Technology Foresight for IT Investment: Multi-Criteria Decision-Making versus Prediction Markets

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This paper presents and compares two original techniques for disruptive technology assessment and foresight based on opposite paradigm: a management science approach (Multi-Criteria Decision-Making) versus a Web 2.0 approach (Prediction Market). These approaches are intended to support the management of a technology portfolio and the assessment of new technology by an IT organization. In order to explore the relevance of the research, we conducted several experiments in real environments. The results demonstrated that the rigor of management science and the participation of the Web 2.0 approach are complementary strengths for technology foresight.

Introduction

According to McKeen et al. (2003), one of the critical issues in IT management is to "situate the challenges facing the IT managers regarding emerging technology …". This requires companies to adopt a systematic process for staying up-to-date and assessing new technology for a potential integration into organizations. This article focuses on techniques that support the assessment of new (potentially disruptive) technology in order to evaluate how business can take advantage of them. Different management tools and techniques have been proposed in the scientific community and the literature (scenario planning, technology roadmap, ROI, real option) but few of them have been widely adopted by companies.

In this article, we briefly present and compare two approaches we designed and evaluated in two recent research projects. The first completed research assumed that a management science approach, "multi-criteria decision-making (MCDM)", is well adapted for technology foresight. We used and validated this approach for assessing mobile payment solutions. The second in-progress research investigates a Web 2.0 technique, "prediction market (PM)", was applied to technology assessment. Both research projects adopted a "design science" paradigm, such as defined by Hevner et al. (2004), which recommends a build-and-evaluate loop for building artifacts and evaluating them with field studies before being refined and reassessed.

In the next section we present the MCDM research we conducted in order to assess mobile payment solutions. Section 3 sketches the prediction market research for assessing portfolios of technologies. Section 4 compares the strengths and weaknesses of both solutions. Lastly, section 5 gives a first conclusion and also provides some ideas to be investigated in the future.

1. MCDM: A MANAGEMENT SCIENCE APPROACH

MCDM methods aim at supporting decisions in an effective way by analyzing a problem using either quantitative (e.g., cost, weight) or qualitative (e.g., quality of service, beauty) criteria simultaneously and concurrently. The idea behind MCDM methods is not to find the optimal solution (like a mathematical programming model) but rather try to determine what solution is the closest to be "optimal" in regards of several criteria or among existing solutions. To collect the data, decision-makers (i.e., experts) need to express their preferences by evaluating the alternatives and weighting the criteria.

Previous research indicates that MCDM could be used for technology foresight (Salo et al. 2003). Our research confirmed this claim as the results were quite convincing. We selected two formal MCDM methods to conduct an assessment and foresight of the mobile payment market in Switzerland. To support the research, we designed an integrated multi-actor multi-criteria approach with an original IT artifact.

1.1. Research Assumptions

Three distinct phases of the decision have been characterized by Simon (1955). These are intelligence, design, and choice. Bui (1984) argued that MCDM methods usually focus on the two last phases. In our case, the objective is to use MCDM methods for the intelligence phase of the decision process. The idea is to examine the environmental conditions and unveil potential issues before the establishment of the decision.

Technology foresight is a complex activity which implies a relatively high number of parameters to consider in order getting a complete picture. By definition, multi-criteria analysis is a very good candidate method to deal with this type of complex problem. In line with this idea, Salo et al. (2003) have suggested the use of MCDM methods for technology foresight. However, they reported that the potential of MCDM has not been fully explored in this context. They justified this phenomenon because of the recent emergence of technology foresight activities. Salo et al. (2003) also argued that one of MCDM incontestable strengths is the theoretical foundation, which is an advantage compared to the work that has previously been done in technology foresight.

We tested the hypothesis of MCDM's appropriateness for technology foresight in the field of mobile payments. We have assessed the current payment technology (i.e., card-based) and attempted to detect a possible disruption caused by an upcoming technology (i.e., phone-based).

1.2. Build phase

The requirements for a multi-actor multi-criteria analysis are not easily fulfilled as a great amount of data has to be collected, computed, and visualized. Obviously, the digitalization of the processes seems necessary. In other words, we need to use an IT artifact (i.e., a Group Decision Support System, GDSS) along the processes of an MCDM approach. As none of the existing MCDM tools found encompassed the features needed, we designed a new and original prototype with unique characteristics. We concentrated our efforts on the development of the user interface in order to improve the data collection, computation, and visualization.

