PREDICTION MARKETS FOR COST AND RISK ASSESSMENT

By

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ABSTRACT

Several temporal and political factors can sometimes limit the effectiveness of traditional methods of project tracking and cost estimation. A large organization is susceptible to internal and external risks that are difficult to predict by a single person. Use of collective intelligence tools can help gather inputs from a crowd of people and help provide insight into future events with their collective wisdom. A prediction market is one such tool that provides an environment for traders to buy and sell contracts, whose values are tied to uncertain future events. Efficient prediction markets have been shown to outperform available polls and other forecasting mechanisms.
This thesis focuses mainly on the features of a prediction market, its use in the context of a large organization and the steps needed for its implementation. We believe that prediction markets can be a useful supplementary tool along with the existing cost estimation and project management tools in a large organization. They can help aggregate information and identify any direct or indirect factors that can impact cost, or schedule estimates, or create risk for the completion of a project.
Major design principles for implementation of prediction markets have been identified by the author based on seven mini case studies from different industries. The author also conducted three pilot studies at MIT and the observations from these have been used to identify best practices related to design and implementations of markets.
We found increased involvement of participants and increased awareness in the projects to be one of the major benefits of prediction markets. From the case studies, research and data collected from simulations, we found positive evidence that prediction markets can supplement the use of current estimation and risk assessment methodologies when deployed correctly, and help keep a check on the pulse of an organization by preparing it for any future events or outcomes.

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1.1 INTRODUCTION

A large organization comprises of a complex system formed of numerous physical, functional and conceptual elements that continuously interact with each other. Managing projects in such an environment is always challenging. A constant vigilance is required by the project manager to ensure that all the deliverables are completed on time and delivered within the scheduled budget. The complexity of project increases manifold as the number of involved stakeholders increases and as the internal and external dependencies to the deliverables increase.

Identification of risks early in the project life cycle and implementation of corrective measures always forms the key to successful projects.

Figure 1 shows some of the factors that a project manager needs to account for while managing a project.

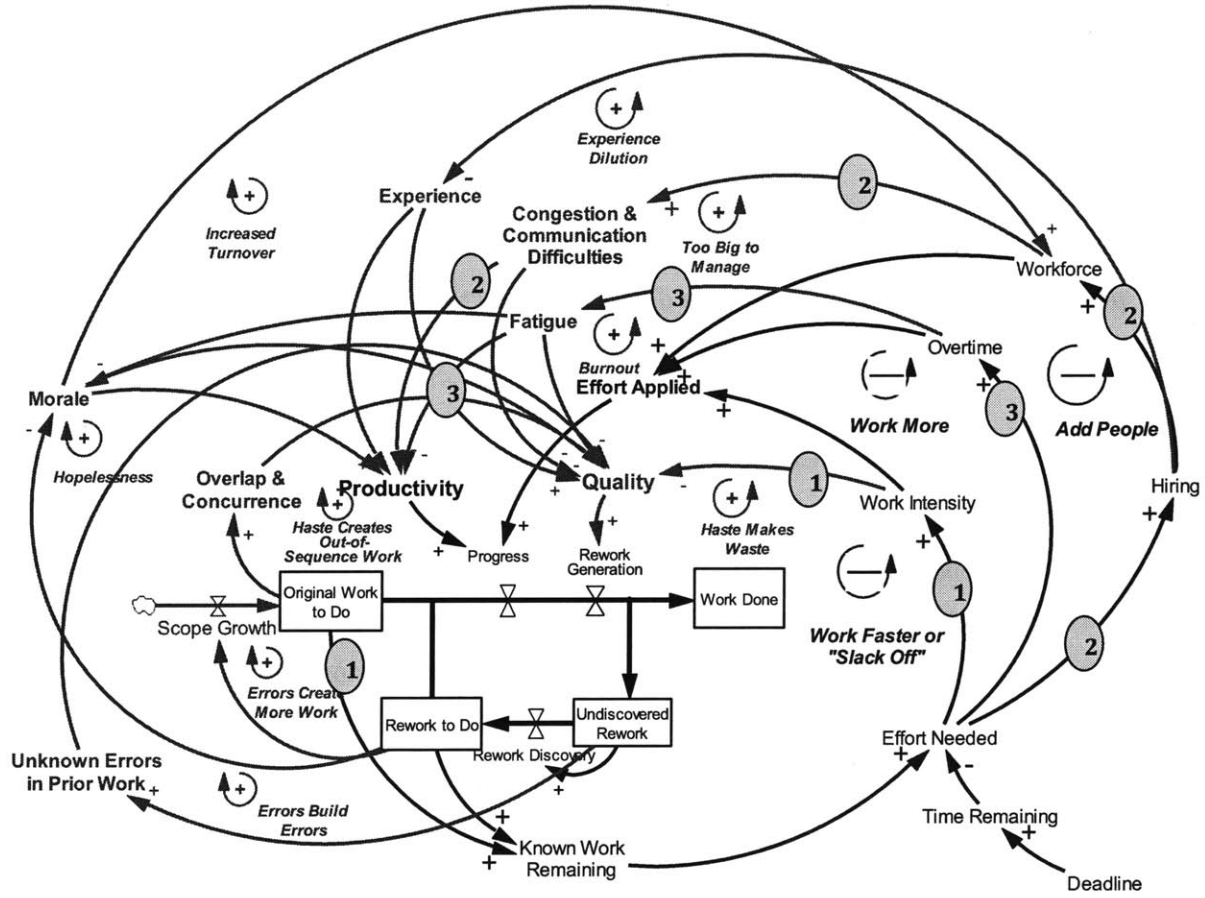

Figure 1: System dynamics view of project management (Class Material, MIT-ESD.36: Systems Project Management)

The larger the scale of the project more will be the risk involved. It is clear from the figure that managing a project is not a straightforward task, as many factors need to be considered prior to making a decision.

For example, consider *loop 1*. As the original work to be done increases, the work remaining also increases. The means more effort is required to finish the work, which leads to risk of increase in work intensity. Increase in work intensity can affect the quality of work, which can in turn create more rework to be done.

Consider another case when increase in scope of work or decrease in time of the project can lead to increase in effort required for completion of the project. The project manager can handle this by either hiring more people in the team (*loop 2*) or by asking his employees to do overtime (*loop 3*). Hiring more people (*loop 2*) will result in increase in workforce, which can lead to risk of communication difficulties in the project, negatively impacting the productivity of the project. As the productivity decreases, the progress of the project decreases ultimately leading to more pressure and rework. Doing overtime (*loop 3*) can lead to the risk of fatigue in the employees again negatively affecting productivity. These are examples of just some of the risks faced in the projects. To manage such issues, two main steps are required:

- Assuring that the cost and risk assessment methodologies used in the project are as accurate as possible.
- Keeping track of the pulse of the project and the organization, so as to identify as soon as possible any events that may have a direct or indirect impact.

In the next sub-sections we will talk in brief about each of these steps.

1.2 UNCERTAINITIES IN COST AND RISK ASSESSMENT

It is never possible to perform accurate estimations for a project, as the amount of information available at the start of the project is usually limited. As a project progresses through different phases, the uncertainty involved decreases and more relevant information becomes available; but at the same time, it becomes harder and more expensive to correct prior errors or to revise existing estimates. This concept was popularized by Barry Boehm (Boehm, 1981) and Steve McConnell (McConnell, 1996) as 'Cone of Uncertainty'.

Figure 2 shows the cone of uncertainty in software projects (Boehm, 1981):

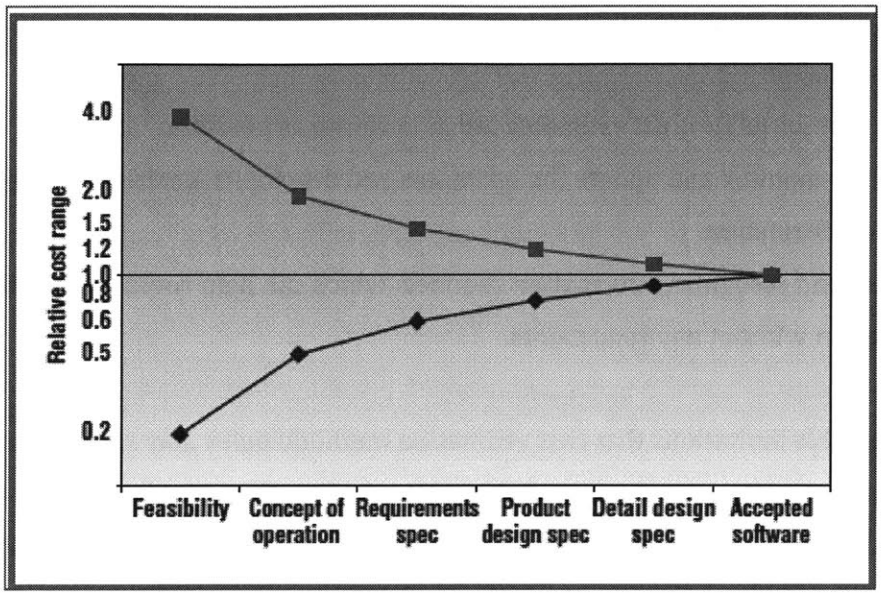

Figure 2: Cone of Uncertainty (Little, 2006)

Thus, in order to optimize the project execution, it becomes important that the uncertainty factor be reduced as early as possible through efficient information aggregation and by identifying the triggers of change in the project as early as possible.

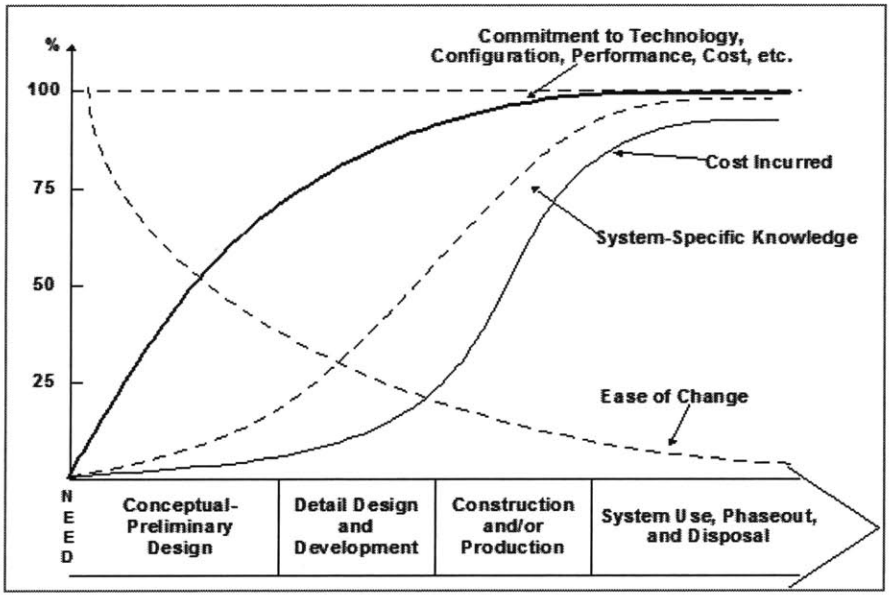

Figure 3: Commitment vs. Cost vs. Ease of Change (Blanchard & Fabrycky, 1998)

Also as shown in Figure 3, the gap between commitment to the project for various parameters and the system specific knowledge available is quite large initially. As the project progresses, the ease of implementing any change based on new knowledge decreases while the cost incurred for making any change increases.

Hence, for successfully executing and managing projects, accurate cost and risk assessment is crucial. It is essential to:

- Ensure that initial forecast estimates are as accurate as possible.
- Constantly monitor and update the estimates and develop risk mitigation steps based on updated information.
- Establish and recognize information channels which can help reveal and distribute useful information without any constraints.

Some of the probable limitations that cost estimation methodologies may suffer from are:

- Cost Estimating Relationships (CERs) based on technical factors (e.g. - number of resources, etc) rather than programmatic "soft" factors (e.g. - loss in employee motivation due to lay-offs)
- Most estimates are not dynamically updated and hence there is a time lag involved which may make the original estimates outdated.
- Generally estimation is done by key decision makers who are few in number, and thus may carry specific biases or may be driven by limited information.
- Time pressures and other constraints like hierarchy and bureaucracy may affect the quality of estimates, making it necessary that they are reviewed and updated continuously.

The above scenarios are not limited to software projects only, but are valid for all industries. For example, defense programs for weapons acquisition have historically taken longer, been over budget and delivered fewer quantities and capabilities than planned.
Some of the reasons reported for such discrepancies include:

- *Lack of discipline in estimation:* sometimes all the required factors or experienced people are not consulted during the estimation process (GAO, 2008).
- *Unrealistic expectations:* The estimates can sometimes be too optimistic (GAO, 2008)
- *Initial estimates tend to "anchor" expectations* (Aranda & Easterbrook, 2005): Initial figures of estimates set too high expectations from the start which is difficult to meet later on. Also, it is later on difficult to incorporate any modifications.

It is also worthwhile to note that of the 23 programs assessed by the GAO report (GAO, 2006), around 10 are expecting development cost overruns greater than 30% or have delayed the delivery of initial operational capability by at least one year. See Table 1 for more details.

Table 1: Development Cost Overruns by Decade (in Fiscal Year 2005 Dollars) and Key Reform Efforts (GAO, 2006)

1970 - 1979	1980 - 1989	1990 - 1999
Development cost overrun: **$13 billion** (30%)	Development cost overrun: **$12 billion** (39%)	Development cost overrun: **$15 billion** (40%)
Key Studies and Initiatives Impacting the Defense Acquisition Process		
• 1970 Fitzhugh Commission • 1972 Commission on Government Procurement	• 1981 Carlucci Initiatives • 1982 Grace Commission 1986 Packard Commission	• 1994 Federal Acquisition Streamlining Act • 1996 Clinger-Cohen Act
DOD Acquisition Policy Changes		
• 1971 DOD 5000 policy established • 1975 Policy revised • 1977 Policy revised	• 1980 Policy revised • 1982 Policy revised • 1985 Policy revised • 1986 Policy revised • 1987 Policy revised	• 1991 Policy revised • 1996 Policy revised

Source: DOD (data); GAO (analysis and presentation).

One of the key recommendations for executive action from this report (GAO, 2006) is to ensure that appropriate knowledge and information is captured and used at critical junctures, specifically at the following key points:

- Program start
- Design review for transitioning from system integration to system demonstration
- Production commitment

There exist several risks that need to be accounted for sustainability and profitability of an organization. Some of the risks are mentioned in Table 2 (Light, 2010):

Table 2: Different Project Risks (Light, 2010)

RISKS	DEFINITION	EXAMPLES
Operational Risk	Will the organization be able develop a deliverable successfully so that the benefit exceeds the total operation costs.	• Unavailability of resources and infrastructure • Excessive support costs • Iterative costs not accounted for in initial estimates • Increased costs resulting from difficulty in tracking and reporting system capability
Complexity Risk	How complex the project is and will they have an impact on project benefits	• Independencies with other projects or programs • Multiple technologies • Multiple stakeholders • Complex or intricate operation or construction
Technology	How reliable are the	• Security risks due to limitations of

Risk	chosen technologies	technology • Integration problems due to complex technology • Vendor skill shortage
External Risk	Will external conditions have an impact the project	• Incorrect or inadequate economic considerations • Leadership changes leading to change in priorities • Merger and acquisitions
Organizational Risk	Will there be an impact due to weak sponsorship or inadequate management	• Management changes affecting project sponsorship • Inexperienced or ineffective project management
Schedule Risk	Will the project be delivered within the promised schedule	• Staff unavailability • Inadequate backup options for resources can affect schedule • Work from multiple locations and environments can impact coordination and schedule
Financial Risk	Will the project be completed profitably within estimated budget	• Influence of any of the above risks can lead to increased financial costs • Unclear or uncertain scope of the project • Lack of experience and inefficient estimates

Most of the organizations focus on capabilities to handle these risks with better frameworks, tools and strategies. Managing risks requires that organizations not only focus on their mitigation but also keep a close check on any trigger points that can give an earlier indication of these. One of the ways to do this is to gather information from the most valuable component of a project or program – the group of people involved directly or indirectly with the program.

1.3 GENERATING VALUE FROM COLLECTIVE WISDOM

As the World Wide Web has grown in popularity, the world has been becoming smaller and smaller. New social interaction platforms, business models and communication mechanisms are being developed everywhere. This advancement has made it possible for large organizations to operate in multiple locations or environments, large group of people to work together from anywhere in the world, and for information to be accessed and distributed in real time across the world.
Many terms like 'Collective Intelligence', 'Crowd-sourcing', 'Wisdom of Crowds' etc. are being used to demonstrate the effectiveness of the new operating models that have been evolving. These terms

refer to similar concept of harnessing collective inputs from large group of people and generating valuable insights for the operator.

