# Negotiation, Auctions, and Market Engineering ♦

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**Abstract**

Market engineering is the discipline of making markets work. It encompasses the use of legal frameworks, economic mechanisms, management science models, and information and communication technologies for the purposes of: (i) designing and constructing forums where goods and services can be bought and sold and (ii) providing services associated with buying and selling. Against this background, this paper sets out the need for a coherent and encompassing agenda in this area and highlights the key constituent building blocks.

Keywords: Markets, Auctions, Negotiations, Economic Engineering

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# 1. Introduction – Design Matters

In 1899, Leo Baekeland sold the rights to his invention, Velox photographic printing paper, to George Eastman. Velox was the first commercially successful photographic paper ever developed and the price Eastman paid was $1 million. Baekeland had planned to ask $50,000 and to go down to $25,000 if necessary, but – fortunately for him – Eastman spoke first and offered $1 million [1].

From an economic perspective, the main lesson of this short historical example is that the design of markets and negotiations matters. The rules of who discloses information at which time and how the market transforms bids to prices and allocations impact the behavior of market participants as well as the market result.

Eastman Kodak Company started manufacturing its newly purchased paper, but they discovered that they were not able to produce photographic paper. Baekeland told Eastman that he should expect troubles because he paid for patent but not for Baekeland's knowledge. Apparently, it was customary for the inventor to omit one or two important steps from the patent so that those who tried to use the patent without the consent of the inventor would fail. After receiving another $100,000 Baekeland gave the full details of how to produce the paper [2].

What this story indicates is that if one wants to guide behavior of market participants in order to achieve a desired outcome, e.g. an efficient allocation of resources, one has to carefully engineer the respective market. But one may also realize that in situations when there is one buyer and one seller or only a few of them, they may decide to ignore the market rules, or change them during the course of the transaction. A renegotiation of terms and interactions outside of the market is in such situations possible.

Speaking more generally, new markets emerge constantly and their conscious de-sign is important as markets don't always grow like weeds – some of them are hot-house orchids which have to be administered and cultivated; Time and place have to be established, related goods need to be assembled, or related markets linked so that complementarities can be handled, and incentive problems have to be overcome [3]. In this context, where oftentimes the point is not to understand the world but to change it, economics looks like engineering. Just as a civil engineer applies principles of physics and mechanics to design bridges, economists apply principles of economic analysis to design exchange mechanisms [4].

In this vein, the FCC spectrum auctions in the US [5], the job market for graduates in medicine [6], the electric power market in California [7], and the spectrum license auctions in Europe [8] teach us several important lessons. These markets and/or their participants rely on the information and communication technologies (ICTs) which allows for the participation, the number and complexity of exchange mechanisms, and the types, complexity and speed of transactions, which in the old physical markets were not feasible. These markets are engineered because, among others, they are technological solutions rather than places where people traditionally met and con-ducted business.

The current approach to market engineering foremost requires the recognition that different types of exchange mechanisms may operate on markets. A market engineer may differently configure the mechanisms and adjust them to the requirements of the market participants and types of products or services. The main types of mechanisms are catalogues, auctions and negotiations (bargaining). Catalogues (posted prices) are relatively simple mechanisms whose roles in markets and whose design and implementation have been well studied. Given this, we concentrate here on auction and negotiation mechanisms for two primary reasons:

1. Auctions, in addition to catalogues, are the most widely implemented and discussed mechanisms but only recently the complex, multidimensional and combinatorial auctions have gained interest of researcher and foremost practitioners; and

2. Negotiations have been somewhat neglected market mechanisms; the proliferation and acceptance of web and internet technologies made the replacement of some negotiated transactions with auctions not only possible but it also led to new efficiencies. Negotiation-based mechanisms however, remain the preferred choice when the good and service attributes are ill defined and there are criteria other than price (e.g., reputation, trust, relation and future contracts).

