Market Engineering:
An Interdisciplinary Research Challenge

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Abstract

Market engineering is making markets work. Markets are information processing and information producing information systems which mediate allocation of resources within or between organizations. Setting up and operating a market in a way that it works effectively and efficiently is an art and a science. This paper outlines challenges in this interdisciplinary field of research and presents frameworks for assessing markets.

Keywords: Markets, Auctions, Negotiations, Economic Engineering, Market Engineering

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1 Introduction – Market 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 George Eastman payed 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 (Asimov, 1982). From an economic perspective, the main lesson of this short historical example is that market design matters. The rules of who discloses information at which time, how these bids are transformed to prices and allocations etc. impact the behavior of market participants as well as the market result. Thus, if one wants to guide behavior of market participants in order to achieve an desired outcome, e.g. an efficient allocation of resources, one has to carefully engineer the respective market.

New markets emerge constantly and their conscious design 'is important because markets don't always grow like weeds—some of them are hothouse 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, incentive problems have to be overcome, etc.' (Roth, 2002). In this context, where oftentimes the point is not to understand the world but to change it, 'economics looks more like engineering than it does pure science. Just as a civil engineer applies principles of physics and mechanics to design bridges, economists apply principles of economic analysis to design exchange mechanisms' (Varian, 2002).

The engineering of the FCC spectrum auctions in the US (e.g. McAfee and McMillan (1996)), the job market for graduates in medicine (Roth and Pearson, 1999), the electric power market in California (Wilson, 2002), and the spectrum license auctions in Europe (Klemperer, 2002) all teach several important lessons. Market engineering requires ...

1. ... an *integrated, holisitic view* on markets comprising the microstructure, the business structure, the IT infrastructure (if existent), the design of the trading object, the regulatory framework etc.

2. ... a *multiplicity of methodologies* including theoretical modeling (microeconomics, game theory, industrial organization theory, value chain theory, Monte Carlo and agent-based simulations etc.), empiricism (lab experiments, field experiments, analysis of field data etc.), and constructive approaches (creation of innovative artifacts like e.g. software prototypes).

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

4. ... the understanding that *details matter*. There are no standard market designs which can easily be copied from one application to another—a market mechanism 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 recent development that clearly underscores the necessity of conscious engineering of markets is the increasing presence and relevance of electronic markets. 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 they have to be implemented in computer systems and do not allow spontaneous changes. A predominant domain where economic engineering has been applied in the last decade is market design (Roth, 2002; Varian, 2002); Weinhardt, Holtmann, and Neumann (2003) coined the term *market engineering*.[1]

2 The origin of Institutions and Markets

Markets have been studied in various disciplines and, not surprisingly, many renowned researchers have worked on understanding the origin and working of markets: In neoclassical economic theory, a market is a frictionless place of exchange. It is made up of supply and demand. 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 mechanisms which usage creates transaction costs. In information systems, markets are inter-organizational information system. In jurisprudence it is a bundle of contracts and topic for regulation. The outcome of a market are allocations and information.

Friedrich August von Hayek.[2] In order to equate supply and demand, as neoclassic economic theory postulates, the market has to have information on its participants' preferences. If so, the allocation of goods and services is a relatively easy optimization problem—von Hayek (1945, pp. 519-520) puts it as follows: 'If we possess all the relevant information, if we can start out from a given system of preferences, and if we command complete knowledge of available means, the problem which remains is purely one of logic. This, however, is emphatically *not* the economic problem which society faces. And the economic calculus which we have developed to solve this logical problem, though an important step toward the solution of the economic problem of society, does not yet provide an answer to it. The reason for this is that the "data" from which the economic calculus starts are never for the whole society "given" to a single mind which could work out the implications and can never be so given.

[1] See also Neumann (2004) for a more extensive discussion.

[2] In 1974, Friedrich August von Hayek received the Nobel Prize in Economics for his pioneering work in the theory of money and economic fluctuations and for his penetrating analysis of the interdependence of economic, social, and institutional phenomena.