Collective Intelligence is broadly defined as "groups of individuals doing things collectively that seem intelligent" (Malone, Laubacher, & Dellarocas, 2009). Websites like Wikipedia, Google etc are all examples of groups or organizations operating effectively through collective intelligence.

Crowd sourcing is another term that is frequently used to demonstrate effectiveness of using the crowd, and refers mainly to the act of outsourcing tasks traditionally performed by the owner, to a large number of selective or undefined groups of people or community. Popular examples include Amazon Mechanical Turk, Linux operating system, etc.

James Surowiecki popularized the term 'Wisdom of Crowds' by stating that "a diverse collection of independently-deciding individual is likely to make certain types of decisions and predictions better than individuals or even experts on their own" (Surowiecki, 2005). He states that the ability to tap into the minds of the crowd can potentially change the way a business or organization operates. Crowd wisdom or collective intelligence can be advantageous in the following areas as per Surowiecki (Surowiecki, 2005):

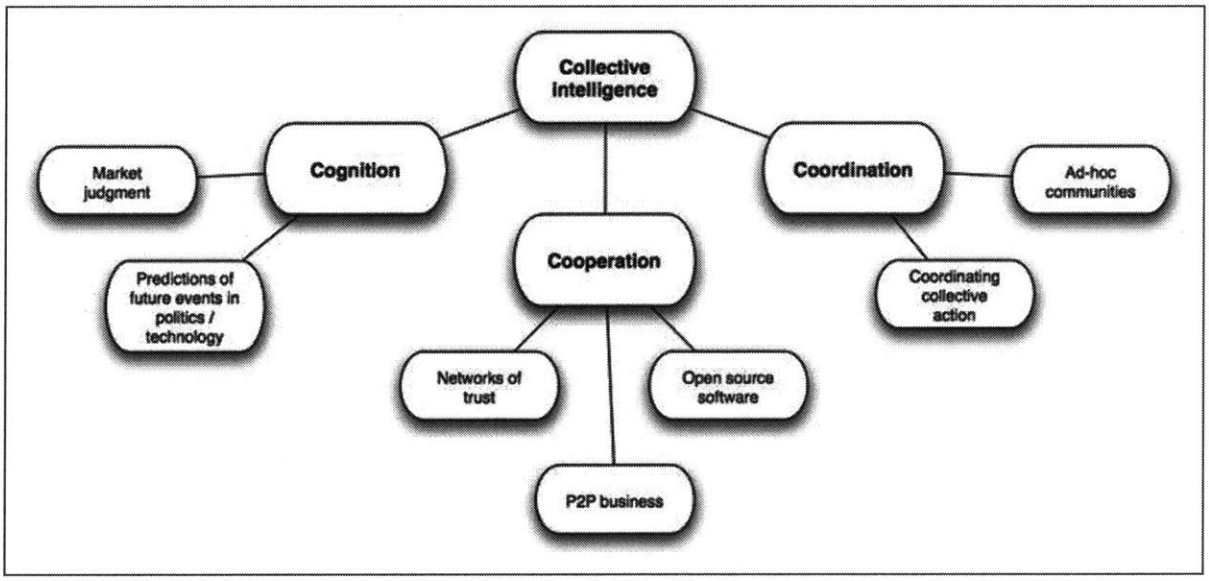

Figure 4: Types and examples of collective intelligence discussed in the books 'The wisdom of crowds' and 'Smart mobs' (Generozova, 2006)

Cognition refers to the ability to think and process information.

Cooperation refers to the ability of groups of people to build networks of trust and to operate without any control or enforcement on their behavior.

Coordination refers to the ability to work together or in accord with each other without collision and with the purpose of optimizing mutual benefits.

Thus, an organization can improve its efficiency substantially by harnessing and utilizing the collective wisdom of the crowd ('crowd' can be the employees of the company or people outside of organization possessing the knowledge relevant to the organization).

While working with the crowds through the collective intelligence tools, the main organizational goals can be listed under two categories (Malone, Laubacher, & Dellarocas, 2009):

- *To generate something new or to 'Create'*
- *To evaluate and select alternatives or to 'Decide'.*

Further, an activity can be accomplished by using the crowd in different ways - either the members of crowd work 'independent' of each other or they are 'dependent' on each other for contributions (Malone, Laubacher, & Dellarocas, 2009).

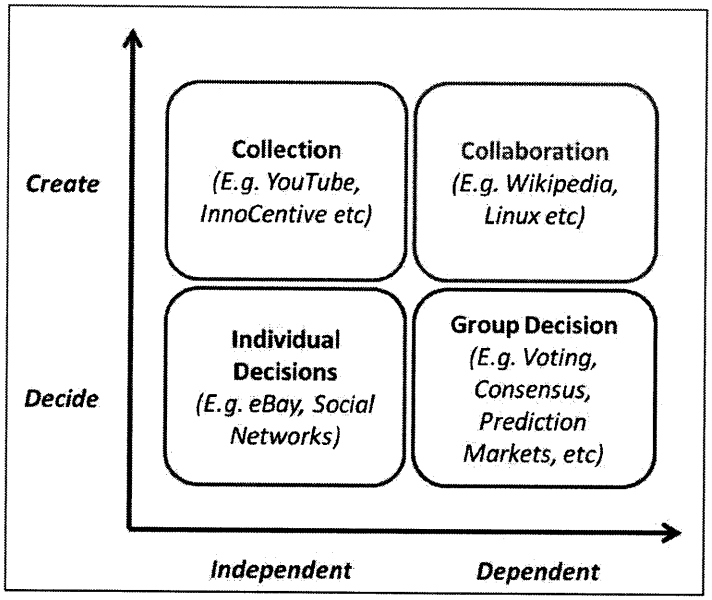

Figure 5: Primary Organization Goals in Collective Intelligence Systems (Malone, Laubacher, & Dellarocas, 2009)

An effective collective intelligence tool that facilitates group decision is Prediction Markets. This tool allows people to buy and sell shares of information or predictions related to future events and will be discussed in detail in the next chapter.

Prediction markets can be effective for organizations in a situation when inputs from the members of the crowd need to be collected and aggregated so as to generate a decision represented by the crowd as a whole. These can also help keep track of the organization's pulse and get an earlier glimpse of any trigger events that can have an impact on the project, program or organization.

1.4 ORGANIZATION OF THE THESIS

This thesis has the following objective: "Determine feasibility of implementing prediction markets to surface potential program risks, and generate cost /schedule estimates as a supplement to existing estimation methodologies".
It also attempts to answer the following questions:

- How can prediction markets be useful to large organizations?
- What are the best practices and design principles for implementing prediction markets?

Chapter 2 discusses in detail the concept of prediction markets. We will briefly overview their history and purpose. We will also study the different types of prediction markets and contract structures. The advantages of prediction markets and some of the challenges associated have also been discussed.

Chapter 3 reviews some of the case studies in which prediction markets were used. Their objective, strategy and results have been outlined. These case studies were selected from various sources and provide an insight into different applications and aspects of prediction markets. The key observations and lessons learned from each case study have also been discussed.

Chapter 4 gives an account of three pilot simulations that were conducted by the author at MIT. The execution strategy and the results of each simulation have been outlined. The key observations and lessons learned from each exercise have also been discussed.

Chapter 5 deals with the design considerations required for prediction markets. Key components of the market are discussed in detail. A case study related to defense acquisition program is also described.

Chapter 6 is a summary of the author's perception of usefulness of prediction markets for cost and risk assessment. Recommendations and best practices based on the case studies and simulations have also been listed.

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2 INTRODUCTION TO PREDICTION MARKETS

An effective way to capture knowledge and to utilize collective intelligence of all team members is to use prediction markets or information aggregation markets. Such a market can be used to support the existing estimation methodologies for generating more accurate cost and schedule estimates.

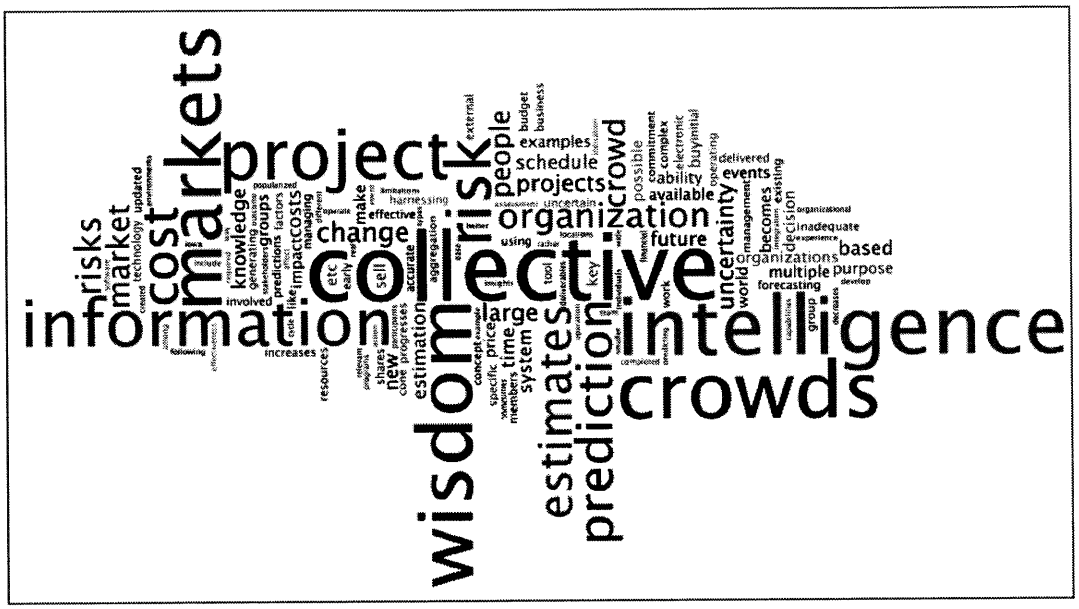


Figure 6: Terms associated with prediction markets

2.1 PREDICTION MARKETS: HISTORY AND PURPOSE

Prediction Markets are steadily emerging as a promising forecasting mechanism for efficiently handling the dynamic aggregation of dispersed information among various agents (Tziralis & Tatsiopoulos, 2007). The terminology used to describe the prediction market concept is rather wide and can be described as 'prediction markets', 'information markets', 'decision markets', 'electronic markets' or 'virtual markets' (Tziralis & Tatsiopoulos, 2007)

They are a judgmental forecasting method (Graefe, 2009) where the price mechanism of the market automatically mines and aggregates information scattered among participants and uses this information in the form of market values, so as to make predictions about specific future events (Berg & Thomas, 2003). In essence, prediction markets are speculative markets created for the purpose of predicting outcome of an uncertain future event. It provides an environment for traders to buy and sell contracts whose values are tied to uncertain future events.

Prediction markets first appeared in 1988, when researchers at the University of Iowa's business school came up with idea of giving students hands-on experience in trading markets, such as stock or commodities. Instead of using play money, they created a real market in which students could

buy and sell contracts whose payoff depended on outcome of future election events- e.g. the next president of the United States. The Iowa Electronics Markets (IEM) is now a thriving nonprofit enterprise. (Tetlock & Hahn, 2006)

Figure 7 shows the performance of Iowa Electronic Markets compared to Gallup Polls in predicting Presidential election outcomes in United States:

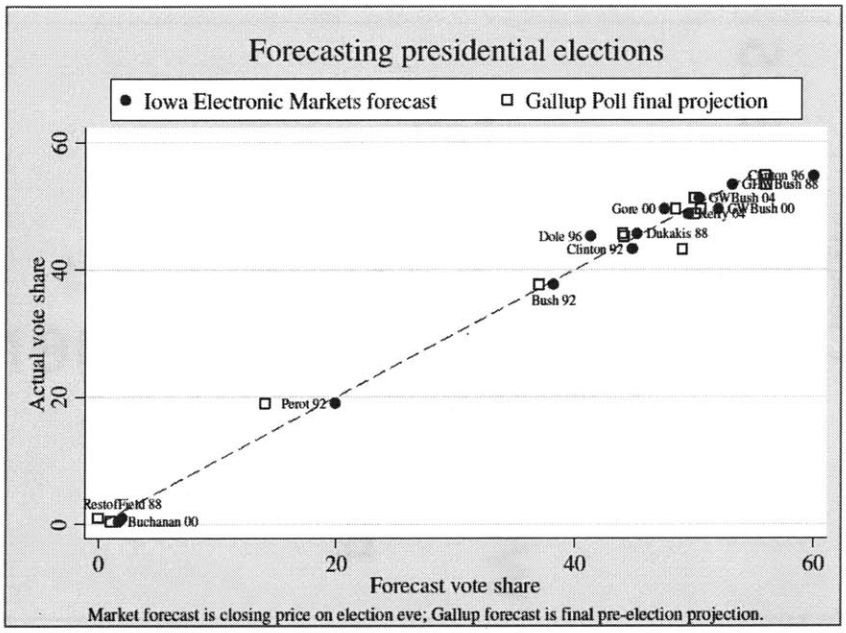


Figure 7: Iowa Electronic Markets - Forecasting Presidential elections (Zitzewitz & Wolfers, 2006)

In the above figure, it is to be noted that over the 13 candidacies from 1988-2004, the average absolute error of forecasts by IEM was 1.6 percent, while the corresponding error for Gallup Poll was 1.9 percent (Zitzewitz & Wolfers, 2006).

The figure 8 shows a sample prediction market that is commercially available (intrade.com):

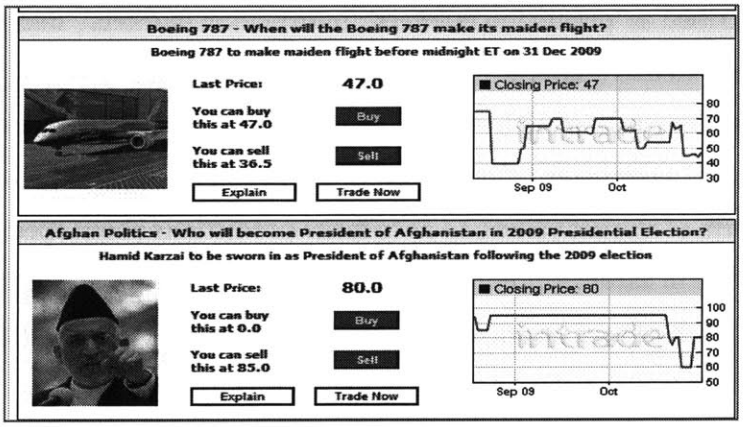


Figure 8: Sample commercial Prediction Market on intrade.com (intrade.com)

In the above market for example, users can trade on the 'stock' or question "Boeing 787 to make maiden flight before midnight ET on 31 Dec 2009". If they believe this event will occur, they can buy the shares for this stock at the price of $47, otherwise they have the option to sell their shares at price of $36.50. Based on the action they take, the price of the share will change and will give an indication of user belief. The share they buy will give an indication of their belief in the likelihood of the event, while the number of shares they buy will give an indication of the confidence they have in their belief. The final value of the share should represent the mean belief of the likelihood of occurrence of this event by the people who traded in the market.

Table 3 contains a list of some of the popular existing prediction markets and their purpose:

Table 3: Existing prediction markets

Prediction Market	Purpose
Foresight Exchange (ideosphere.com) ***FTPredict (FTPredict.com)*** ***Inkling Markets (inklingmarkets.com)*** ***Intrade (Intrade.com)***	Public play money markets to predict future events
Hollywood Stock Exchange (HSX.com)	Buying and selling shares of movies
The Sim Exchange (simexchange.com)	Predicting upcoming best selling and top rated video games
BlogShares (blogshares.com)	Stock market for web blogs
Iowa Electronic Markets (tippie.uiowa.edu/iem)	Market for trading on political outcomes
Tradesports (this site recently closed)	Market for trading on sporting events
Media Predict (mediapredict.com)	Market for predicting various aspects of mass media

2.2 THE THEORY BEHIND PREDICTION MARKETS

It is believed that if the prediction market is well functioning, contract prices will reflect the collective wisdom of market participants.

The theoretical foundations of prediction markets lie in the efficient market hypothesis, which states that a sufficient number of marginal traders with rational expectations, who maximize utility through maximizing profits, drive prices in the market in such a way that there is no opportunity or arbitrage (Shvarts & Green, 2007).

In other words, if there is an all-or-nothing contract that pays a dollar for the occurrence of a specific event and nothing otherwise, then the price of such a contract denotes the market

probability or the likelihood of the occurrence of that event (Manski, 2005). Thus, as per efficient market hypothesis, prediction markets can efficiently aggregate relevant private information from all traders, and the price of contract acts as an indicator for that information.