The recognition that auctions, negotiations and other (including hybrid) mechanisms may operate and compete on markets is one requirement for an open, inclusive perspective on market engineering. The requirement for inclusiveness is the result of markets serving widely differing customers who expect not only a neutral market-place but also services associated with market activities, including, price comparison, matchmaking, fulfillment support and automated notification.

Against this background, we propose that:

**Market engineering** is defined as the use of legal frameworks, economic mechanisms, management science models, and information and communication technologies for the purpose of: (1) designing and constructing places where goods and services can be bought and sold; and (2) providing services associated with buying and selling.

In order to engineer markets that function effectively and efficiently and can serve participants coming from different constituencies and representing different interests, the process has to be informed. In particular, market engineering needs to be the process that has:

- An integrated, holistic view of markets comprising the microstructure, the business structure, the ICT infrastructure, the design of the trading object, and the regulatory framework.

- The use of multiple methodologies including theoretical modeling (e.g. microeconomics, game theory, computer science, industrial organization theory, value chain theory, simulations), empiricism (e.g. lab experiments, field experiments, analysis of field data), and constructive approaches (creation of innovative artifacts like e.g. software prototypes).

• An interdisciplinary approach to cope with the complexity of the integrated, holistic view and to provide the multiplicity of methodologies. Especially relevant are economics, business administration, information systems, computer science, law, sociology, and psychology.

• The understanding that details matter. There are no standard market designs which can easily be copied from one application to another – a market mechanism, negotiation protocol, or system has to be engineered with attention to details and rigorous consideration of the specific requirements and surrounding conditions.

Besides the examples for market engineering mentioned above, another area of re-cent development that clearly underscores the necessity of conscious engineering of negotiations and markets is the increasing presence and relevance of electronic commerce. While in traditional physical markets the rules might evolve over time, electronic markets make the conscious and structured design of the rules of interaction indispensable, as software engineers have to implement them in computer systems. This implementation does not allow spontaneous changes. A predominant domain where economic engineering has been applied in the last decade is the design of markets, auctions, and negotiations [3, 4, 9, 10, 11, 12].

The remainder of the paper is structured as follows: Section 2 broadly reviews different disciplines involved in engineering negotiations and markets and clarifies some terminology. Sections 3 and 4 then present a framework and a process model for negotiation and market engineering. These concepts are meant to structure the engineering process and to help researchers and practitioners with different backgrounds to gain a common understanding of negotiations and markets. Section 5 outlines the papers presented in this book and Section 6 concludes.

## 2. Interdisciplinary Research

Negotiations and markets have been studied in various disciplines and, not surprisingly, many renowned researchers have worked on understanding their origin and working: In neoclassical economic theory, for example, a market is a frictionless place of exchange. The market equates supply and demand and thereby takes care of the allocation problem, if permitted to do so. In new institutional economics, it is a mechanism whose usage creates transaction costs. In computer science, markets are coordination devices for decentralized systems. In information systems, markets are inter-organizational information systems. In jurisprudence it is a bundle of contracts and a topic for regulation. Other disciplines concerned with negotiations and markets are psychology, sociology, political sciences, and applied mathematics.

The various involved disciplines and fields of study have created different terminologies, definitions, notations, concepts, and formulations. Consequently, interdisciplinary cooperation among concerned researchers suffers from inconsistencies and contradictions [13].

There is, however, no possibility to build such complex systems as markets relying on a single discipline. Markets require an interdisciplinary approach because of their psychological, social, and cultural character; economic, legal, and political aspects; quantitative and qualitative considerations; and strategic, tactical, and managerial perspectives. Interdisciplinary approaches thereby provide richer and more comprehensive models. By way of illustration, Figure 1 lists the disciplines required in the design of negotiation, just one type of market mechanism. Here, the four arrows depicted in the figure connect areas of studies with results. The bidirectional arrow indicates that tools, agents, and platforms often base on the results of the studies in economic and social sciences, and also that, increasingly, computational models and systems influence the construction of strategies, tactics, and techniques for negotiations and markets [14]. The same and other disciplines need to be included in the design of auction mechanisms and by extension of markets.