The peculiar character of the problem of a rational economic order is determined precisely by the fact that the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess. The economic problem of society is thus not merely a problem of how to allocate "given" resources—if "given" is taken to mean given to a single mind which deliberately solves the problem set by these "data." It is rather a problem of how to secure the best use of resources known to any of the members of society, for ends whose relative importance only these individuals know. Or, to put it briefly, it is a problem of the utilization of knowledge which is not given to anyone in its totality.' Thus, according to von Hayek, markets are no mechanical optimization device but a mechanism to exchange and process information of individual market participants in order to facilitate exchange transactions.

Ronald H. Coase.[3] As this information processing is not costless, Coase (1937, 1960, 1988) discussed the role of so called transaction costs for the existence of markets. The main sources of costs related to transactions are search and information costs, bargaining and decision costs, and policing and enforcement costs. In Coase's view, markets 'are institutions that exist to facilitate exchange, that is, they exist in order to reduce the cost of carrying out exchange transactions. In an economic theory which assumes that transaction costs are nonexistent, markets have no function to perform, and it seems perfectly reasonable to develop the theory of exchange by an elaborate analysis of individuals exchanging nuts for apples on the edge of the forest or some similar fanciful example. This analysis certainly shows why there is a gain from trade, but it fails to deal with the factors which determine how much trade there is or what goods are traded. And when economists do speak of market structure, it has nothing to do with the market as an institution but refers to such things as the number of firms, product differentiation, and the like, the influence of the social institutions which facilitate exchange being completely ignored.' (Coase, 1988, pp. 7-8).

George J. Stigler.[4] This view is corroborated by Stigler, who stressed that the 'world of zero transaction costs turns out to be as strange as the physical world with zero friction. Monopolies would be compensated to act like competitors, and insurance companies and banks would not exist' (Stigler, 1972, p. 12).

[3] In 1991, Ronald H. Coase received the Nobel Prize in Economics for his discovery and clarification of the significance of transaction costs and property rights for the institutional structure and functioning of the economy.

[4] In 1982, George J. Stigler received the Nobel Prize in Economics for his seminal studies of industrial structures, functioning of markets, and causes and effects of public regulation.

Douglass C. North.[5] According to Coase and Stigler, a market is more than supply and demand and transaction costs have to be taken into account: A market is an institution and its working and performance are determined by the market structure, i.e. the rules of interaction. According to North (1991, p. 97), 'Institutions are the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights).' Even if North (1991) does not discuss the market structure in Coase's (1988) view, his perspective on institutions helps understanding what a market institution is. A market is a set of humanly devised constraints that exist in order to reduce the cost of carrying out exchange transactions.

Vernon L. Smith.[6] If a market institution is a set of humanly devised constraints, the question on the origin of these constraints arises: Where does a market structure come from? Following Smith (2003), there are two main origins of market institutions as a rational order: conscious design and undirected evolution. 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' (von Hayek, 1967, p. 85). Accordingly, many market structures are determined by conscious design.

On the other hand, undesigned, evolutionary processes determine market structures. Different market places and market structures compete with each other and the fittest markets survive. 'Adam Smith developed the idea of emergent order for economics. Truth is discovered in the form of the intelligence embodied in rules and traditions that have formed, inscrutably, out of the ancient history of human social interactions. This is the antithesis of the anthropocentric belief that if an observed social mechanism is functional, somebody in the unrecorded past must have used reason consciously to create it to serve its perceived intended purposes.' (Smith, 2003, p. 470)

Deliberate construction and spontaneous evolution both affect market institutions. 'Constructivism is indeed an engine for generating variation, but 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.' (Smith, 2003, p. 470)

[5] In 1993, Douglass C. North received the Nobel Prize in Economics for having renewed research in economic history by applying economic theory and quantitative methods in order to explain economic and institutional change.

[6] In 2002, Vernon L. Smith received the Nobel Prize in Economics for having established laboratory experiments as a tool in empirical economic analysis, especially in the study of alternative market mechanisms.