Manski (2005) used a model to state that price of the contract is a "particular quantile of the distribution of traders' beliefs", and does not reveal the mean belief that the traders hold.

Wolfers and Zitzewitz on the other hand, through several models summarized that prediction markets actually do aggregate beliefs and the prediction market price equals the mean beliefs among traders (Zitzewitz & Wolfers, 2006). A brief description of the model is given below:

Consider a prediction market, where traders can buy and sell a binary contract (i.e. an all-or-nothing contract), which pays \$1 when the event occurs, and \$0 otherwise.

The traders' beliefs are heterogeneous, and the trader *j*'s belief that the event will occur is denoted by *Qj*

All traders wish to maximize their subjectively expected utility.

Wealth is only affected by the event via the prediction market and the initial wealth level is denoted by *Y*. Let *X* denote the number of prediction market securities purchased at price π.

The following equation summarizes the trader's trading activity:

$$Max\ EUj = Qj.Log[Y + Xj(1 - \pi)] + (1 - \mathrm{Qj}).\mathrm{Log}[\mathrm{Y} - \mathrm{Xj}\pi]$$

Solving this equation, yields: $Xj = Y.\frac{Qj-\pi}{\pi.(1-\pi)}$

For the prediction market to be in equilibrium, supply should equal demand. For solving this condition, the following relation is obtained:

$$\pi = \int_{-\infty}^{\infty} Q.f(Q)dQ = \mathrm{Q_{Mean}}$$

This proves that prediction market price equals mean belief among traders (Zitzewitz & Wolfers, 2006). The authors also state that efficacy of forecast price may differ slightly ("close to \$0 or \$1") from actual probability in some cases due to factors like low trade volume; disperse distribution of beliefs or higher risk-acceptance.

The above theories however do strengthen the claim that the contract prices can give us an indication of the beliefs of traders. If operated in an organizational setting where our focus is not on the exact price of contract, but on the behavior of price changes, prediction markets can prove to be useful tools.

2.3 TYPES AND CONTRACT STRUCTURES

There are three primary types of prediction markets (Zitzewitz & Wolfers, 2004):

- **Winner Takes All Market:** In this type, the contract pays a specified amount if and only if the world achieves some specific conditions, with the price of the contract reflecting the market's assessment of the probability of that occurrence.
- **Index Market:** In this type, contract pays an amount reflected in some condition of the world, such as the percentage of the vote a candidate receives or the inches of cumulative snowfall in a city.
- **Spread Market:** In this type, contracts specify the cutoff that determines whether an event occurs (such as win margins in football). These basic contract types can be extended to generate additional predictions and measures of market uncertainty, such as the probability that a candidate will receive 40% percent of the vote, 50%, 60% etc

Table 4 illustrates some examples for each type:

Table 4: Different Contract Structures (Adapted from (Zitzewitz & Wolfers, 2004)):

Contract	*Example*	*Details*	*Reveals market expectation of . . .*
Winner-take-all	Event y: Al Gore wins the popular vote.	Contract costs $\$p$. Pays \$1 if and only if event y occurs. Bid according to value of $\$p$.	Probability that event y occurs, $p(y)$.
Index	Contract pays \$1 for every percentage point of the popular vote won by Al Gore.	Contract pays $\$y$.	Mean value of outcome y: $E[y]$.
Spread	Contract pays even money if Gore wins more than y^*% of the popular vote.	Contract costs \$1. Pays \$2 if $y > y^*$. Pays \$0 otherwise. Bid according to the value of y^*.	Median value of y.

Prediction markets are most notably used today for predicting election outcomes, forecasting product sales, movie box office returns and sporting events (Zitzewitz & Wolfers, 2004). Information markets have also been deployed at Hewlett-Packard Corporation for making sales forecasts, and were found to be more effective than traditional methods. "Not only did the market predictions consistently beat the official HP forecasts; the outcomes predicted are consistent with

the probabilistic predictions of the IAM (Information Aggregation Market)." (Charles & Kay-Yut, 2002)

Google also launched an internal prediction market in April 2005. The Google markets are similar to Iowa Electronic Markets, and have survey questions like "How many users will Gmail have?" Common type of markets included those forecasting demand. (Masse, 2008) "Google's prediction markets are reasonably efficient, but did exhibit four specific biases: an overpricing of favorites, short aversion, optimism, and an under-pricing of extreme outcomes. New employees and inexperienced traders appear to suffer more from these biases, and as market participants gained experience over the course of our sample period, the biases become less pronounced." (Masse, 2008)

2.4 ESTABLISHING USEFULNESS OF PREDICTION MARKETS

In chapter 1, we talked about some of the challenges faced by large organizations in performing cost and risk assessment. Let us discuss some of the benefits that prediction markets can provide either directly or indirectly, in addressing these challenges.

2.4.1 VALUE PROPOSITION AND POSSIBLE BENEFITS

Prediction markets have been generally found useful in forecasting future events, for information aggregation and for opinion generation. They can also act as a supplementary tool to existing estimation methods and prove to be a valuable project management tool.

2.4.1.1 PREDICTION MARKETS AS A SUPPLEMENTARY TOOL FOR ESTIMATION

Figure 9 below gives a brief comparison between existing cost estimation techniques and the prediction markets. The goal here is to compare the probable shortcomings of the former, with the possible advantages of the latter.

- Prediction markets can help take into account the "soft" factors for estimation by leveraging information from individuals with diverse backgrounds, who can all participate via this medium. Various rewards can be given to participants, which can incentivize them to seek out quality information.
- Prediction markets can help dynamically update original estimates or help identify triggers for change by enabling frequent sampling of information.

- Shifting the focus from few individual decision makers to a larger group helps in eliminating or reducing any personal biases or errors that could creep in due to time or information constraints.

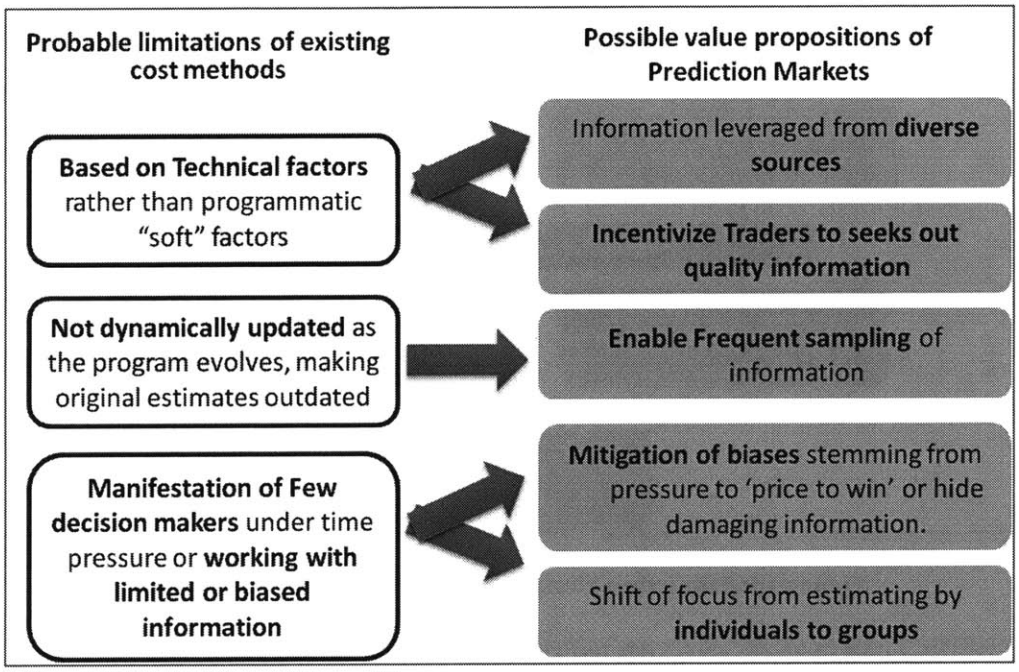


Figure 9: Value Propositions of prediction markets

2.4.1.2 PREDICTION MARKETS AS A PROJECT MANAGEMENT TOOL

Along with supplementing the cost and risk assessment practices of an organization or program, prediction markets can also provide secondary benefits as a valuable project management tool. Figure 10 shows some of these benefits:

- Prediction markets satisfy the current need for better forecasting tools and also help in identifying informal and formal information channels within the company.
- They can help realize various benefits with minimal investment in terms of cost, resources and staff time.
- They can help organize and integrate the tacit information within the organization, which is difficult to measure using other methods.
- Prediction markets can be easily implemented using customized tools and available software solutions. Most of the organizations these days do not need to build the prediction market software themselves.
- Ability to be deployed in a secure software environment helps usage in all industries like defense, medical devices, automobile etc.

- Information can be easily conveyed to different participants through the prediction markets and serves as a communication channel for participants to share ideas or opinions.

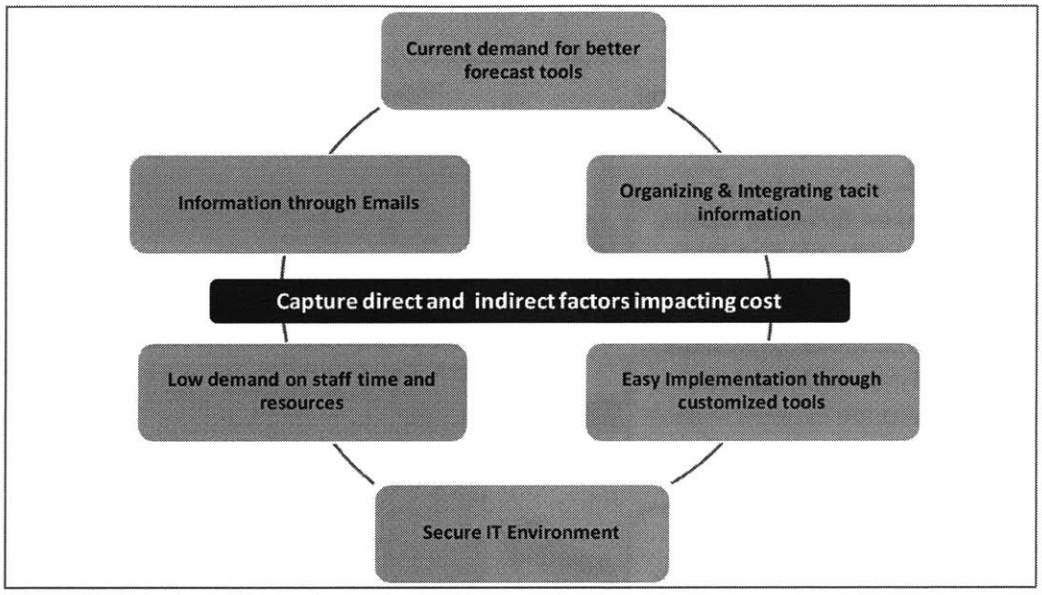


Figure 10: Prediction Markets as a useful Management tool

2.4.1.3 PREDICTION MARKETS AS AN INFORMATION AGGREGATION TOOL

The most useful and perhaps the most obvious function of prediction markets is to act as a medium for collecting dispersed amount of information from various users and to display it collectively in one place.

The main difference between prediction markets and other information collection tools like surveys is that in surveys, all participants have the same incentives for participation, while in prediction markets, there is an opportunity for a participant with additional information to gain better incentives compared to others (Heyman, 2010). Thus, there is a greater probability of getting information that is not commonly available.

Prediction markets can offer the following benefits (Hall, 2010), if used correctly:

- **Capture tacit knowledge:** Prediction markets can help take into account the tacit knowledge of participants gained through experience or a particular job, and is otherwise difficult to convey.
- **Neutralize Bias:** Aggregating of information also helps in accounting for the errors due to incomplete information, by supplementing the information from other sources. Participants from different backgrounds and departments can use their knowledge to fill in gaps and hence neutralize any biases that may have been introduced in the system.

- **Anonymity:** Participants can be more receptive in revealing their beliefs using prediction markets, as it helps them to reveal information while remaining anonymous or without any obligation to reveal how they received their information.
- **Eliminate Bias:** Once the disincentives for revealing information have been removed, participants can freely reveal information with the sole purpose of gaining profit in the market. This can help reduce any biases they may have due to personal or professional preferences.
- **Suppress Bias:** As with the participants in the market, decision makers implementing the market can get an insight into the information revealed, and take decisions more objectively and try to remove any biases that may creep into their decisions.
- **Real-time view:** Effective information aggregation also depends on how frequently the information is collected. Given the dynamic nature of prediction markets, participants can trade throughout the market cycle and reveal information as soon as it is available. This helps give a real-time view on what the beliefs of different participants are.

2.4.2 ISSUES AND BIASES IN PREDICTION MARKETS

Prediction markets can suffer from certain issues, and it is essential to utilize their full benefits that these issues addressed properly:

- **Thin Markets:** Prediction requires enough buyers and sellers making enough transactions to produce a clear market price that summarizes the market prediction. In "thin" markets where buyer, sellers and their trades are few, the prediction market can sometimes be ineffective. This can lead to two type of problems (Hall, 2010):
    - **Liquidity problems:** This means that there are not enough buyers in the market to buy the information from the sellers and vice-versa. One way to address this problem is by using the 'Market Scoring Rule' suggested by Robin Hanson (Hanson, 2003), based on which an automated market maker can be used for facilitating trades.
    - **Aggregation problems:** This means that there are not enough knowledgeable traders in the market, or in other words the market does not have enough information. As the number of traders decrease, chances of finding useful information can also decrease (Hall, 2010). Such an issue can be addressed by ensuring that participants from different business areas and environments are invited to participate.

Some research also suggests that prediction markets can be effective with as few as sixteen active traders (Christiansen, 2007).

- **Biases and irrationality:** While prediction markets have been strikingly accurate when they meet the criteria for effective markets, scholars have noted some deviations from "perfect" rationality.
    - First, while traders' preferences may bias their trades, such as when partisans buy political futures contracts for their favored candidate (Forsythe, Rietz, & Ross, 1999), the prediction market price of contracts will remain accurate so long as the enough marginal traders remain objective (e.g., their profit motives outweigh their preferences). 'Marginal traders' refers to the traders who "submit limit orders close to the market price" (Hall, 2010), with the intention of earning profit and high rate of returns. Marginal traders generally show no indication of bias in their transactions and thus help in neutralizing any biased trades from other participants. Hence, prediction markets do not require all traders be rational as long as marginal market exchange is motivated by rational traders (Gruca & Berg, 2007), (Tziralis & Tatsiopoulos, 2007).
    - Secondly in some cases, as in horse racing, prediction markets participants may over-price long shots (so that contract holders receive a smaller payoff relative to the true probability of the event occurring) and under-price high probability events; though (Cowgill, Wolfers, & Zitzewitz, 2009) suggest that precisely the opposite biases occurred when Google employees traded in internal company prediction markets forecasting Google's future. Moreover, prediction markets may be less effective at accurately predicting extremely likely or unlikely events (Zitzewitz & Wolfers, 2004)

- **Manipulation and Bubbles:** A sufficiently endowed and motivated trader might attempt to manipulate a prediction market by purchasing contracts in desired directions. A candidate for elected office, for example, might purchase contracts on himself to generate apparent momentum and publicity. Manipulation can be due to various reasons like:
    - **Profit-driven manipulation:** Some traders could make uninformative trades meant to mislead other participants, so as to make profit at a later stage. This can be particularly harmful in case of thin markets. This can be countered by increasing

liquidity in the market, and also making the crowd aware that there might be some manipulators involved who can resort to such tactics (Hall, 2010).

- **Self-fulfilling trade manipulation:** If some traders have control over the real outcome of an event, they might try to alter the outcome in accordance with their trades (Hall, 2010). For example, a manager can deliberately try to extend the deadline of a project if he has bet against the successful completion of the project by that deadline. This can be avoided by ensuring that the incentives for trading are in line with the goal of organization and success of the project.

Speculative bubbles are also possible in prediction markets, a non-trivial concern in light of recent macroeconomic events. Wolfers and Zitzewitz (2004) propose that a speculative bubble occurred in political prediction markets on whether Hillary Clinton would win the 2004 Democratic presidential elections. To some extent, markets may self correct manipulation and bubbles. The best defense against manipulation is sufficient liquidity so that profit seeking traders, recognizing that the manipulated market prices are inaccurate trade for contracts to bring predictions back into line.