Our prototype, PylaDESS, implements side-by-side two formal MCDM methods: ELECTRE I and the Weighted Sum Model (WSM). To collect the data, we used computerized card game, which greatly enhances the collection process and the interaction with the experts. To assist the visualization of the data, we implemented many different data cross-analysis modules. All of these features make PylaDESS a unique MCDM tool to support multi-actor and multi-criteria analysis. The iterative and incremental development of the IT artifact was done in laboratory and its testing was organized in a real environment. The design iterations allowed us to better managed the different constraints encountered during the analysis.

1.3. Evaluation phase

The design and evaluation phases were closely linked because of the build-and-evaluate loop. To evaluate our MCDM approach and tool for technology foresight, we conducted a three-year study (between 2003 and 2006) of the mobile payment market in Switzerland. Our analysis involved more than 20 companies represented each time by one to three experts. The experts interviewed were the mobile payment decision-makers in their respective companies. By involving a majority of the Swiss key actors (i.e., financial institutions, telcos, retailers, public transportation, technology providers), we were able to ensure a good representation of the current payment market in Switzerland.

Firstly, we asked the experts to assess a collection of existing mobile payment technologies. We collected the data with several campaigns of interviews during which we met the experts individually. Thanks to the group decision features of the IT artifact, we were able to easily gather, store, analyze, and visualize the data. This MCDM analysis also validated a set of relevant criteria (e.g., cost, ease of use, reliability) to evaluate mobile payment technologies. Moreover, it provided a consistent picture of the situation in the mobile payment market in Switzerland. The results of the research have already been presented in several academic papers such as (Ondrus and Pigneur 2007).

Secondly, in order to explore the relevance of our approach in a foresight context, we organized a workshop with the experts. The objective was twofold. First, we tested the use of PylaDESS in a group setting. Second, we analyzed the disruptive capabilities of an upcoming technology (i.e., NFC) in the current market. In general, PylaDESS performed quite well and the experts recognized that the results of our research reproduced a realistic image of the situation. We were able to confirm the current trends and potentially unveil some weak signals of emerging or disruptive technology.

2. PREDICTION MARKETS: AN EMERGING APPROACH

Prediction markets are future trading platforms whose contracts are ideas rather than goods or services. They have been used in many different contexts and often produced more accurate forecasts than traditional methods (Berg et al. 2003; Spann et al. 2003; Wolfers et al. 2004). Still considered as an emerging approach, they enable everybody to trade by aggregating the information disseminated among all actors. Furthermore, they allow traders to trade based on their own assumptions, without taking care on the hierarchy or other social pressures. Hanson (1992) made the assumption that prediction markets should improve the progress of science based on the absence of social, economical or political pressures.

Our early stage research already demonstrated the usefulness of prediction markets for technology foresight. It showed that the information disseminated between all actors was not equal to the information reported among the hierarchy. This difference was partially explained by the anonymity of the traders on the prediction market and by the rewarding process, based on the best performances, aka, based on the quality of the supplied information. To support this research, we iteratively designed, developed, operated and evaluated several prediction markets. Furthermore, following a design science paradigm, we designed our artifacts using build-and-evaluate loops supported with a field study, which consisted in operating the prediction markets in three different settings.

2.1. Research Assumptions

In R&D portfolio management, it is admitted (Chien 2002; Cooper et al. 1999) that in order to be effective, a mix of various qualitative and quantitative methods has to be applied for (1) selecting the right criteria, (2) collecting the data, (3) and negotiating the portfolio between the different stakeholders. Based on (Hanson 1992) our research assumption is that a prediction market could improve the R&D portfolio management for assessing the technologies of the portfolio. Prediction markets collect information coming from different actors who trade on the market, and aggregate this information in an automatically negotiated equilibrium price, corresponding to the valuation of the project. This market mechanism addresses the three weaknesses mentioned above: (1) no more criteria to be explicitly selected, (2) less data to be collected, and (3) fewer issues to be explicitly negotiated between actors. These three activities are replaced by the buy and sell trading of claims concerning the portfolio contents.

2.2. Build phase

To design our prediction market named MarMix, we used the three design steps from (Span et al. 2003). We decided to use YES/NO contracts with a "winner takes all" payoff function. To motivate the traders, we choose a play-money design with tournaments based on individual performance level. Finally, to ensure sufficient liquidity, we combined a continuous double auction market with a market maker. We conducted three iterations of the build-and-evaluate loop which allowed to us to improve and validate our design. This process was driven by the five following design fundamentals:

- To allow each trader to acquire the same comprehension of contracts and claims, we developed a specific *ontology* in order to formulate and understand the projects claims.
- The prediction market should allow any actor to test their ideas among the group, without requiring a review process or preliminary validation. For this purpose, we integrated an easy *IPO mechanism* for proposing new technologies on the market.
- The fact that usual "traders" are not specialists in market finance implies specific usability requirements on the human-computer interface for hiding *financial mechanisms* in order to reduce the trader's learning curve.
- Since it is sometimes difficult to motivate stakeholders to trade, an *incentive mechanism* seems to be appropriate. Our prediction market can be either remotely accessed by traders, or used during a group session with traders in the same location, for stimulating the market activity.
- Our prediction market includes an automatic negotiation agent i.e. an *automatic market maker*, allowing the traders to buy or sell each time new information is available. Thus the evaluation aggregates more information, compared to a double auction market were the traders must wait for a similar offer to make the deal.