3 Frameworks for Assessing and Engineering Markets

Following the historical excursus on markets in Section 2, a market is defined as follows:

Definition 3.1 (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,
- a set of constraints which have to be established,
- a set of constraints which compete for survival,
- an information processing system,
- an entrepreneurial activity, and
- a service.

Engineering markets includes the conscious, structured, systematic, and theoretically founded procedure of analyzing, designing and introducing market institutions. It can be defined as follows:

Definition 3.2 (Market Engineering) *Market engineering is the process of consciously setting up or re-structuring a market in order to make it an effective and efficient means for carrying out exchange transactions.*

Objectives of market engineering are

- to analyze and design transaction objects, microstructures, infrastructures, and business structures of markets,
- to identify areas of application in which market-based coordination is an effective and efficient means of coordination, and
- to develop methods, procedures, tools, and knowledge for the engineering of markets as well as the identification of areas of application for market-based coordination.

In light of the multiple facets of markets and market engineering, it is hardly surprising that several frameworks can and should be employed to understand, build, and run markets. Some of them are outlined in the following.[7]

[7] Note, that not all of these ideas on engineering markets are entirely new here. See e.g. Holtmann and Neumann (2003); Neumann and Holtmann (2004); Neumann (2004); Neumann et al. (2006); Weinhardt et al. (2007).

3.1 Market Lifecycle Management

Like any product or service, a market follows a lifecycle. As pointed out in Section 2 by quoting Coase (1988, p. 8), the term *market* is ambiguous: on the one hand it refers to a market institution like the NYSE, for example, and on the other hand it refers to a wider context like the stock market in general, for example.

3.1.1 Lifecycle of markets in a wider context

New markets—not market institutions but markets in a wider context—emerge constantly, e.g. markets for electricity, emission rights, spectrum licenses, or markets for granting private credits. The typical phases of a product lifecycle transfer to a market lifecycle, they are sketched in Figure 1.

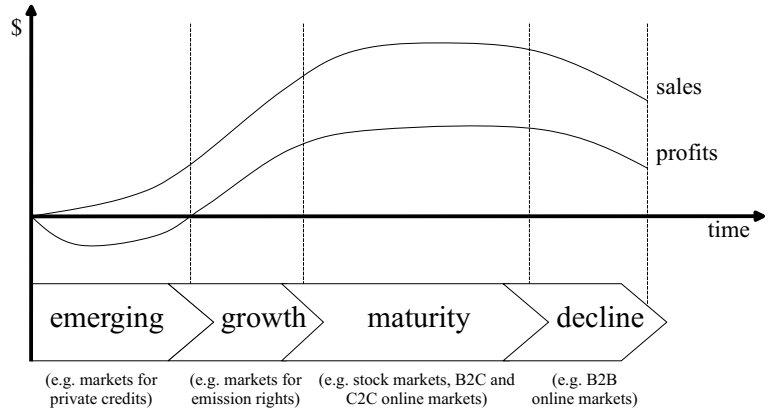

Figure 1: Stylized lifecycle of a market in general

Emerging: While a market is emerging, it's existence is hardly known to the public. Operators of market institutions have rather few competition and have to concentrate on R&D and engineering, define the product to be traded, and create a customer need for exchange transactions and an exchange institution, i.e. a marketplace. In this phase, market operators have rather high expenditures for the aforementioned activities and cannot yet cover them with revenues generated by the marketplace. Thus, overall profit is at first negative, as it is virtually for any business one starts in an emerging market.

An example for a currently emerging market is the market for exchanging credits between private persons via Internet platforms. This direct interaction of creditors and borrowers bypasses the conventional intermediation by banks.

Growth: In this second phase, the market in general is growing rapidly and new market operators likely enter to compete for revenues. Traditional strategies are to emphasize

marketing, focus on quality, and manage rapid growth of the network of market participants, the market operator's organizational structure, and likely the employed IT systems.