- **Decision-maker Interventions:** When prediction markets are used for decision making, the decision makers might study the market for likelihood of outcome of an event, and then use that information for making further decisions or taking actions that might alter the original outcome of the event (Hall, 2010). This affects the traders negatively as their position in the market might change. This may make them reveal lesser or incorrect information or discourage them altogether from trading leading to market failure. Some of the solutions to address this problem are:
  - **Designing the contracts with very short time horizons:** Short time horizons will imply that the market would have been liquidated by the time the decision makers take any action that can alter the outcome (Hall, 2010). But this will also reduce the utility of the market as most of the contracts with longer time horizons can provide useful information like pattern of price changes, identification of trigger events in case of long term projects etc.
  - **Including only those events in the market on which decision makers do not have an impact:** This can solve the problem, when the questions are related more to policy etc. E.g. Forecasting GDP of a country (Hall, 2010). In a commercial

organization most of the events to be included in the market are usually ones on which decision makers wish to have certain control.

- **Asking multiple questions in the market:** A market can include multiple events and contracts so that the traders can hedge their bets across various contracts and the effect of decision-makers' intervention is minimal on the traders.

In such situations we may find that the solution to this problem includes all the above three points to some extent. Varying the time horizon of the markets, selecting the right type of questions to ask and asking multiple questions can help resolve this problem. Also, decision makers can liquefy the market if the feel that their decision might affect the outcome, and create a new market related to that outcome.

3 SETTING UP PREDICTION MARKETS IN A LARGE ORGANIZATION

Prediction markets can be particularly useful in a large organization setting where employees may be constrained – legally, professionally, bureaucratically or politically - from directly revealing information underlying their beliefs (Hall, 2010).

3.1 SOME CASE STUDIES OF PREDICTION MARKETS IN PRACTICE

This section briefly discusses some of the case studies related to prediction markets. These case studies have been collected from different sources, and are helpful in giving a general picture of how such prediction markets have been used in the past, and how the results can be used.
Key observations from each case study have been listed, and later summarized in form of best practices that can be used for implementing prediction markets.

3.1.1 CASE STUDY 1: SUPPORTING IT PROJECT MANAGEMENT

OBJECTIVE:

A large multi-national corporation, Acxiom wished to implement a new integrated software test environment (Remidez, 2007). As part of the first phase, 26 projects were to be transitioned into a new testing environment, with each project having a milestone associated with it. A prediction market was implemented in which the contracts were related to the 26 milestones.

EXECUTION STRATEGY:

Commercially available software was used for deploying prediction markets. Around 33 participants were invited, based out of four locations, with all being part of the software testing business unit. They were asked to trade stocks based on their beliefs on likelihood of the projects meeting their milestones on time.
Sample question asked was: "Project XYZ will complete automated testing in the new system by 6/15" (Remidez, 2007). Incentives were provided for being the highest portfolio holder at the market closure, in the form of "half-day off work for first place, company T-shirt for second place and gift certificate for restaurant in third place". The trading period was six weeks.

RESULTS:

The preliminary results of the study included:

- High participation (87%) with average trader making 23.28 trades.
- Market was able to correctly predict 24 out of 26 milestones.

- Due to prediction market, project manager was able to clarify and revise an important milestone.
- Overall experience was found positive and led to increased discussions and cohesion between groups.
- There were some concerns raised over insider-trading since the market participants had control over the outcome of contracts.

Key Observations and lessons learnt:

- *If used effectively along with usual project management methodologies, prediction markets can supplement the information available to the project manager.*
- *Incentives for participants should be aligned with the company goals and project aspirations in mind. Some companies may not be very liberal in incorporating prediction markets results with their company policies. E.g. - 'Half-day off work' for the winner might not be in line with some companies' policies, while such an incentive may also lead to market manipulation and hence fueling the concerns regarding insider-trading.*

3.1.2 CASE STUDY 2: TOOL FOR MBA COURSE LEARNING

OBJECTIVE:

The University Of Haifa School Of Management employed prediction markets (Geifman & Raban, 2009) to enhance the experience of learning aspects of decision making taught to students, by supplementing theoretical concepts with hands-on experience of internet-based tools. The activities were designed to address the class objectives, and the trading topics were aligned with the MBA program.

EXECUTION STRATEGY:

Three types of markets were implemented in class, in order to aggregate information, to predict future events and to collate opinions. All markets were implemented using commercially available software.

As part of the first market, students were presented with a crime scenario and details about 6 suspects. Segments of partial information (like suspect alibi etc) were distributed among all participants in such a way that when all information is collected, the guilt person could be identified. Students bought the stocks of suspect they thought was guilty, and sold the stock of ones

they believed to be innocent. The activity ran for 20 minutes and students were not allowed to talk with each other. The incentive (a book) was given to the student with highest account balance.

As part of the second market, students were asked to manage firms competing in a virtual environment. They were required to manage a firm for number of game-years (lasting few days) with the goal of achieving the highest shareholder value by end of last year. A prediction market was set up to predict the winning team based on the events happening across the number of game-years.

A third market was set up to identify public opinions and preference regarding measures that should be taken to decrease the economic divide between the rich and the poor. Three measures were proposed for students to trade against. The trading activity was supplemented by class discussion on the suggested measures. As per available information, this module is still under progress.

RESULTS:

In the first market regarding information aggregation, only one group was able to correctly identify the suspect. Although most of the groups' responses were incorrect, the exercise served its purpose by supplementing the learning process for students.

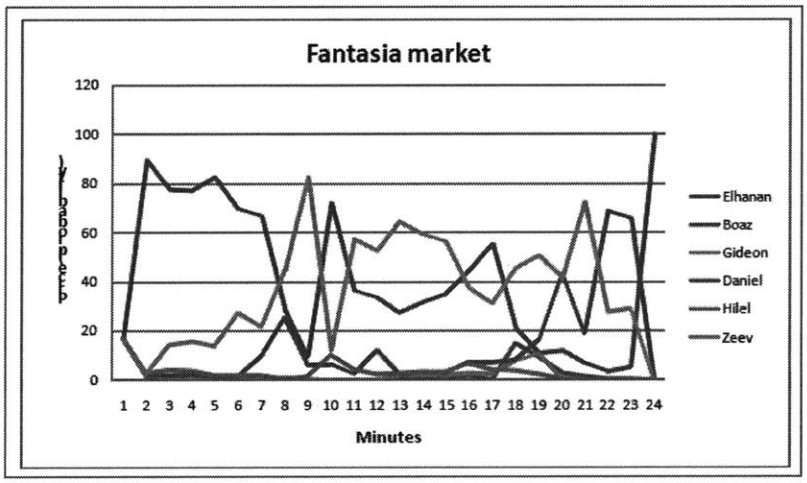


Figure 11: Information Aggregation Market Trading Chart (Geifman & Raban, 2009)

In the second market regarding prediction, about 38 students participated in the trading, representing 18 firms. Three such markets were run, and two out of these three markets were able to correctly predict the winning firm.

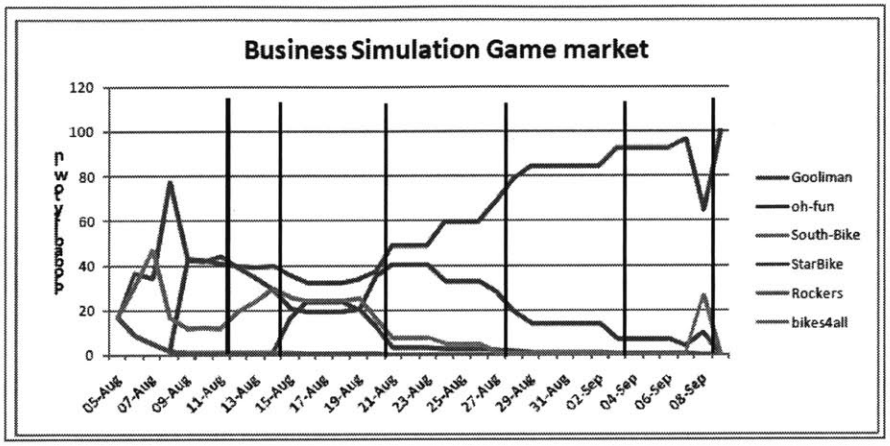


Figure 12: Prediction Market Trading Chart (Geifman & Raban, 2009)

In the third market regarding opinion formulation, there was not supposed to be any correct answer as there was no 'objective truth' regarding the question. Nevertheless, the market helped reach a group consensus regarding the measure to be adopted and offered useful insight on how the opinions changed during the discussion process.

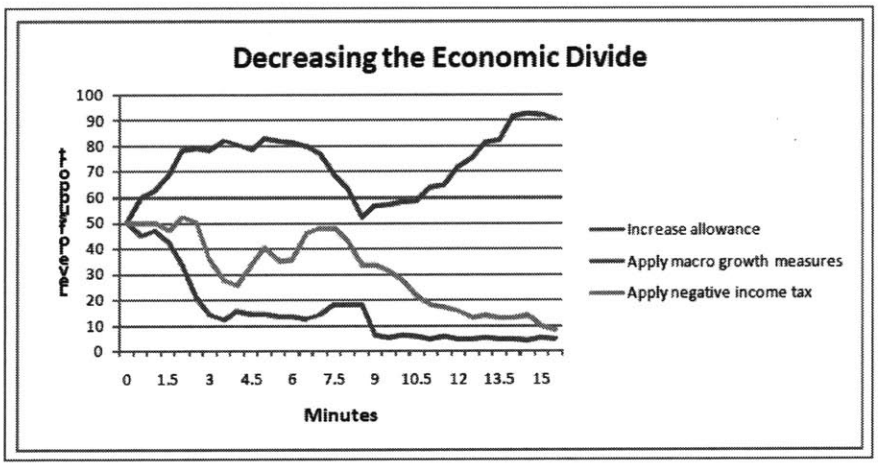


Figure 13: Opinion Formulation Market Trading Chart (Geifman & Raban, 2009)

Key Observations and lessons learnt:

- *Initial training on how the prediction software tools are to be used should be provided to the participants. This can help reduce participant's initial hesitation in participating and also help run prediction market more effectively.*
- *Prediction market can be used in various ways – in terms of collecting data, predicting outcomes or for opinion formulation. It is essential to determine what purpose will best suit an organization's needs.*
- *The length of the trading period is important. The authors of the case study observed that in the first market after 6-8 minutes of trading, the focus of students shifted from information*

aggregation to game-like competition. The duration of trading cycle played a key role in the other two markets as well.

3.1.3 CASE STUDY 3: FORECASTING THE OPENING DAY OF NEWLY CONSTRUCTED BUILDING

OBJECTIVE:

Researchers at Carnegie Mellon University designed the Gate Hillman Prediction market (Sandholm, 2010) to predict the opening day of the Gates and Hillman Centre – a new computers science building at Carnegie Mellon University.

EXECUTION STRATEGY:

The prediction market was accessible to everyone publicly on the web, and trading was open to anyone with Carnegie Mellon email-addresses. People who had direct influence on the building construction were not allowed to participate. Raffle tickets were used as currency; with each user being allocated 20 tickets on sign-up with an additional bonus of two tickets per week depending on user participation. Incentives were given in the form of cash prizes and allocated in proportion to the number of raffle tickets each user possessed at the end.

The following question was traded against:

"The earliest date on which at least 50% of the occupiable space of the GHC receives a temporary occupancy permit".

The market traded for about a year, starting from September 4, 2008 and finally closing on August 7, 2009. Since the purpose of market was to converge on a single date, the market was very fine grained with 365 separate contracts, each representing one day of the year. The authors of the market combined these contracts with a 'span-based elicitation' method, by which users could trade against a range of dates instead of selecting a single date. They could further shorten this range based on experience or confidence in their information. Automated market maker was used for facilitating trades in the prediction market.

The information in the market was supplemented by official public communications (through blog and email). Other source of information to traders was the exterior construction state of the building itself and the weather conditions.

RESULT:

Market ran for about a year, with 169 traders performing at least one trade, and 39,842 bets placed in all. The price of the contract of August 7, 2009 converged to 1 about five hours before the public

announcement regarding the building occupancy was made. Thus, the market was able to predict the result five hours before the official announcement. Figure 14 shows the trading activity on the Gates-Hillman prediction market.

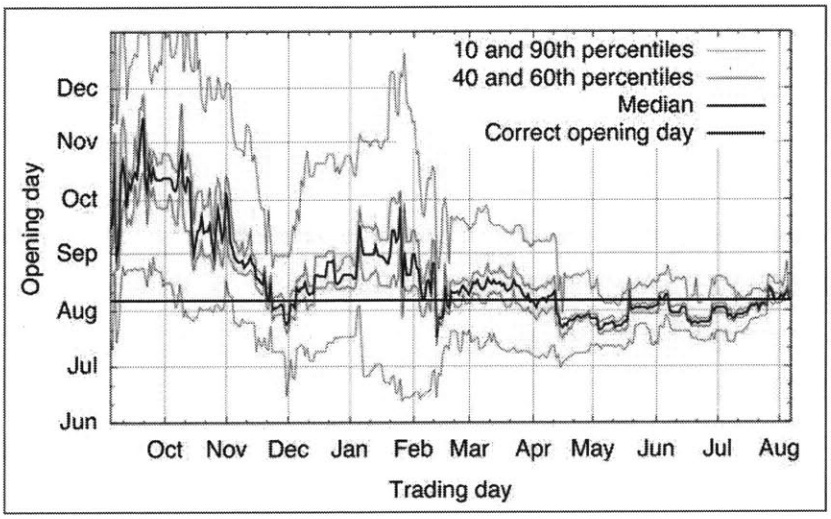


Figure 14: Trading Pattern for Gates-Hillman Prediction Market (Sandholm 2010)

There were two main issues observed in the prediction market by the authors which were attributed to the automated market maker. These issues are described as 'spikiness' and 'liquid-insensitivity' by the authors.

The 'spikiness' represented high volatility of prices between choices (i.e. dates), and occurred as a result of trader's bets amplifying the small differences between individual dates with low prices. The authors attributed the reason to the cost function of the automated market maker. Please refer to the paper for more details. The authors also stated that the automated market maker is liquid insensitive[1] and thus, can further contribute towards huge price variations between the contracts.

Key Observations and lessons learnt:

- *As per this case, if there are lots of contracts with low price, huge price variations between contracts can occur during trading. This can be avoided by either using an automated market maker with an optimum cost function, or by avoiding a large number of contracts in designing the market.*

[1] Liquid insensitivity implies that a one dollar bet placed at the start of the market, changes the price by the same amount as the one dollar bet placed anytime afterwards in the market. This is in contrast to transactions in the real world, where small bets have smaller impacts on the prices as the market grows larger (Sandholm, 2010).

- *Market maker should be designed in such a way that it is 'liquidity sensitive', i.e. takes into account the state of the market and frequency of trades in deciding the price impact of a particular trade.*

3.1.4 CASE STUDY 4: TRACKING INFORMATION FLOWS IN A LARGE PRODUCT COMPANY

OBJECTIVE:

Google set up an internal prediction market (Coles, Lakhani, & McAfee, 2007) to track information flows and to forecast events like product launch dates or to the scenario of a competitor taking a particular action.

EXECUTION STRATEGY:

Google prediction markets (GPM) were set up internally within Google in 2005. An entirely new set of markets were chosen for every quarter, and a play money currency called 'Gooble' was used. The markets were open to all Google employees and every employee could browse and see the results of the market.

Each trader's account was reset at beginning of a quarter and all traders were given 10,000 Goobles to trade. The trading was based on the standard continuous double auction method. At the end of each quarter, the traders' final balance of Goobles was converted into lottery tickets. Six lottery tickets were drawn at random and $1,000 were given to each ticket holder. Award of $1,000 was also given to the most active trader each quarter and gift-certificates and T-shirts were given to other top performers.

Google built its own software platform for trading purposes. In the first quarter of operation, there were 24 markets or questions within GPM and 95 total contracts or answers that were being traded. These markets or questions were decided upon based on interviews with managers to find events of interest within that particular quarter. The questions asked included forecasting demand for a particular product, opening dates for a specific international Google office, list of important quarterly corporate objectives of Google and questions related to product launch of a competitor. There were also fun questions based on movies, television and sports to make the markets more enjoyable. Figure 15 shows the distribution of questions in the Google prediction market.

Type	Example	Share of markets
Demand forecasting	# of Gmail users at end of quarter	20%
Performance	Google Talk quality rating	15%
Company news	Russia office to open	10%
Industry news	Will Apple release an Intel-based Mac?	19%
Decision markets	Will users of feature A users use feature B more?	2%
Fun	How many "rotten tomatoes" will Episode III get?	33%
Unique participants		1,463
Orders		253,192
Trades		70,706
Markets run (questions)		270
Securities (answers)		1,116

Figure 15: Google prediction market Distribution (Cowgill, Wolfers, & Zitzewitz, 2009)

RESULT:

In the first quarter, about 1085 traders participated, with 7685 trades being made in all. Most of these traders were from sales, engineering, operations and product management functions in the company. The group of most active traders comprised of 13 traders, and accounted for 48% of the total trades in the market for that quarter.