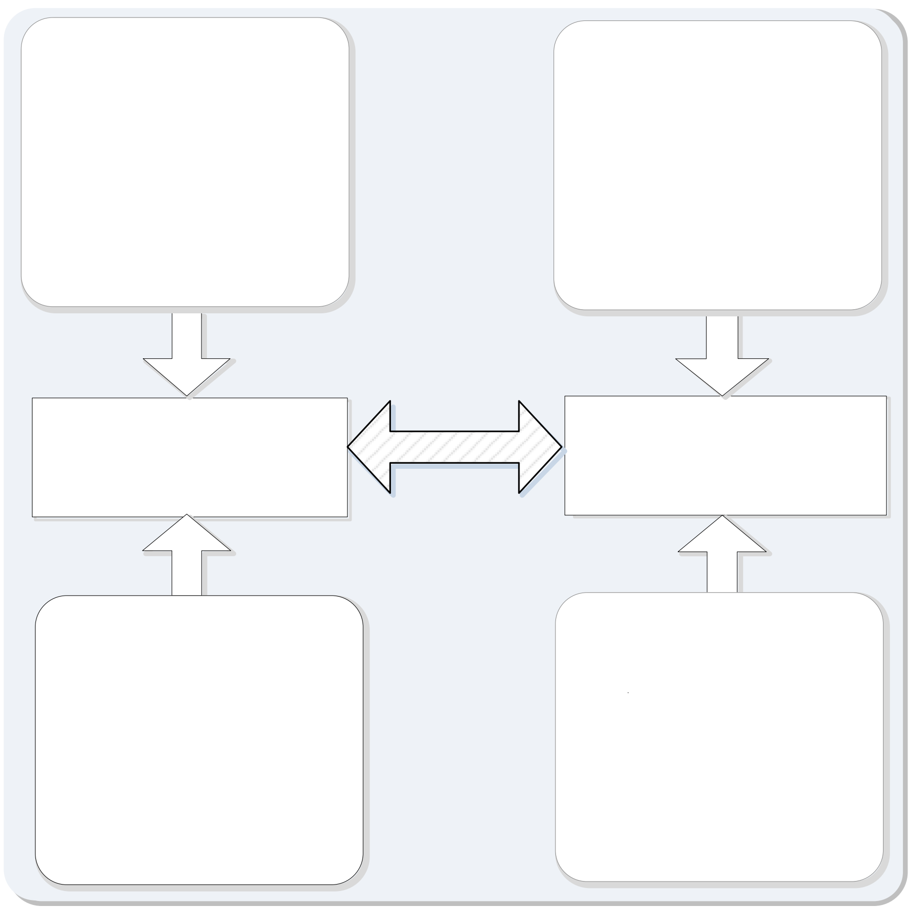

Fig. 1. Negotiation research areas, their results and key influences [cf. 0].

To lessen inconsistencies and contradictions from interdisciplinary work on negotiations, auctions and markets, a few terms need to be clarified for the following discussion. The three definitions proposed here are formulated having the market engineering process in mind; they build on and expand the market engineering definition formulated in Section 1:

**Market**. A market is a set of humanly devised rules that structure the interaction and exchange of information by self-interested participants in order to carry out exchange transactions at a relatively low cost. As such, markets are constrained by a socio-cultural and legal framework and can be seen as:

- the equation of demand and supply,
- sets of constraints which have to be established and compete for survival,
- information processing systems,
- entrepreneurial activities, and
- services.

**Auctions.** Auctions are market mechanisms with an explicit set of rules determining resource allocation and prices based on bids from the market participants [0]. Auctions are markets and they are a special subset of negotiations as they satisfy the above description of non-individual decision-making processes. Arguments are rare in auctions, but agents resolve a dispute on the allocation of resources by communicating via offers.

