Market Engineering

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1 Why Market Engineering?

The difficulty in designing and implementing electronic markets is oftentimes the interdependence of technical and economic objectives (Weinhardt et al. 2006). From an economic viewpoint, an electronic market must encompass common economic performance desiderata such as allocative efficiency. Relying on existing market mechanisms known from other contexts when constructing new markets may, however, result in poor efficiency (Lai 2005). The mechanism designer also has to account for the technical conditions of the target domain. To give an example, in case of a market for allocating Grid computing resources these conditions comprise the underlying environment in terms of Grid middleware and the requirements of potential Grid users and applications. The market should act as a resource allocation manager, hence, fulfilling general requirements upon such a manager. This allows the introduction of the precondition that a market apt for the Grid has to be realized as an electronic market. Otherwise, the market cannot fulfill an automated resource allocation as required by a Grid resource management system.

Different requirements from technical and economic viewpoints may lead to different and oftentimes conflicting objectives. Lai (2005, p.4) points out that "*a pure mechanism designer is likely to design an economic mechanism with high economic efficiency, but with little concern for traditional metrics of computational efficiency, reliability, security, complexity, and ease-of-use. Pure system designers have generally done the inverse.*" As such, neither a pure mechanism design driven nor a pure system design driven approach may lead to a useful overall design and implementation of an adequate electronic market. When constructing electronic markets, it is essential to consider different influences that arise from technical fundamentals, potential user requirements, business constraints, and economic objectives. Each of these influences has a profound impact on the outcome and, as a consequence, on the acceptance of the market (Weinhardt et al. 2003). The market engineering approach manages these influences by means of a structured, systematic, and

theoretically founded procedure of designing, implementing, evaluating, and introducing electronic market platforms (Weinhardt et al. 2003; Neumann 2004; Holtmann 2004).

2 Market Engineering – A Structured Approach

The market engineering approach is structured by means of a process as depicted in Figure 1: Taking into account the objectives of the new electronic markets, the requirements of the new electronic market are deduced in the first stage. Subsequently, the new market is designed with simultaneous consideration of the transaction object, the market microstructure, the IT infrastructure, and the business model. In the third stage, the mechanism is tested on its technical, economic and business properties. If needed, there is an iteration loop between designing and evaluating the market in order to make sure that the requirements are met. In the fourth stage, the thoroughly evaluated design is realized and implemented as a software system. Finally, the market platform is introduced. At any stage of the market engineering process, there is a decision whether to proceed with the next step or to repeat an earlier one.