When results were compared, the GPM final prices were good estimates of the real world outcomes as shown below (Figure 16):

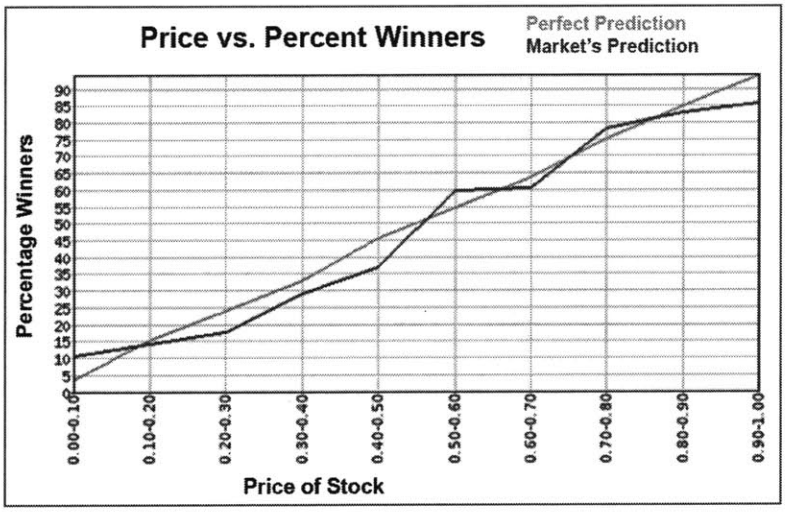


Figure 16: Accuracy of Google Prediction Markets (Coles, Lakhani, & McAfee, 2007)

In some cases it was even observed that the price of the most expensive contract 10 weeks before the closing date represented the final outcome of the real world. It was observed that more than the financial incentives, traders were more motivated by non-monetary incentives like T-shirts, recognition among colleagues and reputation as a top trader in the market.

After data analysis, two main biases were revealed for the Google prediction market (Cowgill, Wolfers, & Zitzewitz, 2009). The first was the optimistic bias – i.e. the contracts related to optimistic

outcomes were observed to be overpriced (by 10 percentage points) and extreme outcomes were underpriced. This bias was even greater on the days when the Google stock price increased in the real market. This bias could be attributed to trading by newly hired employees

Another important observation was that opinions on certain questions was correlated among employees (Cowgill, Wolfers, & Zitzewitz, 2009) who had close proximity to each other – either in terms of physical proximity in office (correlation was very strong between employees sitting next to each other, and declined as the distance increased, with no correlation between employees on different floors of the building); and also in terms of proximity of a project work – i.e. employees working on same project had more correlated trading.

Key Observations and lessons learnt:

- *Prediction markets, apart from helping in project management decisions and forecasting can also give useful insight into the information flow within an organization.*
- *A company's culture drives the incentives that motivate the employees – in this case the social incentives were much more effective than financial incentives.*
- *Google prediction markets had about 30% of the questions as 'fun' questions. This keeps all employees involved and ensures a fun experience.*
- *Care should be taken on selecting the traders for the market and their demographics should be kept in mind while analyzing the data. As the number of traders increase, the effectiveness of the market also increases, provided there is enough diversity in the focus group. Otherwise, biases like the optimistic bias can influence the accuracy of the market.*

3.1.5 CASE STUDY 5: IMPLEMENTING CULTURAL CHANGE AND IMPROVING DECISION MAKING

OBJECTIVE:

Ford Research and Advanced Engineering group implemented prediction market (Montgomery, Cavaretta, & Stieg, 2010)within the company to make sound decisions based on facts and data, and also to develop a cultural change.

EXECUTION STRATEGY:

Ford R&A group developed and tested an internal prediction market, called Ford Prediction Exchange in 2006. They were used for predicting sales volume and yielded better error rates than official forecasts.

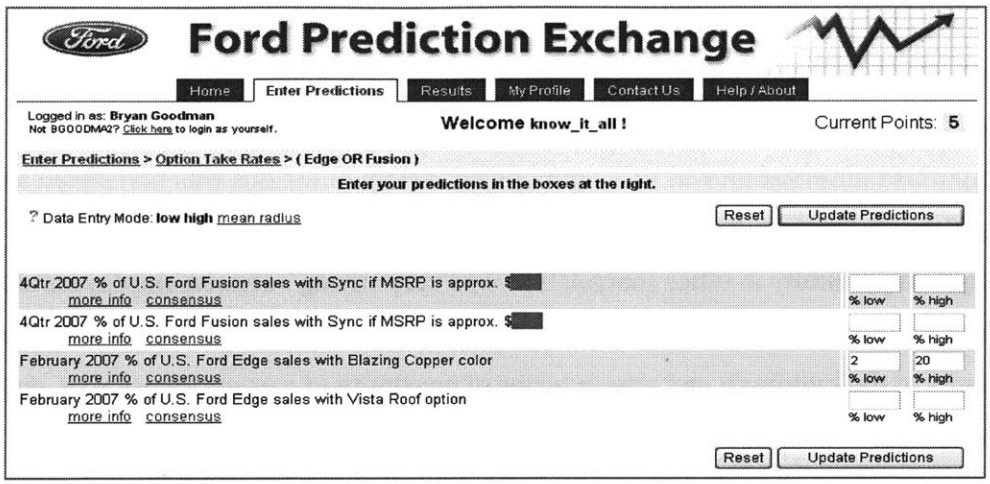


Figure 17: Ford Internal Prediction Market (Montgomery, Cavaretta, & Stieg, 2010)

Figure 17 shows the screenshot of the internal prediction market used by Ford in 2006.

Based on initial results, internal prediction market was improved and implemented in 2009 (using commercially available software) with more monetary investment. The primary business customer was the Vehicle feature planning group and questions like "Which features should Ford develop?" were asked. Since there was no objective answer to questions like these, the Ford Prediction Exchange differed slightly from traditional markets by:

- Having more subjective questions with longer time horizon for forecasting
- Ending the market whenever required and not based upon the actual real event timeline
- Scoring for questions was done based on market results and was not corrected by actual results.

Ford ran an initial pilot in 2009 of 3 week duration, in which 1,000 employees were invited to participate. Participants were mainly from Research, HR, Marketing and IT groups. About one-third of these participants registered and around one-fourth actively traded, with about 7,000 trades in all and 350 user comments. A larger pilot was run in May 2010 of 2 weeks duration, in which 10,000 employees from Product Development, Marketing and IT were invited. Over 900 people in all traded with more than 13,200 trades and 2,700 user comments.

To maintain confidentiality, the participation was limited to Ford salaried employees and select group of traders. Some strategic questions were asked in a more general manner, so as to avoid revealing any sensitive information.

Around eight business partners of Ford R&A group were involved in the internal prediction market and the type of questions asked focused on:

- Vehicle features:

    - Desirability/Acceptance
    - Price points
    - Trader-submitted ideas
- Vehicle sales volumes
- Strategy
- Macroeconomics
- Alternative power-train market penetration
- Employee incentives

RESULTS:

The employees demonstrated strong desire to express their opinions to management through the user comments. This was very useful aspect of the market and every business partner was able to realize their value. These comments increased in frequency and length as the market progressed giving Ford the opportunity to collect useful user inputs.

Another secondary benefit that Ford realized was generating interest and educating the traders. About 93% of the market participants reported that they learned more about the Ford business through the exercise. Ford is still trying to figure out how to best use the internal market for forecasting time and cost for programs which are already employing multiple models of forecasting and how to promote the prediction market concept by collecting more data on their success.

Key Observations and lessons learnt:

- *Depending on the information most relevant to an organization, prediction markets can be customized (like more subjective questions, scoring of market independent of actual event occurrence etc).*
- *The participant comments should be recorded while trading and can prove to be a valuable asset for the business in filling data voids. It not only provides the employees with more information, but also provides an opportunity for the employees to express their opinions to senior management.*
- *Implementation of prediction markets in a large organization may initially take time and effort to prove their value. Multiple markets over long time horizons may be required to get corporate acceptance and full-cooperation.*

3.1.6 CASE STUDY 6: POLICY ANALYSIS MARKET (PAM)

OBJECTIVE: The Policy Analysis Market (PAM) was created by Pentagon in 2003 to forecast and aggregate assessments related to geopolitical instabilities in Middle East (Hall, 2010). It was presumed that information aggregated through PAM would be more effective than traditional methods.

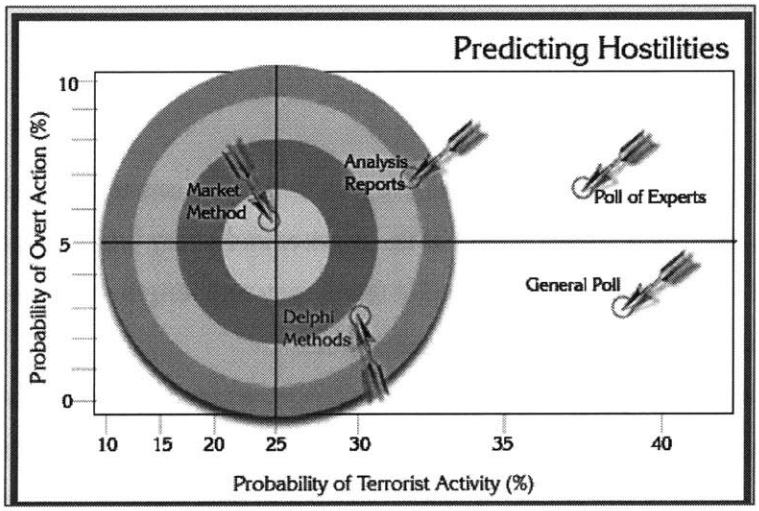


Figure 18: Vision of DARPA for contribution of Markets to Intelligence. (Looney, 2003)

EXECUTION STRATEGY:

This project was funded by Defense Advanced Research Projects Agency (DARPA) and was part of a larger program called FutureMAP (Future Markets Applied to Prediction). A company called NetExchange got the contract for designing the prediction market called PAM. There were three types of securities to be traded: 'Regional',' Global' and 'Special Event' (Hanson, Polk, Ledyard, & Ishikida, 2003).

As part of the 'Regional' securities, PAM was to predict for each major country in Middle East, various indicators of economic health, military activity, political instability, U.S. military activity and financial involvement of U.S. (Abramowicz, 2007)

As part of the 'Global' securities, indicators to be predicted included U.S. equities, U.S. GDP, trade, U.S. military deaths and terrorism related deaths. E.g. "likely occurrence of a regime change in Syria" (Looney, 2003)

'Special-event' securities were more short term issues that were based on observations and nominated within the market. E.g. "e.g., U.S. recognition of Palestine in the first quarter of 2005" (Looney, 2003)

The Intelligence Unit of the Economist agreed to assess the data and judge the value of the securities.

The market was to be open to the public (initially open to 1000 participants with plans of expanding to 10000 participants), while the government was to act as the Market Maker.

RESULT:

The program never got off to a start as there was a strong negative political and public reaction. There was general concern that the market was anti-democratic and could be manipulated by terrorists – E.g. buying futures for a violent attack and then carrying out the attack for gain in the market portfolio (although available information suggests that the markets for predicting terrorist attacks and assassinations were unlikely to be included in PAM). Senators Ron Wyden and Byron Dorgan denounced the program as "harebrained" and "useless" (Surowiecki, 2005). Years after the failure of the market, opinions are mixed and it is still believed that the PAM was in fact a step in the right direction and the initial claims by skeptics at the time were unfounded (Abramowicz, 2007).

Key Observations and lessons learnt:

- *This case study proves that it is very important to set the right context for the market so that participants are aware of what the goal is. This is particularly required when the questions revolve are of sensitive nature. Prediction market thrives on insider information, but such information in case of some scenarios (e.g. terrorism etc) can lead to negative reactions.*
- *PAM was supposed to be open to public and the government was supposed to act as market maker. This meant that to avoid unnecessary losses to the government, there would be a restriction on the amount traders would be able to spend, which would have resulted in lesser trades per person leading to higher probability of false information. In such scenarios where there is restriction on betting amounts and limit on trading* (Hall, 2010)*, it becomes extremely important that the traders are selected carefully so that there is not too much noise in the market. A central market maker should also be useful to avoid any issues due to less liquidity.*
- *This study also demonstrates that it is important to get a buy-in from senior management prior to start of the market. Management support is very important for prediction market to succeed initially.*

3.1.7 CASE STUDY 7: PREDICTION MARKET FOR SALES FORECASTING

OBJECTIVE:

Joint research project between Caltech and Hewlett-Packard laboratories in 1996 with aim of making use of information aggregation methods in solving sales forecasting problems (Plott & Kay-Yut, 2002).

EXECUTION STRATEGY:

For the Hewlett Packard IAM (Information Aggregation Market), small numbers of participants (20 – 30) were selected from 3 different business units so as to ensure diverse information (like strategies, market information etc) regarding the target event. They were based out of different geographical locations and were each assigned a Subject ID to ensure anonymity. A total of 12 predictions were performed over a period of three years, as shown below in Figure 19 (Charles & Kay-Yut, 2002):

	Event to be predicted	Number of active participants	Date [time] of experiment	Experiment Duration	Number of Markets
1	Profit sharing percentage to be announced by upper management	16	10/96 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	8
2	Next month sales (in $) of product A	26	11/96 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	9
3	Next month sales (in units) of Product B	20	01/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	9
4	Quarter ahead monthly sales (in units) of product C	21	05/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
5	Quarter ahead monthly sales (in units) of product D	21	05/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
6	Quarter ahead monthly sales (in units) of product B	21	05/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
7	Quarter ahead monthly sales (in units) of product C	24	06/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
8	Quarter ahead monthly sales (in units) of product D	24	06/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
9	Quarter ahead monthly sales (in units) of product E	24	06/97 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	10
10	Quarter ahead monthly sales (in units) of product F	12	04/99 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	8
11	Quarter ahead monthly sales (in units) of product G	12	04/99 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	8
12	Quarter ahead monthly sales (in units) of product H	7	05/99 [11:00 AM-1:00 PM; 4:30 PM-8:00AM]	1 week	8

Figure 19: Summary of Experiments (Charles & Kay-Yut, 2002)

In all the exercises, trading was allowed for about a week. Markets opened for trading at lunch time and in evenings so as not to disturb the regular schedule of employees. In some exercises participants were given equal shares in all securities, while in other exercises they were they not, to observe different trading behaviors. The software used was developed at Caltech (called Marketscape software) and the market mechanism was based on double-auction. If a buy order matched a sell order or vice-versa, a trade was made; else the order was placed in a trade book. To incentivize traders, HP had to provide small amount of cash to the participants before the market sessions. The time horizon for the markets were kept more than 3 months as the

researchers believed that time horizon shorter than 3 months would make the forecasts less effective. Participants were mainly from marketing and finance, while a few were invited from HP labs.

RESULTS:

The benchmark for market results was the official forecast provided by HP. Official forecasts were available for only 8 out 12 experiments conducted. Results indicated that the market prediction was better than the official forecasts as the market results were closer to actual outcome than official forecasts for 6 out of 8 events (Charles & Kay-Yut, 2002).