The difference between auctions and negotiations is not always clear cut; see e.g. [0]. Oftentimes, negotiations are seen as cooperative process whereas auctions are competitive; negotiations involve multiple issues to be resolved whereas auctions are single issue; negotiations are bilateral and auctions are multi-lateral; negotiations allow for logrolling and auctions have bid improvement rules. However, these distinctions do not capture the key difference of auctions and negotiations as the emergence of electronic negotiations and auctions as well as sophisticated multi-attribute and combinatorial auction formats blur the difference.

The only characteristic that differentiates auctions from negotiations lies in the specification of the protocol to be followed: Auctions may be seen as negotiations with a well specified and enforceable protocol. The three main elements of the protocol that differentiate auctions from negotiations are the termination, the decision on the final contract and the communication.

In an auction the termination may be done solely by the auction owner who follows an earlier established rule while in negotiation any party may “walk away from the table” at any time. The auctioneer (either human or automated) follows a predefined algorithm to compute the final contract only from the offers made. In contrast, in other negotiations, the negotiating parties themselves have the discretion to decide on the acceptability of an offer. This decision is not limited to any predefined algorithm and it is not limited to solely considering the offers.

Concerning the communication, auction participants use 1-, 2- or k-tuples which are well defined (e.g., price, volume, quality) and each element of the tuple is a single value. Furthermore, each participant has to use the same k-tuple. In contrast, negotiation participants may use open communication (free text) with an undefined number of tuples, elements in a tuple might be sets, and the dimensionality of tuples can vary between participants.

**Market Engineering**. Building on the market engineering definition and the broad descriptions of markets and its key mechanisms we describe market engineering as the process of consciously setting up or re-structuring market mechanisms and market infrastructure in order to make it an effective and efficient means for carrying out negotiations and exchange transactions. Engineering markets includes the conscious, structured, systematic, and theoretically founded procedure of analyzing, designing and introducing institutions and systems for negotiations, auctions, and markets.

In the natural sciences, engineering "is the profession in which a knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind." [0]. The "benefit of the mankind" defines the purpose of engineering which often is formulated in terms of finding solutions to practical problems and satisfying customer requirements [0]. The same holds in economic engineering.

Thus the key objectives of market engineering are:

- to analyze and design media, systems, procedures, models, and mechanisms for negotiations and markets,
- to identify areas of application in which negotiation- and market-based coordination is an effective and efficient means of coordination, and
- to develop methods, procedures, tools, and knowledge for the engineering of negotiations and markets as well as the identification of areas of application for negotiation- and market-based coordination.

## 3. An Engineering Framework

Figure 2 shows a framework for negotiation, auction, and market engineering. This is a static view on pivotal elements of negotiations and markets, which an economic engineer should bear in mind. The presentation draws on the micro-economic system framework [0], the market engineering framework [0], and classifications of (automated) negotiations [0].

The objective of an engineer is to achieve a desired outcome or performance, e.g. allocative efficiency. To do so, he can design the transaction object as well as the market structure and auxiliary services. The market structure comprises the microstructure, the (IT) infrastructure, and the business structure. The microstructure defines, for example, the bidding language of an auction and the pricing rule; the infrastructure comprises systems and communication media; and the business structure deals, for example, with the fees associated with trading.

Unfortunately the three different elements in the structure cannot be designed independently. Internet auctions run by eBay.com are a good example: For these proxy auctions, eBay uses fixed end times. Many participants respond to this element of the microstructure by sniping, i.e. bidding in the last minutes or seconds of an auction [0]. This cluster of bids in the last seconds of an auction imposes requirements on the IT infrastructure employed. The database must be able to handle the load while decentralized processing of requests and caching are impractical as they would tamper the participants' information and tie-breaking. To alleviate this, the platform operator could change the business structure and introduce variable bidding fees, which increase towards the end of the auction. Or he could change the ending rule to an automatic extension if a bidder submits a bid very late. Anyhow, the example shows that the different elements of the structure are interrelated and, thus, market engineers have to design them collectively.

