade-off: It is an exchange process in which a decision maker gives up partly on some attributes or issues so as to gain on other attributes.

Utility function: It is a measurement that expresses the subjective value (worth) of different packages (alternatives) by using a numerical scale. The numerical scale used is often arbitrary, typically ranging either from 0 to 1 or from 1 to 100. The minimum number expresses the least desirable and least preferred package. The highest number represents the most desirable and thus, preferred package.