2.3. Evaluation phase

For testing our design choices, we conducted three experiments. For the first two, we involved students and university staff. For the last (in-progress) iteration, we opened a prediction market for an R&D community.

The first experiment gave us the opportunity to test the various mechanisms of prediction markets and to implement the design choices elaborated during the design phase. After this first small-scale experiment, we decided to run a second large-scale experiment to test the improved prototype. This second experiment took place with 99 traders, playing during six weeks on 16 claims in summer 2006. During the whole experiment, we had a total of 3'071 transactions, representing 144'248 contracts. At the same time, we ran another experiment with the same prototype, dedicated to the prediction of the organizing city of the 2014 Winter Olympic Games, with 50 traders coming from various sport federations and specialized medias. The collected results were promising. Finally, we started our third experiment, which is still in progress, with claims specifically on technology and with the 200 researchers participating to a Swiss NSF program in the field of mobile information and communication systems.

3. COMPARISON OF TWO APPROACHES

In this section we compare the MCDM and prediction market approaches. To structure the comparison, we used three perspectives: the actors, the input, and the output.

3.1. The Actors

In the MCDM approach, the actors involved are usually a set of selected and relevant *experts*. They are generally motivated to participate in order to get access to the data and therefore knowledge that would augment their expertise.

In prediction markets, the participants are anybody interested in technology but are not always experts ("the crowd of Web 2.0"). They constitute a community of players who are driven by the game and its financial profits. As opposed to the MCDM approach, the prediction markets can easily indicate if players are good by considering the value of their portfolio and their total profit.

3.2. The Input and Process

A multi-criteria analysis requires a relatively great amount of data to collect. The best way to proceed is to meet the experts in a face-to-face mode. The advantage of this direct contact is a personalized assistance and interaction during the whole process. This should prevent

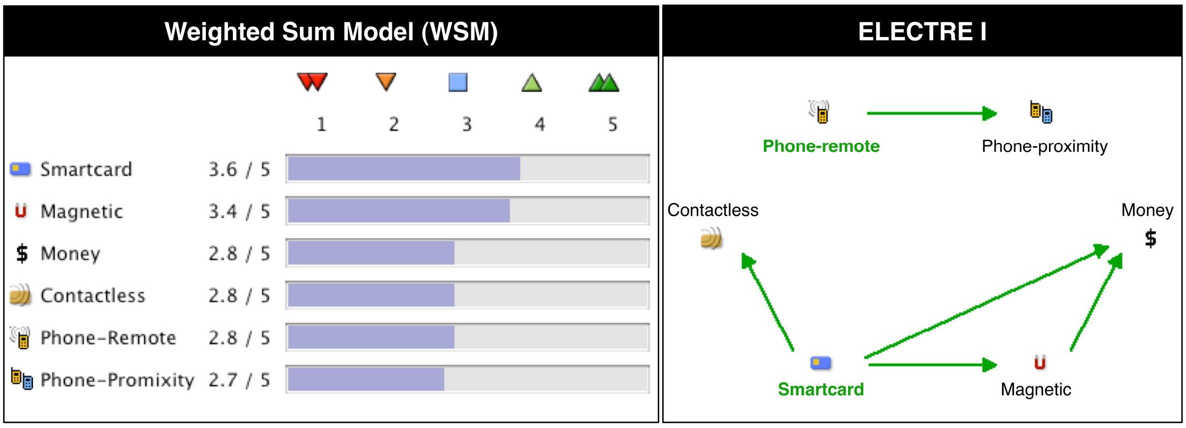

Figure 1: The outputs of the MCDM approach

erroneous data sets.

In the prediction markets, the participation of the players is self-organized. This facilitates the overall management of the analysis. However, the success of the prediction markets outcome depends on the good willing of the players to participate and trade without the pressure of the project managers.

3.3. The Output

The MCDM approach gives *a posteriori* results to support the resolution of a decision problem. At a specific time, the MCDM analysis draws a rather detailed picture of a situation benefiting from the granularity provided by the criteria. These criteria help explaining precisely the reasons of the outcome.