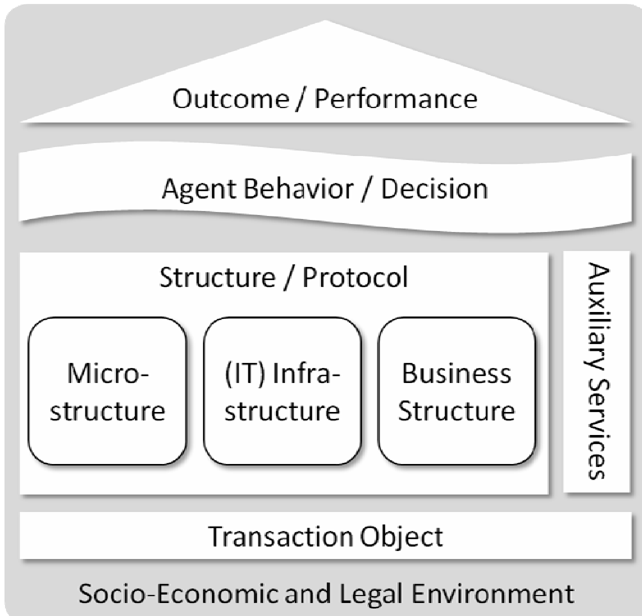


Fig. 2. Negotiation and market engineering framework.

Auxiliary services are services that are not core to the market or negotiation process but rather support participants. Decision support systems (DSS), reputation systems, and clearing and settlement of transactions are examples for such services.

The transaction object, the structure, and the auxiliary services have only indirect effect on the outcome and performance. The link lies in the behavior of agents participating in the market. It is the behavior of participants, which makes the engineering a major challenge as there are no direct cause-effect relationships between structure and performance. In an abstract setting like a game-theoretic model with hyper-rational, utility-optimizing players, there might be direct cause-effect relationships. However, in the real world, where market participants are boundedly rational and prone to cognitive biases, the relation of structure and outcome is not straight forward. Market engineers can employ a variety of methodologies to assess the impact of a specific structure on the participants' behavior and thus the outcome. These methodologies include theoretical modeling (e.g. game theory, auction theory, mechanism design), empirical research (e.g. lab and field experiments, expert interview) and constructive approaches (e.g. prototyping).

The socio-economic and legal environment comprises elements, which the engineer cannot directly influence. Examples are the participants' cultural background and norms, their preferences, and the applicable laws.

# 4. The Engineering Process

There are two main origins of negotiations and market institutions as a rational order: conscious design and undirected evolution [0]. Already in the seventeenth century, the French philosopher and mathematician René Descartes "contended that all the useful human institutions were and ought to be deliberate creation(s) of conscious reason [...] a capacity of the mind to arrive at the truth by a deductive process from a few obvious and undoubtable premises" [0]. Accordingly, conscious design determines many market structures. On the other hand, un-designed, evolutionary processes determine negotiation and market structures. Constructivism is far too limited in its ability to comprehend and apply all the relevant facts to serve the process of selection, which is better left to ecological processes. Different market places and structures compete with each other and the fittest markets survive. Deliberate construction and spontaneous evolution both affect negotiations and markets. Evolutionary approaches work in the long run; however, a market operator who wants to set up a single market place should consciously engineer the market.

While the above engineering framework is a static view on markets, the following process structures the procedure of engineering a market institution. Figure 3 below displays this based on Figure 1 of [0]. Besides the phases of the market engineering process, the figure exemplifies some methods and tools commonly employed in the different phases.

