Decision Markets for Continuously Reflected Collective Decisions

Stephan Leutenmayr
Sven Ziemer
Bauhaus Luftfahrt
Munich, Germany
e-mail: {stephan.leutenmayr, sven.ziemer}@bauhaus-luftfahrt.net

François Bry
Institute for Informatics
Ludwig-Maximilian University of Munich
Germany
e-mail: bry@lmu.de

***Abstract*—The application of the market metaphor to forecasting uncertain future events exhibits appealing characteristics such as forecast accuracy and being considered attractive by most users. Based on the demonstrated success of such so called prediction markets as an accurate forecasting mechanism, the market metaphor has been applied to related domains such as decision making and decision support in order to benefit from its attractive characteristics. However, not all of those characteristics still hold in these application areas. We currently develop Liquid Decision Making (LDM), a market based approach for group decision making. This article reports on three design principles that we devised to address the aforementioned challenges, namely the principles of a collaborative decision making situation, a personal involvement of the participants with the decision at hand and dual incentives provided to the users. A prototypical implementation of this LDM mechanism has been tested for decision making in a scenario building seminar. There, participants gathered, categorized and ranked driving factors for their relevance for scenarios to be developed for the topic of *personalized mobility in 2050*. In this setting, the design principles of the mechanism were deemed to be viable for addressing the challenges of attracting and retaining participants.**

Keywords*—*decision making; market design; incentives

I. INTRODUCTION

Decisions often need to be made, or benefit from being made, by a group of people as they contribute with different perspectives, knowledge and evaluation criteria. The alternatives of the pending decision thereby often need to be considered over a prolonged period of time in order to gather as much relevant information as possible and to allow for informed opinions to be formed. In such circumstances, not all consequences of all available alternatives can be comprehensively considered due to time and informational limitations. Additionally, group members may be heterogeneous in their assessment criteria for the decision alternatives. Engaging a large and heterogeneous group of people to produce a joint result is a main theme of social media [1]. One of these social media methods is the application of the market metaphor. In such decision making situations as delineated above, the market metaphor poses a promising alternative to conventional group decision making approaches. Economic markets have been attributed the ability of efficiently aggregating information from people and representing it in the resulting price [2]. The goal in the application of the market metaphor to decision making is to jointly achieve a decision. The market metaphor thereby offers continuous participation, revisability of one's assessments, immediate feedback on one's actions, anonymity and an intuitive representation of the users' assessments in the market prices. It furthermore encourages decisiveness and first-mover behavior as hesitant and indecisive participants may lose influence due to increasing prices and unwisely spent money. In a market based decision making approach, the decision is represented by a market and the decision alternatives are traded as stocks on that market. Participants buy shares of their favored decision alternatives and sell shares of the unwanted alternatives. At market end, the highest ranking stock of that market is chosen as the jointly determined decision alternative.

Any mechanism based on continued contributions by participants needs to attract and retain users. Markets are no exceptions. In the application as a forecasting mechanism in so called prediction markets, attracting and retaining users is achieved by rewards such as real or play money or reputation that can be granted to participants based on forecast accuracy. There, every participant's ambition to maximize his reward by providing an accurate forecast of the outcome serves the goal of the organizer of attaining such an accurate forecast. Hence, prediction markets are incentive compatible in game theoretic terms. In a decision making situation, however, such performance based rewards are likely to bias the contributions of the participants towards predicting market results instead of contributing their true assessments. This phenomenon is known as the Keynesian beauty contest in which participants try to guess the actions of others and adapt their behavior accordingly [3]. Results of such markets then reflect the average evaluation of the average assessments of participants rather than the aggregation of their true opinions on the respective topics.

Thus, other measures for attracting and retaining users are desirable. We currently develop our LDM mechanism for group decision making that utilizes the market metaphor [4]. To address the aforementioned challenges, we formulated the following principles for the design of LDM. The collaborative decision principle emphasizes the collaborative nature of the LDM approach as people utilize it for jointly determining a decision alternative. It aims at attracting people by the ability to collaboratively identify the decision outcome rather than by speculative prospects. The principle of user involvement ensures that people care for the actual outcome of the market. The more they are personally involved with the result of the market, the more they should be willing to care about the resulting decision alternative and to participate in the market in the first place. The principle of dual incentives caters to the demand of attracting and retaining users by providing push and pull style information to the participants. Market information pushed to participants on a regular basis should encourage users to participate repeatedly. The availability of up-to-date market information on demand should also contribute to the

 ISBN: 978-1-61208-312-4

level of participation.