				IAM	Predictions		
Event				Last Trade	Average Last 60% Trade	Average Last 50% Trade	Average Last 40% Trade
1	Outcome	8.770	IAM Prediction	9.619	9.092	9.259	9.369
	HP Forecast	None	Tail Prob Truncated	0.040	0.038	0.043	0.041
	% error	None	% error	9.683	3.672	5.571	6.829
2	Outcome	220.000	IAM Prediction	234.065	230.136	230.059	230.294
	HP Forecast	249.000	Tail Prob Truncated	0.009	0.008	0.009	0.009
	% error	13.182	% error	6.393	4.607	4.572	4.679
3	Outcome	1152.000	IAM Prediction	1766.399	1814.155	1793.875	1781.017
	HP Forecast	1838.000	Tail Prob Truncated	0.010	0.008	0.008	0.008
	% error	59.549	% error	53.333	57.479	55.718	54.602
4	Outcome	1840.000	IAM Prediction	1612.891	1695.796	1690.102	1683.273
	HP Forecast	1681.000	Tail Prob Truncated	0.008	0.011	0.011	0.011
	% error	-8.641	% error	-12.343	-7.837	-8.147	-8.518
5	Outcome	2210.000	IAM Prediction	1429.839	1526.466	1512.397	1506.579
	HP Forecast	1501.000	Tail Prob Truncated	0.024	0.011	0.011	0.012
	% error	-32.081	% error	-35.301	-30.929	-31.566	-31.829
6	Outcome	128.000	IAM Prediction	91.801	96.985	96.592	95.619
	HP Forecast	90.000	Tail Prob Truncated	0.007	0.010	0.010	0.010
	% error	-29.688	% error	-28.280	-24.231	-24.538	-25.297
7	Outcome	2002.000	IAM Prediction	1828.000	1855.320	1861.382	1867.697
	HP Forecast	2084.000	Tail Prob Truncated	0.008	0.017	0.018	0.019
	% error	4.096	% error	-8.691	-7.327	-7.024	-6.708
8	Outcome	1788.000	IAM Prediction	1728.600	1752.300	1746.033	1755.340
	HP Forecast	1786.000	Tail Prob Truncated	0.008	0.026	0.028	0.021
	% error	-0.112	% error	-3.322	-1.997	-2.347	-1.827
9	Outcome	166.000	IAM Prediction	134.886	126.401	124.748	125.515
	HP Forecast	119.000	Tail Prob Truncated	0.027	0.061	0.073	0.076
	% error	-28.313	% error	-18.743	-23.855	-24.850	-24.389
10	Outcome	30.000	IAM Prediction	15.178	15.017	15.245	15.150
	HP Forecast	None	Tail Prob Truncated	0.148	0.092	0.073	0.072
	% error	None	% error	-49.407	-49.944	-49.184	-49.498
11	Outcome	10.000	IAM Prediction	15.158	15.170	15.308	15.337
	HP Forecast	None	Tail Prob Truncated	0.083	0.082	0.081	0.085
	% error	None	% error	51.583	51.705	53.082	53.368
12	Outcome	17.000	IAM Prediction	15.708	14.991	15.281	15.366
	HP Forecast	None	Tail Prob Truncated	0.085	0.054	0.061	0.064
	% error	None	% error	-7.602	-11.818	-10.112	-9.612

Figure 20: Summary of Results (Charles & Kay-Yut, 2002)

Key Observations and lessons learnt:

- *The results of the market were positive, but these markets were run for a very short time (about 1 week each) with very few participants. The researchers also reported about presence of more sell orders than buy orders. Implementation of automated market maker could have solved the problem of fewer participants.*
- *To ensure that there was no impact on regular office work, the HP employees were allowed to trade only at lunch hour or in evenings. This can be a good practice to implement in organizations where management is concerned regarding time impact of prediction markets.*

3.1.8 SUMMARY OF OBSERVATIONS AND LESSONS LEARNED

All these case studies give us some indicators on various aspects of prediction market concept, design and implementation. To summarize the observations and lessons learned from these case studies:

- If used effectively along with usual project management methodologies, prediction markets can supplement the information available to the project manager.
- Some companies may not be very liberal in incorporating prediction markets results with their company policies. Hence, Incentives for participants should be aligned with the company goals and project aspirations in mind.
- Initial training on how the prediction software tools are to be used should be provided to the participants. This can help reduce participant's initial hesitation in participating and also help run prediction market more effectively.
- Prediction market can be used in various ways – in terms of collecting data, predicting outcomes or for opinion formulation. It is essential to determine what purpose will best suit an organization's needs.
- The length of the trading period is important. Too short trading periods can limit the effectiveness of the markets, while longer periods can lead to decreased interest in participants in absence of any new information updates.
- If there are lots of contracts with low price, then huge price variations between contracts can occur during trading. This can be avoided by either using an automated market maker with an optimum cost function, or by avoiding a large number of contracts in designing the market.

- Market maker should be designed in such a way that it is 'liquidity sensitive', i.e. takes into account the state of the market and frequency of trades in deciding the price impact of a particular trade.
- Prediction markets, apart from helping in project management decisions and forecasting can also give useful insight into the information flow within an organization.
- A company's culture drives the incentives that motivate the employees. In some cases, the social incentives were much more effective than financial incentives.
- Fun questions should be mixed with regular questions to attract diverse crowds and to encourage participation.
- Care should be taken on selecting the traders for the market and their demographics should be kept in mind while analyzing the data. This becomes particularly important if there is a restriction on the amount that they can trade with or if there is very few traders in the market.
- Depending on the information most relevant to an organization, prediction markets can be customized (like more subjective questions, scoring of market independent of actual event occurrence etc).
- The participant comments should be recorded while trading and can prove to be a valuable asset for the business in filling data voids. It not only provides the employees with more information, but also provides an opportunity for the employees to express their opinions to senior management.
- The right context for the market should be established from the beginning, so that participants are aware of what the goal is. This is particularly required when the questions revolve are of sensitive nature. Prediction market thrives on insider information, but such information in case of some scenarios (e.g. terrorism etc) can lead to negative reactions.
- It is important to get a buy-in from senior management prior to start of the market. Management support is very important for prediction market to succeed initially.
- Implementation of Prediction markets in a large organization may initially take time and effort to prove their value. Multiple markets over long time horizons may be required to get corporate acceptance and full-cooperation.
- Trading times for the employees can be limited in case there are concerns regarding the impact of the activity on regular office work.

4 PILOT STUDIES AND SIMULATIONS

In order to study prediction markets, three simulations on a group of students at MIT were conducted with the objective of studying the effectiveness of prediction markets. These were carried out by using commercially available software. Each participant was given a walkthrough on how to use the website. An instruction manual for trading was also sent to these participants, and included details on how to create user accounts, trade and check the user balance. The participants were anonymous in the market, as each created a unique user id upon registration. The participants could see their standings on a leadership board and ranks of other users in the market.
Details of the study are given below:

4.1 PILOT SIMULATION STUDY 1

OBJECTIVE:

To predict Nielsen Rating (NBC – USA) for Sunday Night Football and to study the behavior of participants.

EXECUTION STRATEGY:

A group of 17 participants (N=17) were asked to participate in a private marketplace for predicting the Nielsen Rating (NBC – USA) for Sunday Night Football (Oct 25). Below are some of the screenshots from the market.

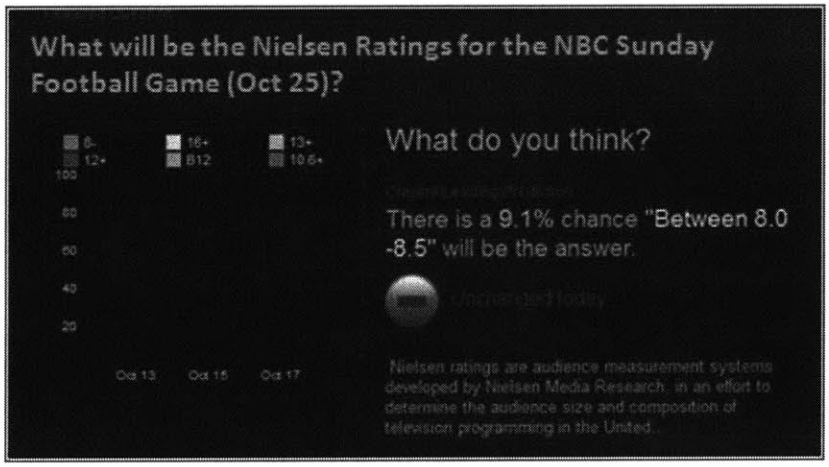


Figure 21: Screenshot of the Market Question. Each contract had an initial probability of 9.1%

The following rules were set in place:

- Time duration for trading was 5 days, with the market set to close 30 minutes prior to game start.
- Each participant was allotted an initial amount of $5,000 for trading (play money).

- The winning criterion was generating maximum worth in the market.
- Incentive was in the form of points for class participation grade for active traders and a popular book for winner.
- Minimum of four trades per person (tied to the incentive of class grade), with no maximum limit on trading.
- 11 rating ranges were present as choices or contracts for participants to trade on, with each rating range being assigned equal probability (about 9.1% each) to start with.
- Participants could 'buy' or 'sell' shares of the choice or contract they found most likely to occur. Every time a user bought a share for a particular idea, the price went up. Similarly, each time users sold a share, the price went down. The User's account was also credited or debited based on his/her choice.
- There was a direct correlation between price and probability – share price of $9.09 indicated 9.09% chance of that particular rating range.
- The buy and sell transactions were managed by an automatic market maker.

RESULTS:

Around 236 trades were conducted in total by 17 participants.

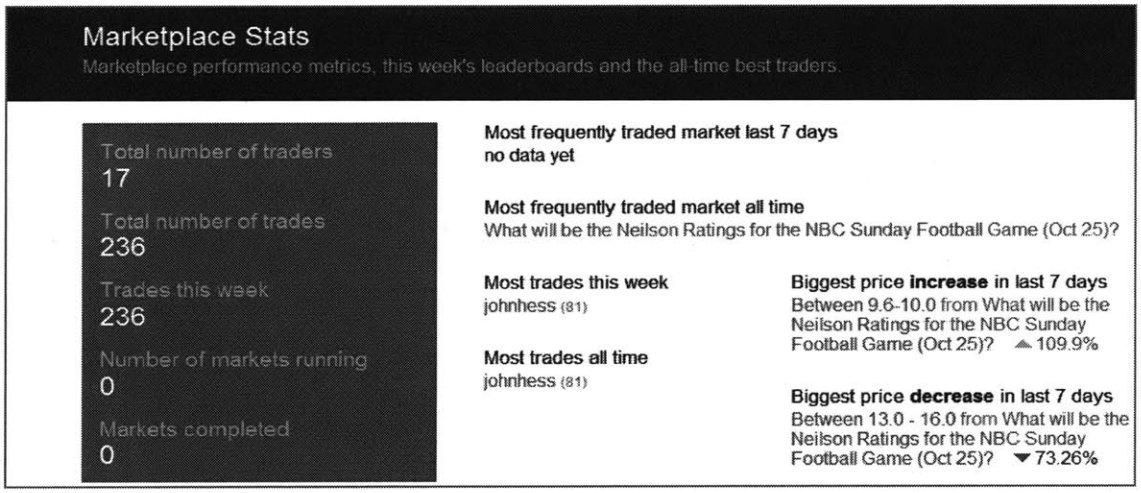


Figure 22: Results of the Market

The highest rating range predicted was of (9.6-10) with a 19% likelihood prediction, followed by range (9.1-9.5) with a 17.3% chance (Figure 23).

What will be the Neilson Ratings for the NBC Sunday Football Game (Oct 25)?

Question will be judged on: 10/25/09 @ 05:00 PM PDT

TIP: Current value = probability prediction will occur, e.g. $10 = 10% chance prediction will occur.

Select a prediction:

PREDICTIONS	CURRENT VALUE	TODAY
Between 9.6-10.0	$19.08	(closed)
Between 9.1-9.5	$17.28	(closed)
Between 10.1-10.5	$12.69	(closed)
Between 8.0-8.5	$11.57	(closed)
Between 11.1-12.0	$11.44	(closed)
Between 10.6 - 11.0	$9.90	(closed)
Between 8.6-9.0	$6.58	(closed)
Between 12.0 - 13.0	$3.65	(closed)
Below 8.0	$2.85	(closed)
Over 16.0	$2.48	(closed)
Between 13.0 - 16.0	$2.43	(closed)

Figure 23: Prediction market final prices

The actual rating range turned out to be (9.1 – 9.5), which differed from the predicted range. Figure 24 shows the trading activity for each range.

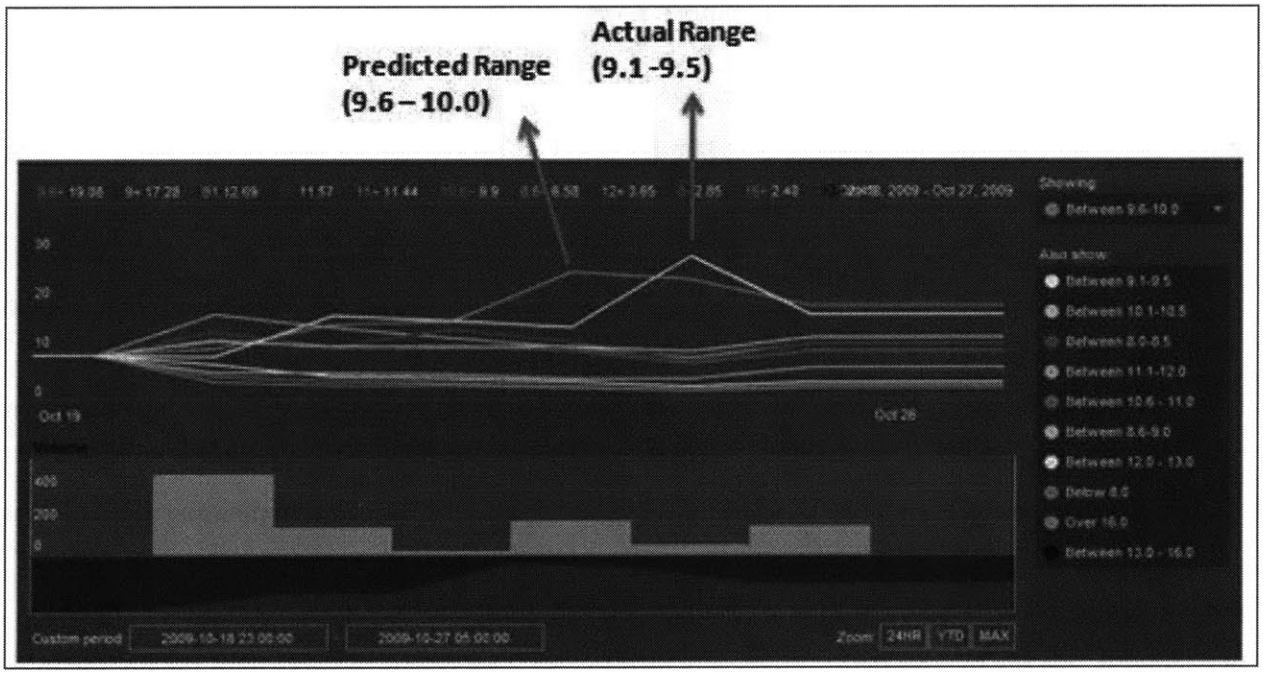


Figure 24: Trading Chart

A probability distribution function (Pdf) for the result is shown in Figure 25, which demonstrates how close the predicted result was to the actual result.

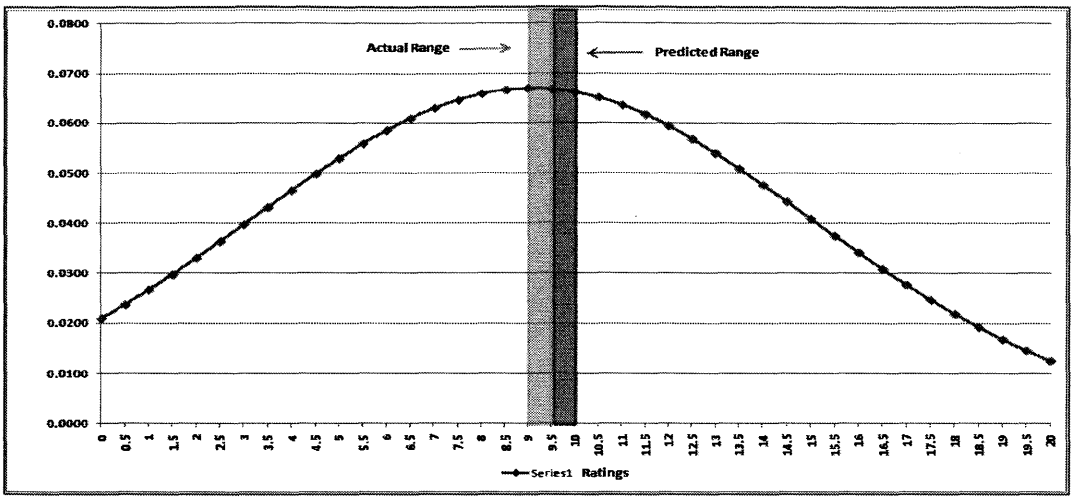


Figure 25: Probability Distribution Function chart for the market results

Although market predicted range was close, there can be two reasons why the market forecast was not exactly accurate:

- On the day of the game, a World Series game (Angels vs. Yankees) ran into extra innings – overlapping with the football game and impacted the expected ratings for the Sunday night football (Cardinals vs. Giants). It turns out that there were no baseball fans in the participating traders, and hence this new information was not accounted for in trading.
- In a study on markets on NFL football games from tradesports.com, there was an evidence of mispricing found (Solomon & Hartzmark, 2008). This was due to a behavioral bias known as disposition effect, which is the tendency of investors to sell stocks which have risen in value and hold on to stocks that have fallen in value, with the objective of earning maximum profit. Thus there might be mispricing and the hypothesis that the prices in prediction markets reveal unbiased estimates of true probabilities of the event happening might not be true primarily in sporting markets.