The engineering process starts with an environmental analysis. Important sub-phases are the design of the transaction object, the identification of potential participants, i.e. customers of the market service, and the analysis of requirements. The design phase deals with the elements of the negotiation and market engineering framework, i.e. the microstructure, the (IT) infrastructure, the business structure, the transactions object, and auxiliary services. The evaluation phase assesses the participants' behavior by theoretical modeling and/ or empirical studies. Furthermore, the evaluation phase might be used to test the infrastructure. Following are implementation and introduction of the designed institution or system. The enumeration of methods and tools in Figure 3 is not meant to be exhaustive, but rather is meant to give a better understanding of an engineer's work in the different phases.

The process model resembles a waterfall model from e.g. software engineering. The arrows indicate a basically sequential process. However, obviously iterations are sometimes useful and necessary and the model allows for such iterations. The most obvious one – from evaluation to design in case the evaluation shows that the (preliminary) design does not (yet) fulfill the requirements – is sketched in the figure. The less frequent ones are omitted here for clarity. See [0, 0, 0] for more detailed discussions of the market engineering process and [0] for an example of applying the process.

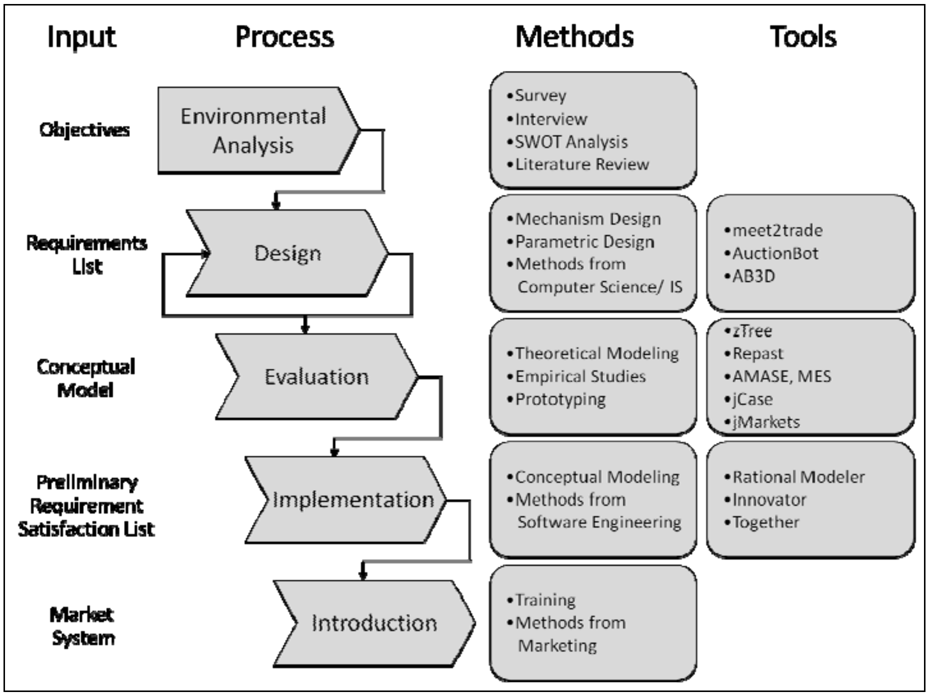


Fig. 3. Negotiation and market engineering process, methods, and tools [cf. 0].

## 5. Outline of the Book

This book contains 16 further chapters on negotiation, auctions, and market engineering. Figure 4 shows their relation to the aforementioned framework and each chapter can be read individually.