Despite these design principles, users may nevertheless participate not according to the market goal of achieving a joint decision. Thus, LDM furthermore incorporates an approach for determining the sincerity of the single contributions by a price perturbation mechanism [5].

The design principles of LDM are introduced in Section II. Furthermore, our prototypical implementation of LDM is delineated. Based on this prototype, a case study has been designed and executed (see Section III-A). The results of the case study are examined in Section III-B. Related work is surveyed in Section IV. Section V concludes and highlights future work for LDM design and potential applications.

II. The Liquid Decision Making Mechanism

In this section, the design principles of LDM are introduced and a prototypical implementation for testing their adequacy is highlighted.

A. The Liquid Decision Making Design Principles

Attracting and retaining participants are special challenges in the application of the market metaphor to decision making. Among the benefits of the market metaphor are the capability of accommodating a large group of people and the potential for continued participation over a prolonged period of time. However, these benefits need to be made palatable for prospective users for them to actually participate. LDM on the one hand seeks to allow group members to contribute their assessments of the single decision alternatives and on the other hand to provide them with incentives for repeated participation. The design follows the principles of a collaborative decision goal achieved with the market metaphor, involvement of the participants with the decision outcome at hand and dual incentives for participation in order to meet those goals. The design principles aim at encouraging certain behavior in participants. These considerations result form observations from the literature and own case studies. Participants in prediction markets are typically assumed to be utility maximizing and to derive this utility from the benefits they expect in return for their participation. We decided to keep up with this assumption and to investigate how we need to design LDM for directing the utility maximizing behavior in helpful lines with respect to the decision making goal.

1) The Collaborative Decision Principle: Markets naturally provide incentives for speculation and gambling by their utilization of real or play money as a voting medium and the associated potential for gains and losses. Participants may primarily follow such speculative considerations in order to gain money instead of bearing the actual decision in mind. Such trading is comparable to technical trading which only deals with trends and correlations without considering the fundamental values of the respective stocks [6]. The collaborative decision principle emphasizes the collaboration of people to find a joint decision alternative using the market metaphor and, to this end, acknowledge the market result as the chosen alternative for the decision. Thus, LDM reduces sources of utility maximizing behavior that do not contribute to the achievement of a joint decision by omitting market information that may fuel market gambling or speculative market trading behavior. People should be drawn to participate rather by the topic than by the market mechanism.

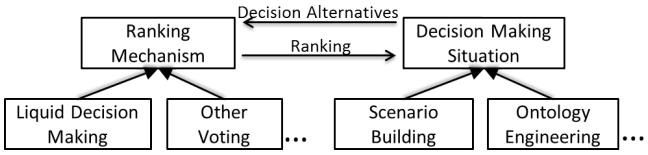

Fig. 1: The integration of the market metaphor with decision making

Fig. 1 depicts this principle as the integration of a decision making effort with a ranking mechanism. There, the decision alternatives are ranked using some mechanism and the resulting ranking is returned to the decision making effort for further processing.

2) The User Involvement Principle: With prediction markets, participants can be rewarded for accurately forecasting a future event. Thus, they are likely to care for providing an accurate forecast. Decision markets cannot rely on such accuracy metrics as there is no external event defining an objective measure. Thus, other means for encouraging meaningful contributions are desirable. The principle of user involvement regards the degree of personal relationship the participants exhibit with respect to the decision outcome. Personal involvement here denotes how much a user is affected by the resulting decision outcome. The more involved, that is, affected, a user is with the decision outcome, the more utility he is likely to derive from the actual outcome. Maximizing this utility would then consist of contributing meaningfully to the selection of a decision alternative and to observe the process and to react to the actions of others. Thus, the user involvement principle stipulates the application of LDM in situations with a significant degree of participants' involvement with the decision outcome. In this way, users should perceive the mechanism as attractive and continually come back. Prediction markets correspond to the common notion of crowd sourcing, that is, the division of an extensive task among many people and of aggregating their partial results. These participants typically only care for their allocated work share and for achieving the associated reward. With LDM on the contrary, a potentially large group of people participates specifically in order to achieve the overall goal of making a collective decision.