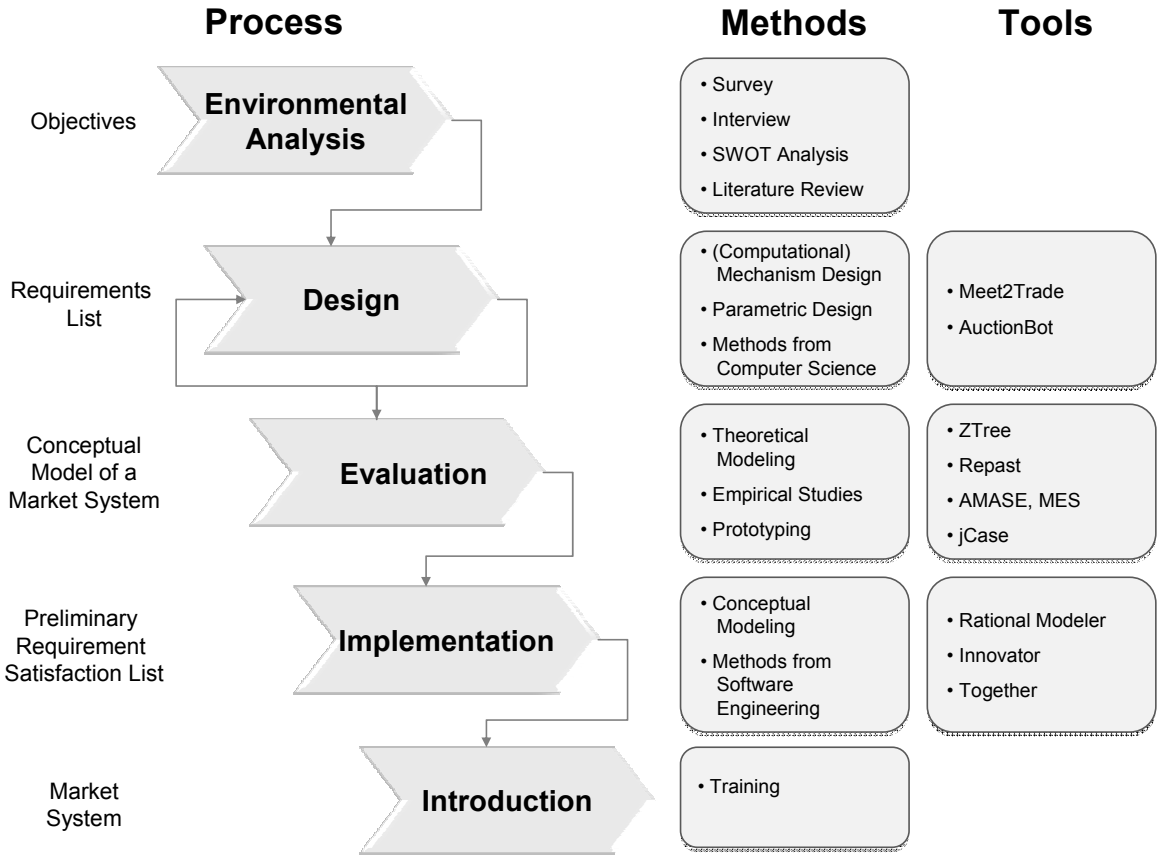

Figure 1. Market Engineering Process

The market engineering process does not only structure the design process as it also provides the designer with a whole array of methods and tools that may support separate sub-tasks. In the following, these stages and a selection of supporting methods are outlined briefly on the basis of Neumann (2004).

2.1 Stage 1 – Environmental Analysis

The objective of the environmental analysis is to formalize the strategies and objectives of a new electronic market. The stage comprises two phases: the environment definition and the requirement analysis.

The goal of the environment definition is to characterize the economic environment for which the market is to be engineered. This phase comprises the collection and analysis of potential trading objects, market segments, and agents that may interact on a particular segment. The environment definition usually starts with the analysis of potential trading objects. On the basis of this analysis, potential market segments for trading these resources are identified and evaluated comparatively. Having selected a target market, information about potential agents is deduced. The target market reveals the economic environment for which the market is intended. In order to gain potential agents acting on it, the market mechanism must fulfill the needs and requirements of these agents. The requirement analysis consists of a thorough extraction of these needs concerning the resource allocation problem and the environmental side constraints. Cramton (2003, p. 8) motivates the requirement analysis as follows: *"Good market design begins with a thorough understanding of the market participants, their incentives, and the economic problem that the market is trying to solve."*

On the basis of the requirement analysis, the market engineer decides whether to engineer a new mechanism from scratch or to reuse and adapt an existing one for the target problem. This decision is usually supported by a literature review, surveys, a SWOT analysis, and interviews with future market participants. The output of stage 1 is a list with all requirements.

2.2 Stage 2 – Design

The second stage of the process comprises the design of the market with simultaneous consideration of the transaction object, the market microstructure, the IT infrastructure, and the business model. Supported by different tools and methodologies such as mechanism and parametric design the market mechanism is deduced as an allocation and payment function. For designing the IT infrastructure in order to e.g. ensure computational tractability we rely on methods from computer science.

We provide different tools that assist the engineer in designing markets. For instance, the market engineer can rely on the generic market system meet2trade that supports different auction mechanisms and negotiation schemes (Weinhardt et al. 2006). The result of stage 2 is a conceptual model of the market system to be evaluated and implemented.

2.3 Stage 3 – Evaluation

Having designed the market, it is tested upon its technical and economic properties. The evaluation stage comprises functionality tests of a software prototype to ensure its correctness, economic tests to measure the outcome performance of the market, and an assessment of the business model. Functionality tests are made to ensure that the prototype system works as it is designed. In other words, these tests ensure that the system correctly reflects the institutional rules. The objective of the economic tests is to ascertain whether or not the electronic market attains the desired economic outcome. This phase is supported by analytical and experimental evaluation methods. Experimental methods are comprised of laboratory experiments (Weber 2006; Gimpel 2007), numerical simulations (Kunzelmann 2006), or agent-based simulations (van Dinther 2006). Tools for this kind of evaluation are e.g. ZTree, Repast, MES and AMASE as part of the meet2trade system and the simulation tool jCASE[1].

After functional and economic tests are performed, additional pilot runs with the software prototype are made. These runs provide information about the agents' acceptance of the market and, if necessary, allow the engineer to adjust the underlying institutional rules or the prototype system.

[1] See http://www.iw.uni-karlsruhe.de/jcase/ for details.