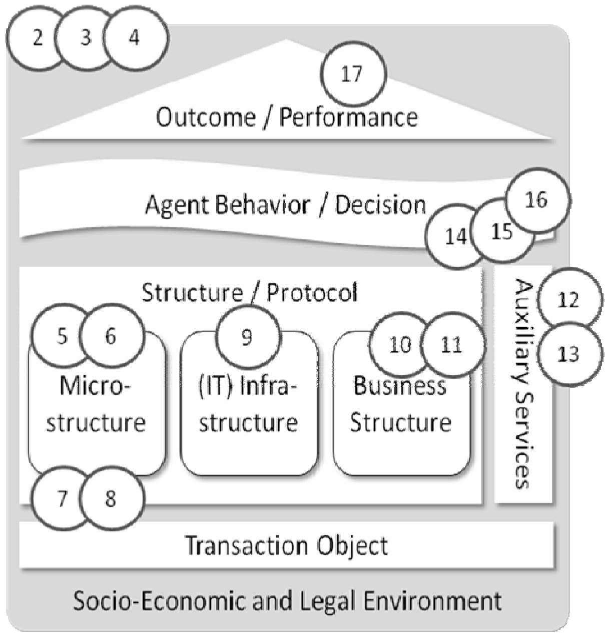


Fig. 4. Chapters of the book in relation to the negotiation and market engineering framework. The numbers in circles correspond to the chapter numbers.

**General Support for Negotiation, Auction, and Market Engineers.** Kersten, Chen et al. present the *Times* model for e-markets, a conceptual framework that integrates the perspectives of behavioral economics and information systems research [0, Ch. 2]. The model puts special emphasis on the interaction of the microstructure and the IT infrastructure of computerized auctions and negotiations. It aims at guiding the design of electronic markets.

Block and Neumann describe a knowledge based system that they designed to help procurement staff in large corporations in choosing the best mechanism for a particular e-procurement scenario [0, Ch. 3]. Their system supports market designers by firstly analyzing procurement mechanisms and their impact on market performance (e.g., revenue, efficiency, immediacy, fairness) and, secondly, providing recommendations for procurement mechanisms dependent on sourcing objectives, supply situation, product characteristics, and market conditions.

Eichstädt compares different auction formats for procurement [0, Ch. 4]. The comparison bases on expert interviews among German corporations and focuses on multi-attribute and combinatorial auctions. According to the interviewees, internal resistance from buyers to the use of auctions and the suppliers' concern for fairness and honesty are major barriers for the use of online reverse auctions. Nevertheless, in large companies auctions are a relevant tool for B2B procurement.

**Microstructure.** Kittsteiner and Ockenfels discuss the design of online multi-unit auctions [0, Ch. 5]. They first analyze eBay's single-unit auction format and the simple extensions eBay made to have a multi-unit auction. They then present ideas on an improved design for online multi-unit auctions, which deals with difficulties such as market power and computational complexities as well as the conflict between simplicity of auction rules and their efficiency.

Byde investigates the efficiency of two different sequential auction mechanisms for allocating computing resources between users in a shared data-center [0, Ch. 6]. He uses simulations – specifically genetic algorithms – to select near-optimal bidding strategies from broad classes of strategies for both auction formats. Given the result of these genetic algorithms, the efficiency of the different auction mechanisms can be determined. It turns out that an inappropriate mechanism can be worse than simply sharing the resources equally; an appropriate mechanism however can consistently do better for the community as a whole.

Schnizler propose a list of requirements for a market mechanism for Grid computing, i.e. a technology for providing access to distributed computational capabilities such as processors or storage space [0, Ch. 7]. He then presents a multi-attribute combinatorial exchange for allocating and scheduling computer resources, which have multiple quality attributes and time constraints. Schnizler approaches the characteristics of the exchange via simulations.

Neumann presents another market mechanism for service-oriented Grids [0, Ch. 8]. His discussion shows the details of the design process and methods used. One requirement of his video-surveillance scenario is immediacy of allocation of resources. This renders the combinatorial exchange presented in the previous chapter inappropriate for this scenario. Instead, an alternative market mechanism is proposed. Schnizler and Neumann both deal with defining the transaction object prior to designing a suitable market mechanism.

**IT Infrastructure.** Kersten, Kowalczyk et al. consider the interplay of people and software agents in e-markets [0, Ch. 9]. They propose the *Shaman* framework, a software environment in which they use a decision support system to coordinate different e-market systems. Shaman provides the infrastructure for helping people who engage in virtual meeting places in coordinating their activities and software agents.