Network effects play a crucial role in this phase. In many two-sided markets, participants directly benefit from a high competition of potential counterparts in an exchange transaction. eBay and its competitors are an example: In many countries eBay is by far the largest B2C and C2C (and partly B2B) online marketplace. When a buyer chooses a market platform to purchase a good, she likely picks eBay as there are many sellers and she thus expects a high chance to find an auction with a low price. On the contrary, a seller likely sets up his auction on eBay as there are many buyers who compete for the good and the seller hopes for a high price.[8] See e.g. Rochet and Tirole (2003); Ellison et al. (2004); Chen et al. (2006) for discussions of the importance of size and network effects for competing market institutions.

An example for a market in the growth phase is the market for emission rights in the European Union. It is well known that emission rights are traded today and trading volume will likely increase over the next years. Market operators try to attract trading volume to become the incumbent and deter entrance by other market operators.

Maturity: When a market is mature, competition among market operators intensifies and prices for their services fall. Operators have to focus on their costs to survive the price competition and/ or to focus on niches like special market segments or additional services.

Stock markets, for example, are rather mature and in Europe we see a fierce competition among market operators for the relatively constant market volume. This includes price competition, quality differentiation, plans for mergers and consolidation of market institutions etc.

Decline: When a market declines because there is no need for transactions any more or participants organize via another venue, high-cost and low-share competitors exit. The remaining market operators further focus on being low-cost or niche players.

B2B online markets are an example for a once bigger market which declined. We do not want to claim that there is no need for B2B markets but rather observe that during the e-commerce hype and dot.com boom there was an exaggerated enthusiasm for B2B Internet market platforms and many of them did not survive the decline of this hype.

[8] Note that on the contrary a buyer would like to choose a marketplace where there is low competition with other buyers. The same holds for sellers.

Besides markets which occur 'naturally' as a product or service emerges and the desire for exchanging it comes up, there are markets strictly controlled by regulators. Spectrum license auctions are an example where a regulator (a country), defines the good (the licenses), determines beginning and end of a market institution (an auction), and runs the market without any competition, as no other market operator can enter the primary market for spectrum licenses.

3.1.2 Lifecycle of a single market institution

While the previous section outlined the lifecycle of markets in general, Figure 2 shows the lifecycle of a single market institution. The lifecycle starts by a market engineer setting of the design of a new market. The major phases during design time are designing, testing, and implementing the set of constraints of the new market institution as well as its infrastructure, e.g. a software. These phases will be detailed in Section 3.3; software tools like the meet2trade platform (Weinhardt et al., 2006), for example, support the work of a market engineer in these phases.

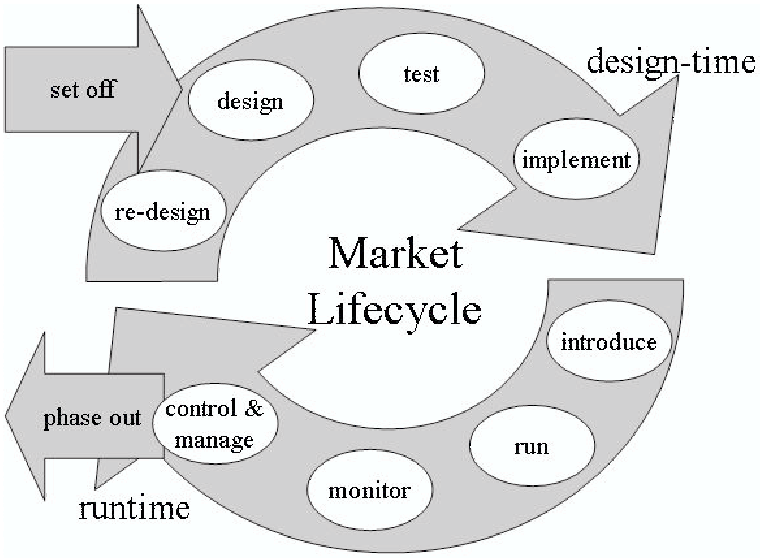

Figure 2: Stylized lifecycle of a market institution

Once the market is ready for operation, it has to be introduced by allowing trades to access the market. Likely this will be accompanied by marketing activity to attract traders and gain liquidity. Running, monitoring, controlling, and managing the market institution are the phases which follow. Here, the market operator has to provision the market service and to monitor trading to detect, for example, malicious behavior (e.g. Blume et al., 2006).