3) The Dual Incentives Principle: Decision markets enable participants to take an active part in determining a decision alternative and to revise their assessments of the alternatives during that process. However, people often need to be incentivized to participate in such a decision making effort. LDM has been designed with dual incentives in mind for both attracting and retaining users. For attracting people to participate for the first time, the goal of this principle is to feature a decision that participating in is beneficial for prospective users. This benefit then needs to be highlighted comprehensibly to participants. For retaining users, that is, encouraging their repeated participation, this principle encompasses the provision of up-to-date market information to participants. Up-to-date information supports the striving for utility maximization. This information should be both available on request by the participants and pushed out to participants as a periodic reminder of the decision making effort. In this way,

 ISBN: 978-1-61208-312-4

participants receive information on the status of the market and their favored alternatives in particular and are encouraged to visit LDM on a regular basis.

B. The Liquid Decision Making System

We currently develop a prototypical LDM system for investigating market-based decision making. This system formed the basis for examining the adequacy of the introduced design principles. The system is realized as a web-based software in order to facilitate an ease of use without the need for a local installation, a low entry barrier due to a familiar web interface and a distributed participation. The software allows for surveying the available cash reserve, the tradable decision alternatives, their prices and rankings, for trading in the single decision alternatives, for proposing additional decision alternatives, for accepting or rejecting the proposals as well as functionality for commenting on trading actions and decision alternatives and for ranking a comment's helpfulness.

The design principles are realized in the following new functionalities of LDM. For emphasizing its collaborative nature, only little information is offered which could fuel speculative behavior or gambling. In this case, the LDM system does not calculate the portfolio worth of each participant and does not compile a user ranking from it. The lack of this striking cue on the ranking of participants should contribute to lowering the temptation of gambling behavior in the market. Furthermore, the system provides a ranked list of the decision alternatives so that every participant can identify the currently selected joint decision alternative. Fig. 2 depicts such a ranking utilizing a bold font for the collectively chosen decision alternatives.

The involvement of the users is ensured on the one hand by providing a meaningful decision to participants. On the other hand, additional functionality may also increase the involvement of users. To foster the involvement of users, the LDM system offers functionality for commenting on the single decision alternatives and on trading actions by the users. Comments can also be rated by participants for their helpfulness. This is to stimulate further engagement with the single decision alternatives. In this way, their involvement should be intensified.

The formulated dual incentive principle summarizes present market functionality as a specific requirement for addressing the decision market design challenges. It is reflected in the LDM system in two ways. First, the goal and utilization

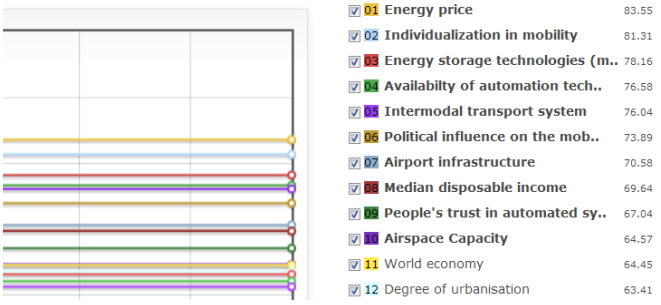

Fig. 2: Detail of the price chart and factor ranking indicating the collectively chosen factors in bold face from the case study

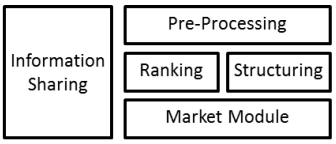

Fig. 3: Architecture of the prototypical LDM implementation

of the result are clearly stated on the system website in order to attract participants for their sincere opinions. Second, up-to-date information is provided to participants, including an overview on the general market status and the decision alternatives and the respective holdings in particular. This information is provided to participants as a push notification realized by a newsletter and a pull notification in the form of a LDM system dashboard. The newsletter acts as a periodic reminder to return to the system and contains information on the development of the market status since the last issue.

The emphasis on collaborative decision making is also reflected in the system's architecture. The domain-specific collaboration part and the market-specific trading part are separated into different modules (see Fig. 3). The preprocessing module is responsible for the contribution mechanism for new factors and their examination by the organizer. This preprocessing module allows the contribution of factors to a public queue. This queue is then processed by designated participants for admission or rejection. Reasons can be given for each. Then, the ranking and structuring takes place. Both of these modules utilize the market functionality of the underlying market module. The information sharing module is responsible for commenting and comment rating.