**Business Structure.** Burghardt explores the design of transaction fees in electronic financial markets [0, Ch. 10]. Transaction fees are a pivotal element of the business structure of market places as they make the entrepreneurial activity of operating the market worthwhile. Burghardt discusses different non-linear pricing schedules for transaction services and design parameters. A field experiment within a prediction market for the 2006 soccer world championship allows investigating the traders' sensitivity to different price schedules.

Gerding, Rogers et al. look into competition between sellers offering similar items in concurrent online auctions [0, Ch. 11]. In their setting, each seller must set its individual auction parameters (such as the reserve price) in such a way as to attract buyers. Game theoretic analysis and evolutionary simulations show that proper auction fees by the platform operator can deter shill bidding and increase efficiency.

**Auxiliary Services.** Haller pictures a reputation system for virtual organizations, which can be offered by market platform operators as an auxiliary service to reduce the uncertainty of traders and facilitate trading [0, Ch. 12]. In this system, trust bases not solely on (subjective) feedback from prior transactions – as it is in many online markets – but rather it derives from objective and observable trust indicators. A taxonomy of such indicators and a stochastic model for their aggregation are then presented.

Vahidov demonstrates how a situated decision support system can help in managing multiple on-going negotiations [0, Ch. 13]. Without such a system, the effort required from human negotiators in handling on-going interactions could offset the potential benefits of discovering the value in integrative negotiations. Vahidov illustrates the feasibility of the approach through simulations; the results show that the system could lead to superior outcomes compared to fixed price mechanisms.

**Agent Behavior.** Dash, Gerding, and Jennings consider procedures for bidders participating in multiple simultaneous second-price auctions [0, Ch. 14]. In such a setting, agents have to decide in which auction(s) to bid and how to coordinate bids as there is the risk of unintentionally winning multiple auctions. The authors present a game theoretic model and derive utility-maximizing strategies for bidding. They show that budget constraints limit the number of auctions that bidders participate in.

Fatima reflects on agent behavior in multi-object auctions in which each object has both common and private value components and bidders are uncertain about these values [0, Ch. 15]. She analyzes sequential and simultaneous auctions with English auction rules, first-price sealed bid rules, and second-price sealed bid rules. For these settings, she determines equilibrium bidding strategies of bidders with unit demand and characterizes the auctions' outcomes in terms of revenue, efficiency, and the winner's profit.

Gimpel proposes a process model for negotiations that combines process models from information systems research with decision making-models from psychology [0, Ch. 16]. This allows identifying elements of the process in which human negotiators are prone to systematic decision errors, i.e. systematic deviations of actual behavior from prescriptive decision-making models like utility maximization. Such cognitive biases like the fixed pie illusion, framing, overconfidence, or the attachment effect are common in negotiations and understanding this actual agent behavior is important for assessing the impact of negotiation or auction rules on market performance.

**Outcome and Performance.** Luckner, Schröder, and Slamka report the results of a field experiment on the forecast accuracy of prediction markets [0, Ch. 17]. They conducted the experiment during the FIFA World Cup 2006 and subjects traded virtual stocks contingent on, for example, the outcome of single matches, the world championship in general. The data show that the prediction market outperforms other means of predicting future events based on historic data. This highlights the importance of markets outside the traditional domain of satisfying the need for exchange transactions and gives insights in the interplay of a market's structure and its performance.

# 6. Conclusions

Engineering negotiations, auctions, and markets is a challenging task as it requires an integrated, holistic view of the problem, the use of multiple methodologies, an interdisciplinary approach, and attention to the details. Nevertheless, in academia and practice, there are numerous examples for well engineered markets; examples are the FCC spectrum auctions in the US, the US job market for graduates in medicine, and some spectrum license auctions in Europe (e.g. in UK).

Against this background, in this paper we have presented an initial framework for structuring the analysis and engineering of markets and discussed terminology. This sets the base for the remainder of this book, in particular, and for the discipline of market engineering in general.

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