In case the performance of the market does not match the requirements, or either the objectives of the market operator or the environmental conditions have changed, the market operator has to re-design the market institution.

For some Internet market platforms, like eBay and Amazon, an interesting tendency can be observed: after the initial introduction of the electronic market platform, there is no clear cut distinction between design-time and runtime any more. This equals the fusion of design- and runtime of other Internet services like Google, for example. These service operators can continuously experiment with subsets of their user groups (e.g. chosen by random or by country of origin) and the real-time feedback allows continuous improvement in the design of their online businesses. This leads to rapid and subtle innovations and allows incumbents to gain a competitive advantage over potential new entrants.

3.2 Market Engineering Object

Figure 3 shows the so called *market engineering object*, i.e. a static view on pivotal elements of a market which a market engineer should bear in mind.

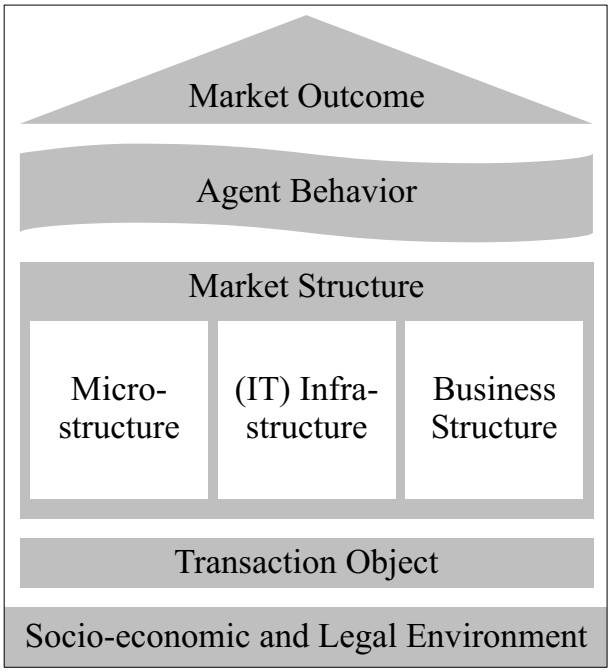

Figure 3: Market Engineering Object

The objective of a market engineer is to achieve a desired market outcome or performance. To do so, she can design the transaction object as well as the market structure. The market structure comprises the market microstructure, the (IT) infrastructure, and the business structure.

These designed elements—the transaction object and the market structure—have only indirect effect on the market outcome. The link from the structure to the outcome lies in the behavior of market participants. It is the behavior of market participants which makes the engineering of markets a major challenge as their are no direct cause-effect relationships between a market's structure and its performance. In an abstract setting like a

game-theoretic model with hyper-rational, utility-optimizing players, their might be direct cause-effect relationships. However, in the real world, where market participants are boundedly rational (e.g. Simon, 1955, 1957; Selten, 2001) and are prone to cognitive biases (e.g. Neale and Bazerman, 1991; Bazerman, 2006; Gimpel, 2007), the relation of market structure and market outcome is not straight forward. Usually, market engineers employ a variety of methodologies to asses the impact a specific market structure has on the participants' behavior and thus the outcome; these include especially theoretical modelling (game theory, auction theory, mechanism design etc.) and empirical research (lab and field experiments etc.).