Many decision alternatives may need to be considered in LDM. Thus, participants may spread over the single alternatives and hence may not find matching counterparts for trading. LDM therefore employs the market maker approach with a central entity acting as a middle man for trading. With such a market maker, trades can be executed by participants at any time with an immediate response from the system [7].

III. The Liquid Decision Making Case Study

Determining the adequacy of a given approach requires a systematic investigation. A first step in such a series of analyses is a case study for collecting qualitative experience with the proposed approach. In the following, the design, execution and evaluation of a case study are presented, which has been executed for testing the effectiveness of the design principles and the applicability with a scenario building process.

A. The Case Study Design and Execution

LDM has been tested in conjunction with a two week university seminar on scenario building at the Technische Universität München, termed *Szenario-Börse* (engl. scenario stock exchange). The topic of this seminar was the development of future scenarios for a personalized mobility in the year 2050. Nine bachelor students participated in the seminar by choice in partial fulfillment of their curriculum. The goal for the students was to learn the methodology of scenario building and to apply it to the topic of personalized mobility. The goal of the scenario building methodology is to produce

 ISBN: 978-1-61208-312-4

a couple of consistent scenarios for a topic concerning the future based on a selected set of influencing factors. The methodology basically includes the identification, gathering and assessment of potential influencing factors, the selection of the most relevant factors, the generation of initial scenarios based on the selected influencing factors and the formulation of plausible pictures of the future [8].

The goal of this case study was to investigate the application of LDM with the scenario building methodology and the impact of our design principles. For the application of LDM with the scenario building, we chose to utilize LDM for making the decisions regarding the gathering, assessment and selection of the influencing factors as an input for the further building of the scenarios. We furthermore employed LDM to gather the experience that the students had gained with the factors after the scenarios had been generated.

The ranking functionality of LDM was utilized for ranking the influencing factors according to their relevance in the generation of the single scenarios as well as for categorizing the factors with respect to the predefined categories of society, technology, environment, economy, politics, values and air transport. In order to provide sufficient time for identifying and gathering factors, we started the decision making system three weeks prior to the actual scenario building seminar. For that pre-seminar period, we expanded the number of participants by 11 additional people from the organizing institutions in order to bring in more diverse knowledge on the subject. During that period, the tasks of the participants comprised the contribution of new factors, the ranking of existing factors and the assessment of their categorizations as well as commenting on factors and trading actions and rating the helpfulness of those comments. Suggested factors were queued and processed by the organizer of the seminar for admission. All participants were given an introductory written tutorial on the system functionality and their tasks prior to the opening of the Szenario-Börse. Participants were required to register with the system in order to track their market actions, cash reserve and share holdings. Anonymity was guaranteed by freely selectable user names. Upon registration, each participant received the same initial endowment of play money that was not redeemable in real currency. According to Servan-Schreiber et al., play money should not significantly impact market results [9].

At the beginning of the scenario building seminar, two trading sessions were held with only the nine students participating as they would have to work with the chosen factors. They were granted additional money for finally selecting the 10 most relevant factors that were to be used as input to the further development of the scenarios. After the second trading session, the market was still open for trading in the factors, however, the scenarios were built based on the 10 highest ranking factors as determined after the second session. At the end of the scenario building seminar, the LDM system was utilized in a third trading session for enabling the participants to reflect their insights on the relevancy of the factors that they gained during the scenario building seminar. After the end of the scenario building seminar, a user survey was conducted for gathering feedback on various aspects of the LDM approach.

B. Evaluation and Discussion of the Case Study Results

The goal of this case study was to investigate the application of LDM in a decision making situation and to gather qualitative experience with our devised design principles in the context of the scenario building seminar. The evaluation of the success of the design principles is based on the post-seminar survey among the students, their qualitative feedback during the seminar and on experience from prior LDM installments that did not fully respect these principles. Overall, LDM was applied successfully with the scenario building methodology, the design principles seemed to be promising for achieving their aspired results in the design of LDM and the prototypical system deemed useful. Participants made use of the continuous nature of the LDM system as is reflected in the total number of 1545 trades, with a maximum of 333 trades, a minimum of 3 trades and a mean of 71 trades per person. The ratings in the following refer to the survey using a Likert scale ranging from 1 (does not apply) to 5 (completely applies). The prototypical implementation of LDM was rated by participants as relatively easy to use (mean of 3.1) and as providing relevant information with a mean of 3.1.