It is interesting to note that the winner was not the trader who was widely regarded 'expert' in the participants, but the person sitting physically next to him. This seems to agree with the finding in the Google prediction market that opinions on certain questions were correlated among employees (Cowgill, Wolfers, & Zitzewitz, 2009) who had close proximity to each other. The winning trader later summed his strategy as trading mainly for gaining maximum profit, but also studying the trading pattern of the expert for valuable insights.

4.2 PILOT SIMULATION STUDY 2

OBJECTIVE:

To predict Nielsen Rating (Cable TV - US) for Monday Night Football and to study the behavior of participants.

EXECUTION STRATEGY:

Based on the previous pilot study feedback, the structure of the next market was modified. The participants were asked to predict the Nielsen Rating (Cable TV - US) for Monday Night Football (Saints vs. Falcons) on ESPN .Instead of providing range choices to participants for bidding, they were asked to bid on an indexed market. Rules were similar to the last market, except for the following changes:

- Instead of ranges, participants were provided only one rating. They had to predict if the rating as per their opinion was to be higher or lower. Based on their responses, the price or rating was adjusted automatically.

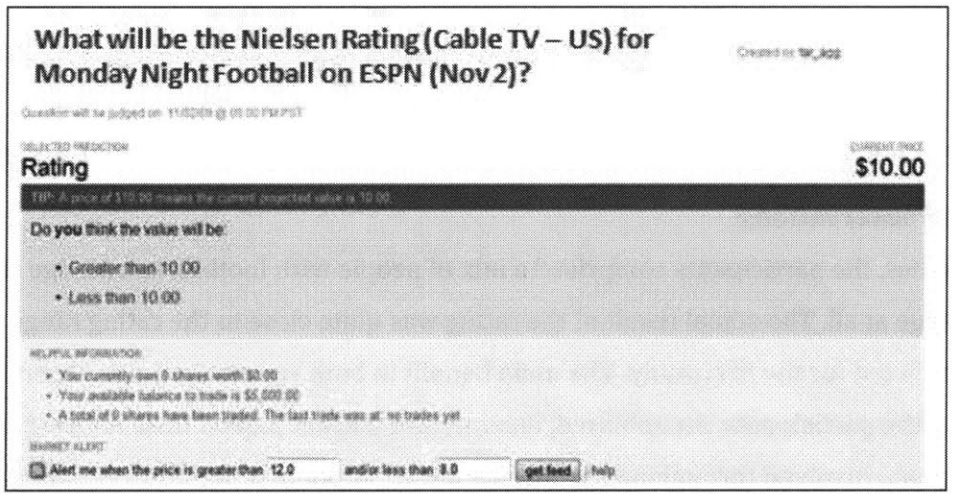


Figure 26: The market question for Monday Night Football

- The initial rating set was 10
- The price and rating scale was 1:1, i.e. a price of $10.00 meant the current projected value of rating was 10.00

RESULT:

Around 116 trades were conducted by 13 participants. The final rating predicted by the market was 10 points.

As shown in Figure 27, there was a huge variation in the ratings predicted, with the highest value being 33.1 and the lowest value being 0.6. The actual rating turned out to be 7.7 and was different

from the predicted market value of 10. The major reason for this was that marketplace was too volatile. A single participant could buy a large number of shares and alter the rating to a great extent, thus making the market susceptible to manipulation.

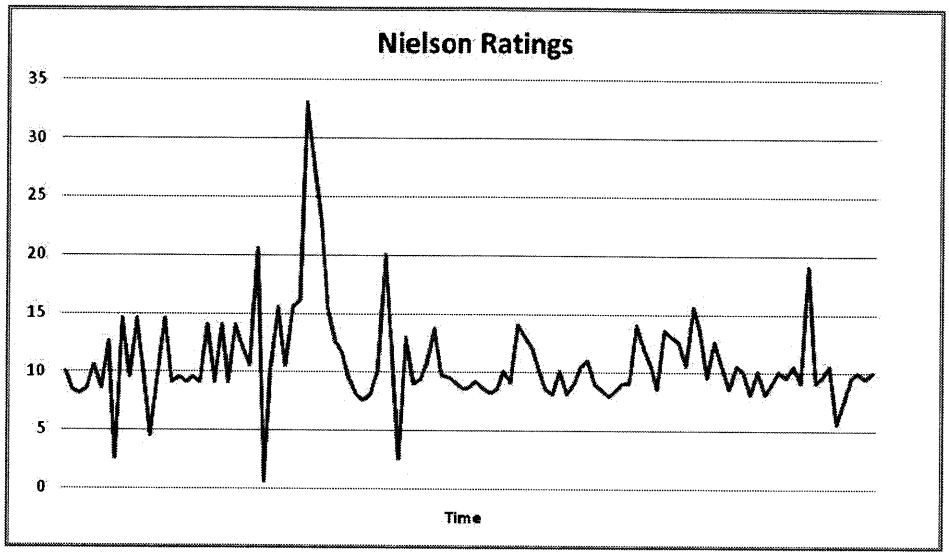


Figure 27: Trading Pattern for the prediction market showing high volatility

4.3 KEY OBSERVATIONS AND LESSONS LEARNED FROM SIMULATIONS 1 & 2

Behavioral observations:

In both studies, the participants comprised a mix of people with football knowledge and others with no knowledge at all. The actual result of the rating was quite close to the rating range that the test market predicted for the first study. The main benefit in both simulations was observed in the behavior of the participants. An unbiased, incentivized market piqued their interest and motivated them to remain involved throughout the market duration. Some other observations were:

- *Increased participation due to internal competition:* friendly rivalry between students for being the winner resulted in greater participation.
- *Attempts at market gaming:* Some of the traders tried to 'game' the market by trading just on basis of prices, or by spreading false rumors regarding the game.
- *Use of first mover advantages:* few traders tried to buy as many shares as possible at the start of the market itself to make use of lower prices.
- *Forming alliances to manipulate the market:* Some traders teamed up to support each other during trading.

- *High incentive to participate led participants to gain more knowledge on the subject:* Participants, who had no knowledge of football or the Nielsen ratings, searched the internet for finding out more details.
- *Use of statistical models by some participants to forecast ratings:* One of the traders developed a mathematical model to best calculate which share could earn maximum profit.

Other Observations:

- Some researches done on prediction market suggest at least 16 participants (Christiansen, 2007) for an effective market. Based on the two pilot studies, the number of participants was lesser in the second study potentially explaining the volatility and resulting significant error in the prediction.
- The market needs to be less volatile, so that it is not easily influenced by a single trader.
- In both the studies, there were not enough 'happenings' regarding the game ratings, during the trading duration to sustain participants' interest due to which trading pattern was infrequent and some traders lost interest after some time. The market is expected to fare even better if some new knowledge is available throughout the trading duration.
- A significant contribution of prediction markets in the field of cost or schedule estimation is to keep the participants involved and make the process exciting. Traders with no knowledge of football got involved by researching more on the subject.
- Some people just executed the minimum required four trades and stopped. Although there was high trading, some people did not care to do all the research. One reason for this was due to incentives not being aligning directly with the objectives of these participants (They did not feel the need for additional grades or for the book).

4.4 PILOT SIMULATION STUDY 3

OBJECTIVE:

To predict multiple events related to movies, sports and weather. Some of the objectives for this study were to:

- Observe the accuracy of the predictions of market.
- Observe how quickly new information is absorbed and utilized by the market.
- Measure any increased awareness regarding the event among participants as a result of trading against that event.

EXECUTION STRATEGY:

A group of 20 participants (N=20) were asked to participate in a private marketplace that consisted of multiple questions (four in all). The following rules were set in place:

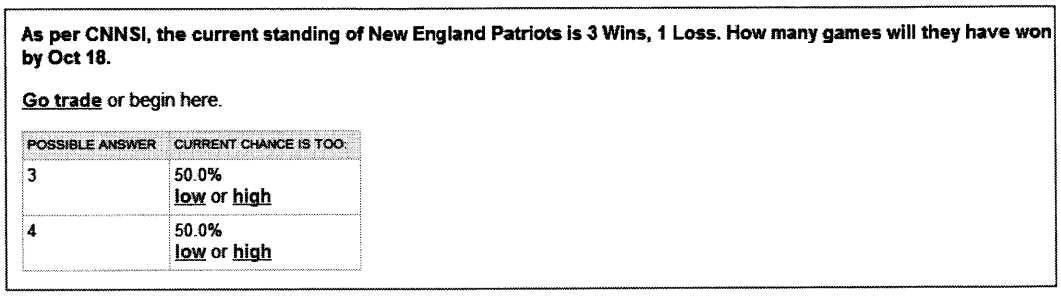
- Time duration for market closure was 7 days and market was supposed to be liquidated after that. Each question had a separate closing time.
- Each participant was allotted an initial amount of $5000 for trading (play money), which they could use to either bet on a single question, or hedge against all the questions.
- The winning criterion was generating maximum worth in the market.
- Incentive was in the form of points for class participation grade for active traders and a popular book for winner.
- Each question had a different contract structure – either the answers were in range format (pilot study 1), or they were in index format (like pilot study 2)
- Participants could 'buy' or 'sell' shares of the choice or contract they found most likely to occur. Every time a user bought a share for a particular idea, the price went up. Similarly, each time users sold a share, the price went down. The User's account was also credited or debited based on his/her choice.
- The buy and sell transactions were managed by an automatic market maker.
- The participants were encouraged to post comments (called "Reasons for Prediction") while trading so as to give an indication of their beliefs or to post any useful information. Other users were only able to see these comments and not the trades associated with the comments.

Participants were asked to take part in a survey before and after the trading process. These surveys were non-evaluative and voluntary. Below is a description of each:

- ***Before Survey:*** The purpose of this survey was to gauge the level of expertise and awareness of the participants in the areas that the market questions were related to. Appendix A shows the template of the survey. First two questions were asked to judge expertise level of participants in football and movies, while next five questions were indirectly linked to the market questions.
- ***After Survey:*** Once the market was liquidated, participants were asked to participate in another survey. This survey consisted questions related to how and why the participants traded in the market. It also comprised of questions from the previous survey, so as to observe any change in responses due to increased awareness of participants. Appendix B shows the template of the survey.

The following 4 questions were asked:

- *Question 1: As per CNNSI, the current standing of New England Patriots is 3 Wins, 1 Loss. How many games will they have won by Oct 18?*



As per CNNSI, the current standing of New England Patriots is 3 Wins, 1 Loss. How many games will they have won by Oct 18.

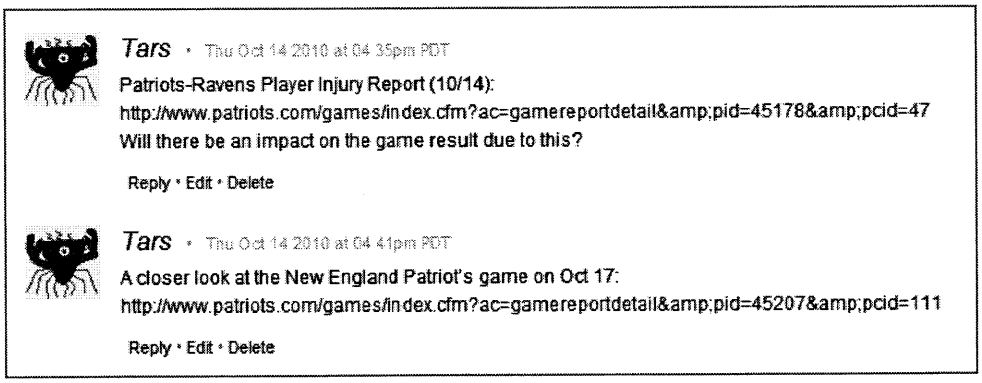
Go trade or begin here.

POSSIBLE ANSWER	CURRENT CHANCE IS TOO:
3	50.0% low or high
4	50.0% low or high

Figure 28: Question 1 in Simulation 3 and the contracts

This question was related to Football, and targeted at all participants. To familiarize participants who were not familiar with the game, internet links about the game, background of Patriots and the teams competing in games before Oct 18 were provided.

Trading for the question started on Oct 12 and was supposed to end about 30 minutes into the game on Oct 17, giving the participants about 6 days for trading. There were two possible answers (contracts) to this question. Additional information like game updates and player injury report were provided in between the trading cycle to encourage participation and to observe how the trading is affected.



Tars • Thu Oct 14 2010 at 04:35pm PDT

Patriots-Ravens Player Injury Report (10/14):
http://www.patriots.com/games/index.cfm?ac=gamereportdetail&pid=45178&pcid=47
Will there be an impact on the game result due to this?

Reply • Edit • Delete

Tars • Thu Oct 14 2010 at 04:41pm PDT

A closer look at the New England Patriot's game on Oct 17:
http://www.patriots.com/games/index.cfm?ac=gamereportdetail&pid=45207&pcid=111

Reply • Edit • Delete

Figure 29: Additional information revealed to participants during trading

- *Question 2: How many 2010 named Atlantic tropical cyclones will be major hurricanes (category 3 or greater) before October 20 as reported in weather.com?*

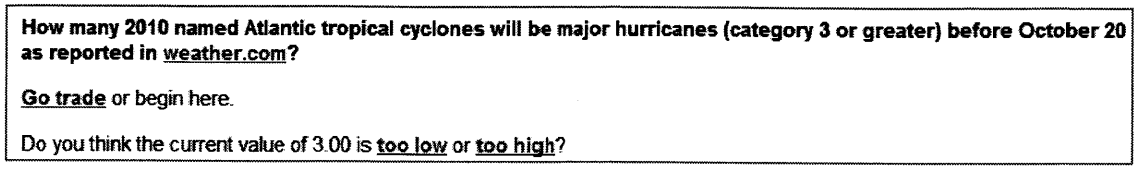


Figure 30: Question 2 and its contracts

This question was related to weather, and was meant to encourage participants to do some research of their own. Additional information regarding hurricanes and their categorization system was provided to the participants at the beginning of trading.

Trading for the question started on Oct 12 and was supposed to end on Oct 18, giving the participants about 7 days for trading.

- *Question 3: As per yahoo finance box office charts, 'The social network' was the top grosser for Oct 1-3 Weekend. Which movie will be the top grosser for Oct 15-17 Weekend?*

This question was related to movies, and was meant to test the quality of research done by the participants. Additional information regarding previous week's box office results was provided to the participants at the beginning of trading.

Trading for the question started on Oct 12 and was supposed to end just after the morning show on Oct 15, giving the participants about 4 days for trading. The question had total of 9 contracts in the form of movie names, with each movie being assigned an initial probability of 11.1%

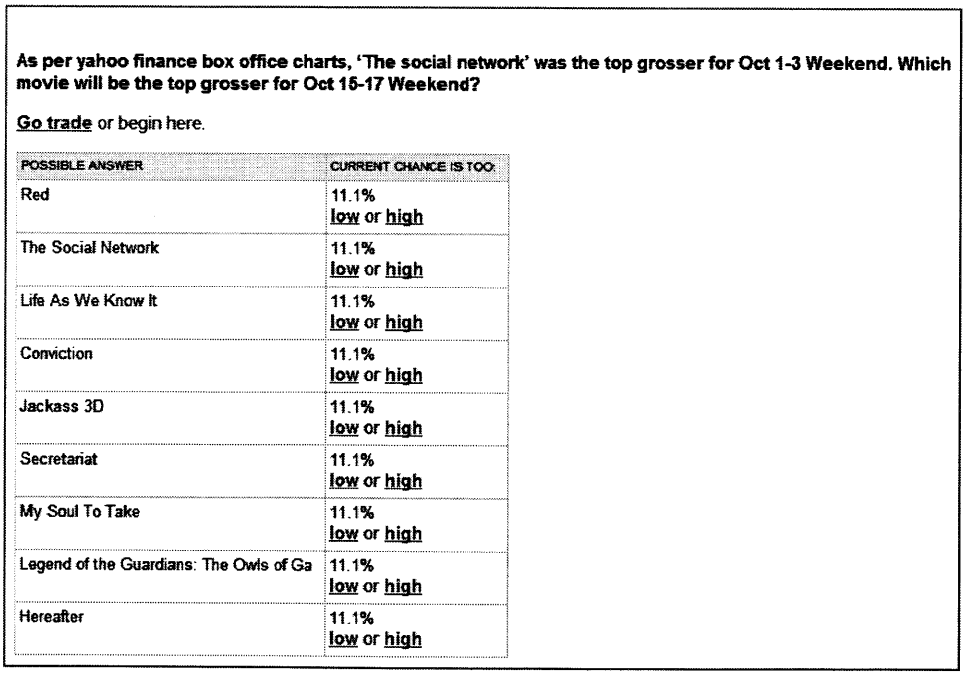


Figure 31: Question 3 and its contracts

One of the movies in the list was only a limited release (which meant it was very difficult for it to be a weekend box office grosser). This information was revealed only one day prior to the question closure (on Oct 14).