On the contrary, prediction markets are excellent tools for longitudinal studies due to the inherent nature of the data collection process. However, they give the prediction (i.e., the claim's price) without further explanations. In other words, MCDM methods are detailed snapshots taken at certain times and prediction markets are movies shot over a period of time.

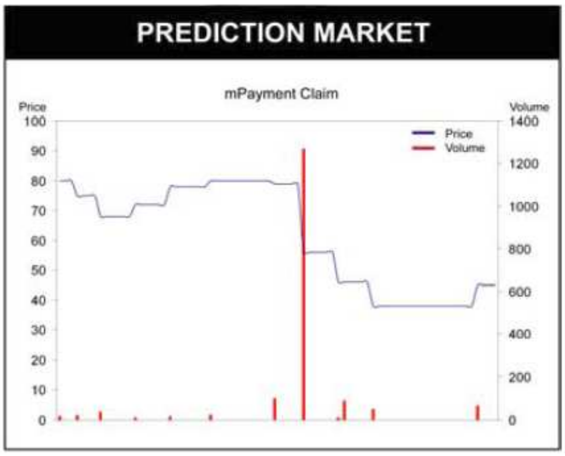

Figure 2: The output of the prediction market approach

CONCLUSIONS

Both approaches revealed some benefits and demonstrated their complementarity. On one side, the MCDM approach brought an *analytic* explanation of the phenomenon by a controlled and criteria-based evaluation. On the other side, prediction markets provide a *synthetic* aggregation of numerous individual beliefs that is constantly adjusted and made available for everyone. Therefore, we could not claim that one is better than the other. Interestingly, we found that the drawbacks identified could partially be solved by opting for the best aspects of both approaches.

For example, we could take consecutive snapshots during a given period of time to follow trends using a MCDM approach. Moreover, after few rounds of analysis, we could improve the data collection process by building an online user interface which would support the elicitation of the preferences without a face-to-face confrontation.

For prediction markets, the quality of the players could be ensured by opening the markets only to a practice community with its experts. Furthermore, the outcome of prediction markets could be enhanced by requesting more information about the actions of the players. The objective would be to monitor the behavior of the players in order to confirm that they are not just following the trend generated by the market.

In this paper, we presented two different promising approaches for technology foresight. We found that the combined strengths of the MCDM approach and prediction markets could be exploited for technology assessment and foresight to improve IT investment decisions.

Further research is required to confirm our first assumptions that a more systematic process for assessing new IT in organizations should rely on computer-based systems which integrate the rigor and experts' knowledge brought by the multi-actor MCDM approach, and the aggregation mechanisms and open participation of prediction markets.

Acknowledgments

The work presented in this paper was partially supported by the National Competence Center in Research on Mobile Information and Communication Systems (NCCR-MICS), a center supported by the Swiss National Science Foundation under grant number 5005-67322.

References

Berg, J.E., and Rietz, T.A. "Prediction Markets as Decision Support Systems," *Information Systems Frontiers* (5:1) 2003, pp 79-93.

Bui, T. "Building Effective Multiple Criteria Decision Models: A Decision Support System Approach," *Systems, Objectives, Solutions* (4) 1984, pp 3-16.

Chien, C.F. "A portfolio-evaluation framework for selecting R & D projects," *R and D Management* (32:4) 2002, pp 359-368.

Cooper, R.G., Edgett, S.J., and Kleinschmidt, E.J. "New product portfolio management: practices and performance," *Journal of Product Innovation Management* (16:4) 1999, pp 333-351.

Hanson, R. "Idea Futures: Encouraging an Honest Consensus," *Extropy* (3:2) 1992.

Hevner, A.R., March, S.T., Park, J., and Ram, S. "Design Science in Information Systems Research," *MIS Quarterly* (28:1), Mar 2004, pp 75-105.

McKeen, J., and Smith, H. Making IT Happen - Critical Issues in IT Management, 2003, pp. 366.

Ondrus, J. and Pigneur, Y., "Cross-industry preferences for mobile payments development in Switzerland," *Electronic Markets*, (17:2), 2007, pp. 142-152.

Salo, A., Gustafsson, T., and Ramanathan, R. "Multicriteria methods for technology foresight," *Journal of Forecasting* (22:2) 2003, pp 235-255.

Simon, H.A. A Behavioral Model of Rational Choice. Quarterly Journal of Economics (6), 1955, pp.99-118.

Spann, M., and Skiera, B. "Internet-Based Virtual Stock Markets for Business Forecasting," *Management Science* (49:10) 2003.

Wolfers, J., and Zitzewitz, E. "Prediction Markets," *Journal of Economic Perspectives* (18:2) 2004, pp 107-126.