The application of LDM to scenario building was successful as participants of the scenario building seminar achieved a joint selection of the most relevant factors. This was validated by the organizer of the seminar who confirmed the relevance of the selected factors. Furthermore, participants appraised the results immediately after the factor finalization as valuable. In the post-seminar survey, they were also satisfied with the factor selection approach with a mean of 3.0 and they rated the adequacy of the selected factors with a mean of 3.3. 25 additional factors were contributed with 18 of them accepted for trading. Finally, the three future scenarios created by the students were rated very well by the organizer of the seminar.

The factors for the scenario building were collaboratively ranked using the Szenario-Börse for their relevance. In the provided information in the Szenario-Börse, the emphasis was on the joint decision making goal rather than on market gambling. Overall, participants rated the provided information to be relevant for the joint goal with a mean of 3.1. They furthermore did not object to the produced factor selection in a discussion session right after the selection and accepted the result as the jointly produced input to the further scenario generation. Two participants criticized the lack of more in-depth market information similar to tools for stock market brokers. The demand for more market-related information is an indicator for the effect of the collaborative decision principle as applied in this case study. The relationship between personal involvement, provided quality of market information and gambling should be interesting to investigate in further, more controlled, experiments in more detail.

The students had to work with the factors further in the scenario building process that were determined by the Szenario-Börse. In this way, they had a personal interest in selecting meaningful factors for further processing. This user involvement was perceived as a motivation for trading with a mean of 3.2 by the students. The produced scenarios were also highly acclaimed by the seminar organizer. This points to the importance of providing a tangible personal involvement and thus meaning for participants in such a mechanism. The third trading session aimed at aggregating the knowledge that the

 ISBN: 978-1-61208-312-4

students gained during the generation of the single scenarios. However, the result of this third session had no personal impact for them and the achievement of the group goal. According to comments in the post seminar survey, users were more drawn to gambling efforts in this session than in the trading period prior to the selection of the relevant factors. This apparently underlines the importance of the user involvement principle for the design of LDM. The LDM system also provided functionality for commenting on decision alternatives and trade actions. This was utilized for 30 comments during the Szenario-Börse. Presumably, this relatively low utilization was due to a low interest in the opinion of the other participants or the expectation to discuss matters in person at the beginning of the actual seminar. For future work, it may be helpful to provide additional incentives for providing helpful comments such as additional money.

In this case study, the Szenario-Börse provided a meaningful decision as the students had to work with the resulting factors further on in the scenario building process. According to the survey, this served as an incentive to participate in the Szenario-Börse with a mean of 3.3, which is also reflected in the average logins of two to five times a week. They furthermore liked the immediate price feedback with a mean of 3.3. Thus, attracting and retaining users seem to have worked.

IV. Related Work

The market metaphor has been applied in several domains and has been investigated from several points of view. This section puts the work at hand in the context of existing work.

A. Related Market Applications

The design of LDM rests on the involvement of the participants, the provision of decision aligned incentives and the setting of a joint decision making goal. Historically, the market metaphor has first been applied in prediction markets for forecasting the outcome of uncertain future events [10]. There, the price mechanism aggregates individual forecasts into a joint prediction of the most likely outcome of the uncertain event [11]. Such prediction markets typically exhibit the characteristics of principal-agent situations in which the principal needs some work to be carried out and offers agents a reward for executing this work properly [12]. In contrast to LDM, agents are not personally involved with the task set out by the principal, incentives are based on the agents' performance in the market mechanism and optimizing this performance is aligned with meeting the goals of the principal.

Hanson first proposes the utilization of the market metaphor for making conditional predictions in what he calls *decision markets* [13]. There, participants forecast the likelihood of future outcomes conditional on the implementation of certain actions. Berg and Rietz as well as Chen investigate conditional prediction markets as a basis for making decisions in order to influence the actual outcome of the future event [14][15]. Abramowicz and Henderson focus on conditional prediction markets in a corporate setting and their forecast accuracy as well as on enhancements in the information flows in a corporate environment [16]. In these settings, the goal of the market application shifts from a pure prediction to the support of selecting strategic actions, however, the principal-agent characteristics still apply.