The socio-economic and legal environment comprises elements which the market engineer cannot directly influence; examples are the participants' cultural background and norms, their preferences, and the applicable laws. See e.g. Neumann (2004) for a discussion of the design parameters of market structures, Seifert (2006) for an example of studying the microstructure, Rolli et al. (2006) for an example of approaching the IT infrastructure, and Burghardt (2006) for an example analyzing the business structure of markets.

3.3 Market Engineering Process

While the market engineering object is a static view on markets, the following process structures the procedure of engineering a market institution. It is displayed in Figure 4 below based on Figure 1 of Weinhardt et al. (2007). Besides the phases of the market engineering process, Figure 4 lists some methods and tools commonly employed in the different phases.

The market engineering process—a more detailed process model of the lifecycle of a market institution as displayed in Figure 2—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 microstructure, the (IT) infrastructure, and the business structure of the market institution and the evaluation phase assesses the participants behavior (cf. Figure 3). Following are implementation and introduction of the designed market. The enumeration of methods and tools in Figure 4 is by far not extensive but is meant to give a better understanding of a market engineers 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 Weinhardt et al. (2003); Neumann (2004); Weinhardt et al. (2007) for more detailed

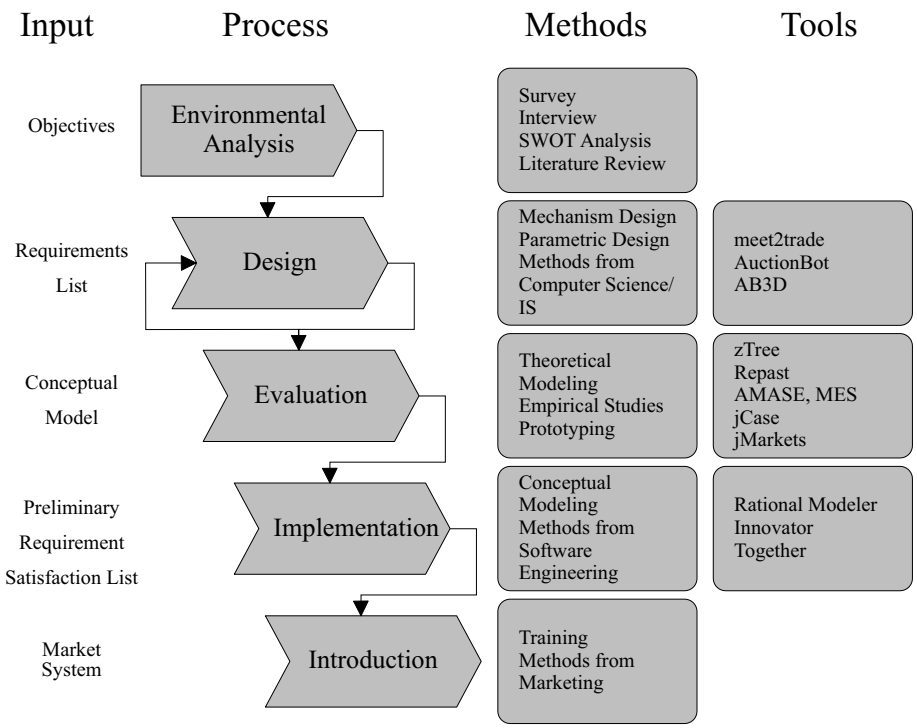

Figure 4: Market Engineering Process

discussions of the market engineering process and Schnizler (2007) for an example of applying the process.

4 Conclusion and Future Work

Market engineering is the process of consciously setting up or re-structuring a market in order to make it an effective and efficient means for carrying out exchange transactions. More bluntly, market engineering is making markets work. This requires an integrated, holisitic view on markets, a multiplicity of methodologies, an interdisciplinary approach, and the understanding that details matter.

To help market engineers in assessing and designing markets, we presented three frameworks: Market Lifecycle Management, the Market Engineering Object, and the Market Engineering Process. Along this presentation, several yet unresolved questions and research challenges have been pointed out. A major challenge lies in integrating the detailed results different disciplines already achieved to a holistic, interdisciplinary view on engineering markets.

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