2.4 Stage 4 – Implementation

In this stage, the thoroughly evaluated design is realized and implemented as a software system. The market system can either be implemented from scratch or the prototype developed in the evaluation stage can be enhanced in an evolutionary process.

This phase is supported by traditional software engineering concepts and tools, such as UML (Arlow and Neustadt 2005), design patterns (Gamma et al. 1995), or the Rational Unified Process (Kroll and MacIsaac 2006). The output of this phase is a fully implemented electronic market with the institutional rules and the business model.

2.5 Stage 5 - Introduction

In the last stage of the process, the electronic market is introduced. The introduction of the electronic market initiates its operation cycle (Neumann 2004).

3 Market Engineering – Use Cases

In the following, we present two use cases where market engineering was applied for constructing electronic markets. The first use case deals with a market for resource allocation in a Grid computing scenario, the second one with designing prediction markets. The use cases illustrate that designing and implementing markets in practice is a complex and interdisciplinary task. The structured procedure of market engineering allows the inclusion of different environmental conditions and supports the incorporation of a variety of requirements.

3.1 Grid Market Engineering

The Grid is a promising technology for providing access to distributed high-end computational capabilities. Thus, computational tasks can be performed spontaneously by other resources in the Grid that are not under the user's control. However, one of the key problems in the Grid is deciding which jobs are to be allocated to which resources at what time. In this context, the use of market mechanisms for scheduling and allocating Grid resources is a promising approach toward solving these problems.

Schnizler et al. (2006) apply market engineering for the derivation of a multi-attribute combinatorial exchange (MACE) for allocating and scheduling services in the Grid. The proposed mechanism accounts for the underlying economic environment of a Grid marketplace. The authors define a set of requirements upon a suitable Grid mechanism that are mapped into an innovative auction schema. On the basis of linear programming techniques, MACE supports the formulation of bundle bids, quality and time constraints and specific co-allocation restrictions (Schnizler, 2006). The auction schema is numerically evaluated by a simulation tool called jCase. The tool can be applied to study the latest available forms of combinatorial auction mechanisms in regard to economical and technical metrics. In addition, the flexible description capabilities for simulation settings allow the analysis of a multitude of different scenarios. As a consequence, jCase qualifies as a simulation environment that assists the market engineer in evaluating combinatorial auctions.

3.2 Prediction Market Engineering

Prediction markets are increasingly regarded as a promising forecasting method. The basic idea is to trade artificial stocks whose payoffs are tied to the outcome of uncertain future events. Until the outcome is finally known, the trading price reflects the traders' aggregated beliefs about the likelihood of a future event. Market prices can thus be interpreted as predictions of the likelihood of those events. Public examples for prediction markets include the Iowa Electronic Markets, TradeSports, NewsFutures, the Hollywood Stock Exchange, and STOCCER. Several major companies are currently also using internal prediction markets.

We apply market engineering to prediction markets to gain insights on how to design such markets in order to increase their prediction accuracy. One specific question we address with our research is how to provide incentives for participation and information revelation. Our results show that performance-compatible payment schemes seem to perform worse than fixed payments and rank-order tournaments (Luckner 2006). Due to the risk aversion of traders, the competitive environment in case of the rank-order tournament seems to lead to the best results. Other questions we are working on are the impact of the traders' country of origin on portfolio and price formation (Luckner 2007), manipulation in prediction markets as well as a comparison of call auctions and continuous double auctions.

Our focus in the field of prediction markets thus is currently on the design and evaluation stages of the market engineering process. Based on our results, however, we build up knowledge for implementing and introducing future prediction markets. Luckner et al. (2005) describes a concrete implementation of a prediction market we operated during the FIFA World Cup 2006.

4 Summary and Future Research Directions

In this paper, we presented market engineering as a holistic approach for designing, implementing and introducing electronic markets. One of our core activities over the last couple of years was the development of the tool suite meet2trade with a focus on the stages design and evaluation of the market engineering process.

In our future work, we want to further foster flexibility of electronic markets by breaking down marketplaces into services. These services can then be composed to customized market processes. This could turn a market operator into a service-broker who provides merely the very fundamental services; all other functions can be delivered by specialized providers. In Rolli et al. (2004) we already presented a framework that enables the configuration and implementation of a service-based electronic market. The market itself can then be provided as a service and integrated into existing enterprise applications.

Moreover, we explore several domains where markets should be increasingly employed in the future for resource allocation, to provide incentives for market participants or for risk management. Examples range from a market-based supply chain coordination to service brokering in service-oriented computing and risk management by means of prediction markets.

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