The information aggregation capabilities of the market metaphor are also utilized for selecting all sorts of innovations and ideas in so called *preference markets*. Such preference markets are used to select ideas in a corporate setting [17][18], to gather product feature preferences [19] and to select innovations for corporate research portfolios [20]. In such preference market settings, the market metaphor is typically employed in a principal-agent fashion. In particular, participants are not personally involved with the topics at hand and are rewarded based on their in-market performance, e. g. , the highest-valued portfolio. Thus, participants are found to engage in beauty contests and trade according to two different motivations, namely truthful reporting and market speculation. This, however, does not contribute to the revealing of the participants' true assessments. Kamp et al. devise a model of influencing factors for such situations [21]. In their model, the nature of the incentives plays a central role for influencing the behavior of participants. They conclude that incentives should be aligned with the market purpose to avoid feeding speculative behavior.

Chen et al. investigate the provision of proper incentives in conditional prediction markets for decision making. In their principal-agent situation, the agents are rewarded based on which action is finally chosen. The agents thus have incentives to influence the principal on which action to take [23]. They design a market mechanism that discourages trying to profit from real world influence. In LDM, participants directly influence the selected decision alternative via the market result without a principal making the final decision. Thus, there is no need for exerting real world influence on some principal. Furthermore, our LDM design assumes a personal involvement of participants and hence meaningful contributions. Nevertheless, participants may not contribute meaningfully for some reason. We thus designed an approach for uncovering the origins of price formations [4] and tested the pertinence of this approach in a lab study [5].

B. Related Decision Making Approaches

The market approach of LDM allows each participant to express his preference for a given *stock* (representing an alternative in a decision to be made) through trading actions. This makes a participant's preference for trading a stock the single decision criterion. Based on the resulting prices of all participants' trading behaviors, a ranking of the decision alternatives is then produced. A number of different prioritization strategies as well as different decision criteria are applied by decision making methods and are discussed in the literature. The Analytical Hierarchy Process (AHP) is a framework for multi-criteria decision-making developed by Thomas L. Saaty [24]. AHP is applied in many different domains, including software engineering [25] and strategic business planning [26]. Using AHP includes the definition of several criteria that are evaluated for each decision alternative by each stakeholder using a scale ranging from 0 to 1. The different assessments are then aggregated into a single indicator using the approach of AHP. AHP provides a rational approach to decompose a decision problem into sub-problems that can be evaluated by the decision makers. An important objective of the LDM mechanism is to enable collaborative decision making. Using a multi-criteria approach such as AHP to decompose a decision problem, serves this objective to some extent. But as Hall and Davis [27] are pointing out, the interpretation of such

 ISBN: 978-1-61208-312-4

criteria is framed by the different value-based perspectives of the decision makers. When reaching out to a large group of heterogeneous decision makers, the involved perspectives may address different domains, including technical, social and economic aspects. It is thus obvious that a single set of criteria cannot reflect the perspectives of all decision makers in such contexts. The use of a single decision criterion in LDM may lack some of the accuracy as found in multi-criteria decision methods such as AHP, but it enables all decision makers to express their particular perspective into a buy/sell preference.

V. Conclusion and Future Work

In this article, the design principles of a collaborative decision, personal user involvement and dual incentives have been introduced that we formulated for achieving meaningful results with LDM. The design principles and our prototypical LDM system have been tested in a case study for building scenarios for personalized transport in the year 2050. In this case study, the devised principles seemed to be adequate for the design of LDM and the approach deemed applicable with the scenario building methodology. According to the study findings, an application of LDM should be organized in such a way that users perceive LDM as a means for collaboratively making decisions rather than for gambling, that users are involved with the resulting decision as a proper incentive for meaningful participation and that dual incentives are provided for attracting and retaining users with the mechanism.

We plan the following strands of future work. Based on the experience gained from the case study regarding the scenario building process, we plan to refine the design principles of LDM, for example in strengthening user involvement through competitive and collaborative elements and in providing additional retaining incentives that encourage continued participation. Further investigations, particularly in controlled experiments, should help establish the precise impact of the single design principles. Second, we envision the application of LDM for collaborative ontology engineering. There, contributions and opinions of many stakeholders need to be gathered and reconciled in order to form a joint ontology. In this reconciliation process, conflicts, both on the logical and collaborative level, are likely to occur. The application of the market metaphor as a conflict resolution mechanism in collaborative ontology engineering by ranking the available conflict resolutions using decision markets seems to be a feasible approach.

Acknowledgment

The authors would like to thank Prof. Hornung of Bauhaus Luftfahrt and Niclas Randt of the Institute of Aircraft Design at the Technische Universität München for integrating the reported LDM case study in their seminar on scenario building.

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 ISBN: 978-1-61208-312-4