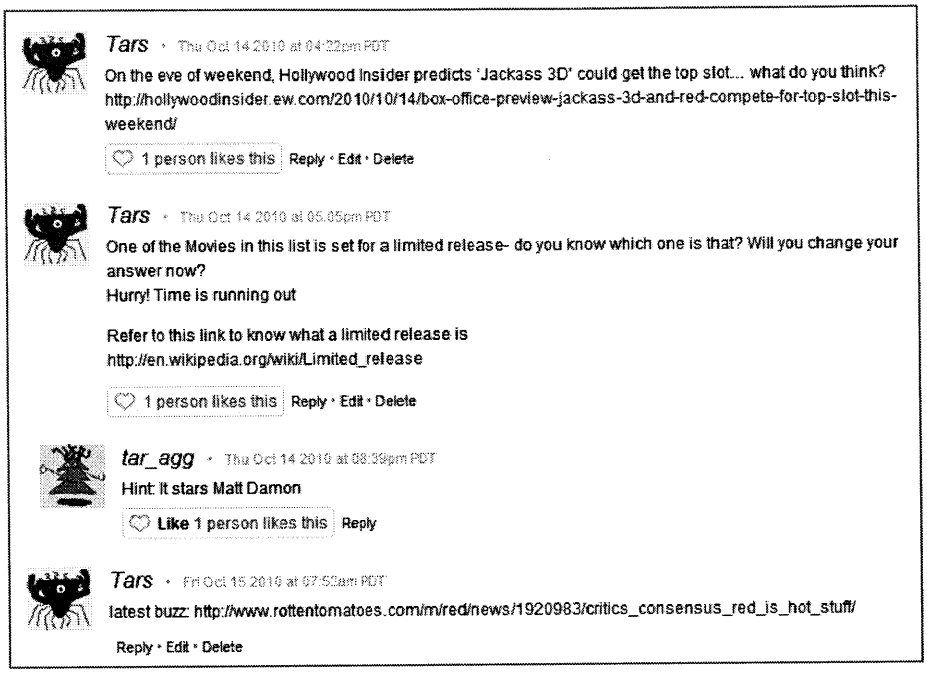


Figure 32: Additional Information revealed to participants during trading

- *Question 4: What will be the margin of victory on Sunday Night Football Game (Oct 17) between the Indianapolis Colts and the Washington Redskins?*

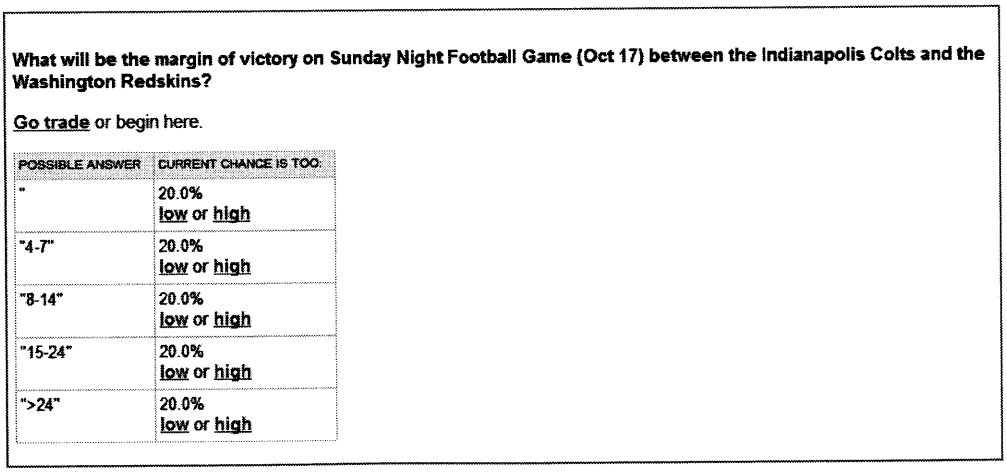


Figure 33: Question 4 and its contracts

This question was related to Football, and targeted at all participants but was most advantageous to serious followers of the game. To familiarize participants who were not familiar with the game, internet links about the game, background of Colts and Redskins were provided.

Trading for the question started on Oct 12 and was supposed to end around half time of game on Oct 17, giving the participants about 6 days for trading. There were five possible answers (contracts) to this question. Additional information like betting odds was provided to encourage participation and to observe how the trading is impacted.

Figure 34: Additional information revealed to participants during trading

RESULTS:

The market was closed and cashed on Oct 18 based on the 'Winner takes all' rule. A total of 16 traders conducted 141 trades over the 7 day period. There were about 30 comments posted by the traders. In all, market was able to correctly predict 3 out 4 outcomes.

Question 1: As per CNNSI, the current standing of New England Patriots is 3 Wins, 1 Loss. How many games will they have won by Oct 18?

The market prediction was that the Patriots will win 4 games by Oct 18. There were a total of 22 trades conducted for this event.

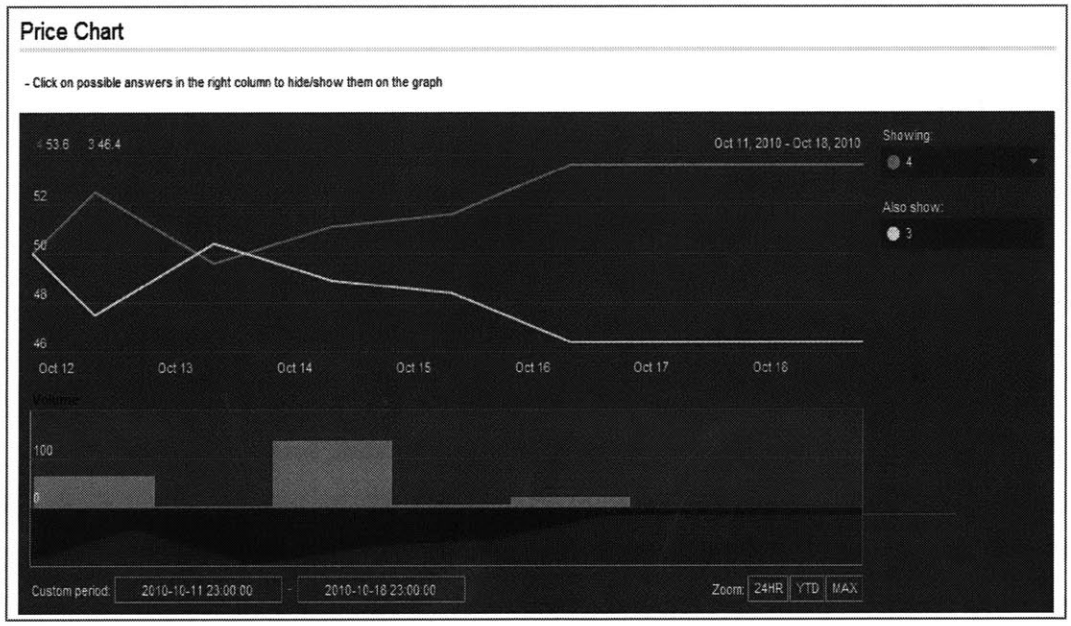


Figure 35: Predicted Result - Wins 4

Most of the traders unfamiliar with game, traded based on profit motivation and intuition, while the football followers traded based on their knowledge and favorite team. The market was able to average all the trades and the final predicted result matched the actual outcome. As can be seen from the trading pattern, volume of trades increased after Oct 14, when new information was revealed in the market to the participants.

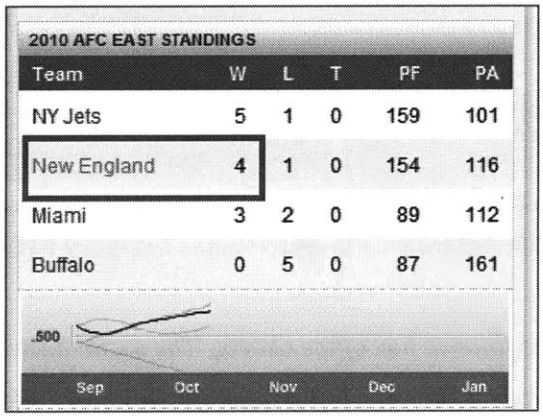


Figure 36: Actual result - Wins 4

Question 2: How many 2010 named Atlantic tropical cyclones will be major hurricanes (category 3 or greater) before October 20 as reported in weather.com?

There were a total of 44 trades conducted for this event, with the market prediction being 5 hurricanes being category 3 or greater.

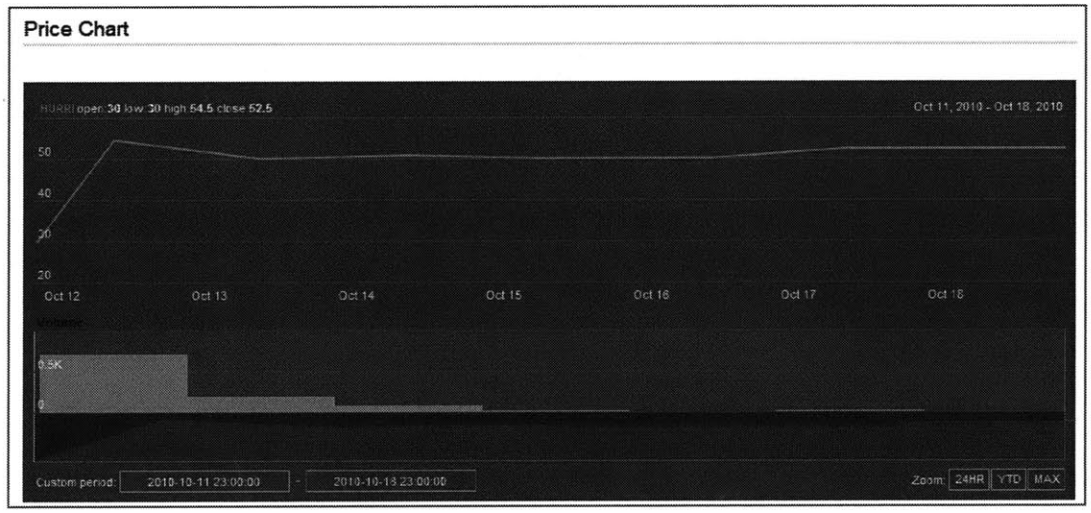


Figure 37: Market Prediction - Hurricanes 5

This was more of a research question, meant to encourage participants to do some external research for participation. Most of the traders were able to find the correct answer through internet

search and the market prediction matched the actual result. As can be seen from the trading pattern, the volume of trades decreased quickly with time as the traders found the required information. Thus, such a question may not be ideal for use in prediction market.

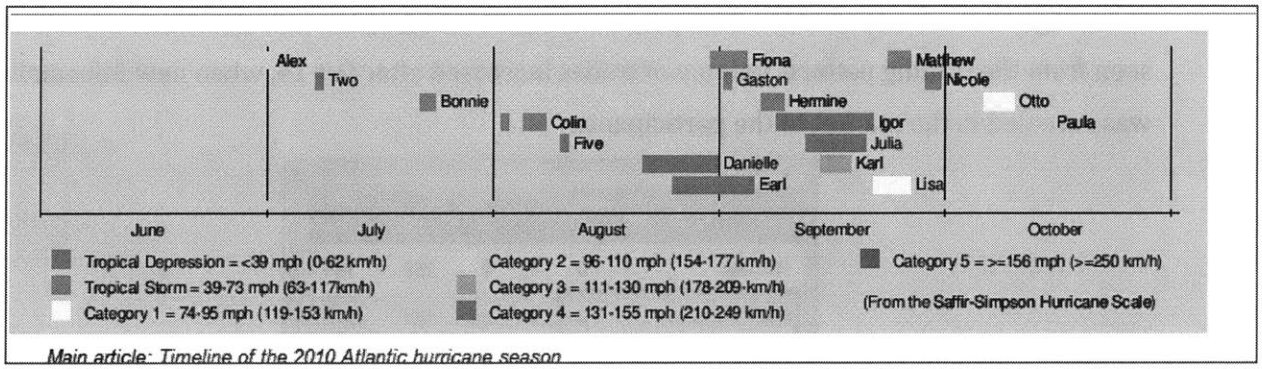


Figure 38: Actual Result - Hurricanes Category 5 (Center, 2010)

Question 3: As per yahoo finance box office charts, 'The social network' was the top grosser for Oct 1-3 Weekend. Which movie will be the top grosser for Oct 15-17 Weekend?

There were a total of 49 trades conducted for this event. The market predicted the movie 'Jackass 3D' as the top box office grosser with a final price of $32.58 or 32.58% likelihood of occurrence.

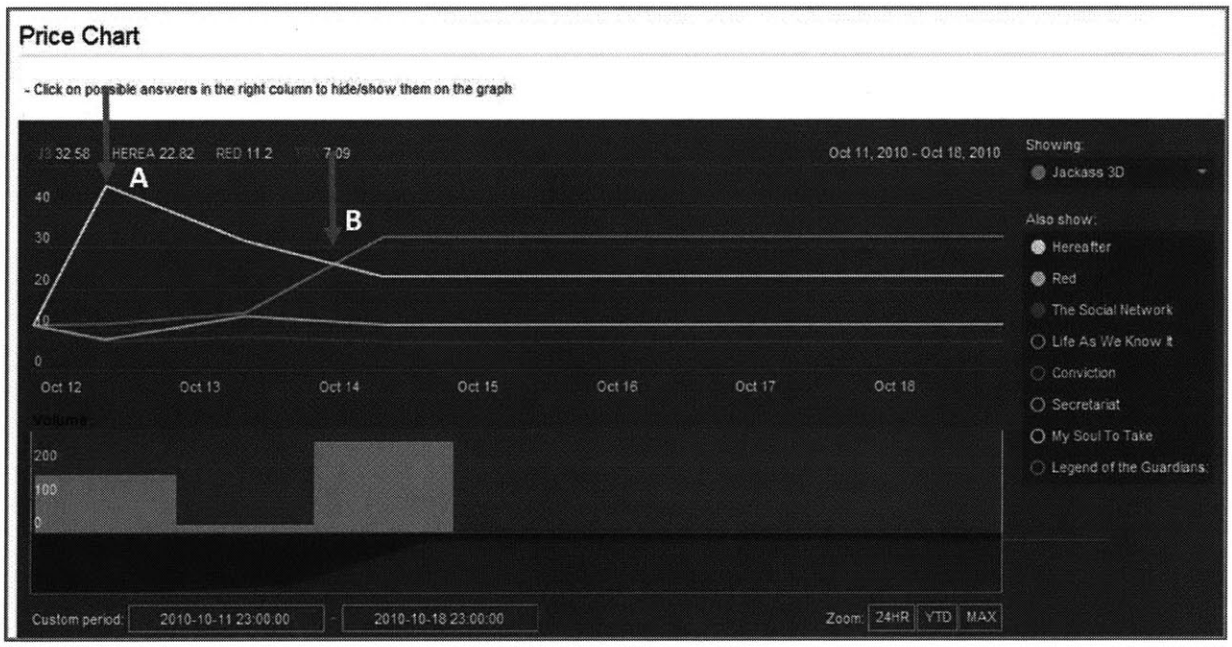


Figure 39: Market Prediction - Movie 'Jackass 3D'

This study provided an interesting observation. At the beginning of trading cycle, each participant was provided with brief description of each movie. Out of the present options, the movie 'Hereafter'

seemed to be the clear favorite being the critics' choice. Hence the initial trades seem to be highly in favor of the movie as shown in Figure 39 (Point A). On Oct 14, additional information was posted in the market that the movie was in fact a limited release. Within hours, the traders acted on this new information and the trading pattern changed drastically (Point B), with the movie 'Jackass 3D' becoming the leading stock.

But the traders who were able to make real profit were those who were aware of this information already (through web search), and traded for 'Jackass 3D' during the time represented between points A and B. The actual results confirmed the market prediction.

Box Office Charts

Weekend Box Office Estimates (U.S.)
Oct 15 - 17 weekend

This Wk	Last Wk	Title	Dist.	Weekend Gross	Cumulative Gross	Rise Wks	# of Theaters
1	-	Jackass 3D	Paramount Pictures	$50,000,000	$50,000,000	1	3081
2	-	Red	N/A	$22,500,000	$22,500,000	3255	3255
3	1	The Social Network	Columbia TriStar Motion Picture Group	$11,000,000	$63,119,000	3	2868

Figure 40: Actual Result - Movie 'Jackass 3D'

Question 4: What will be the margin of victory on Sunday Night Football Game (Oct 17) between the Indianapolis Colts and the Washington Redskins?

There were a total of 26 trades conducted for this event. The market predicted the range of '4-7' margin victory with 26.1% likelihood of occurrence.

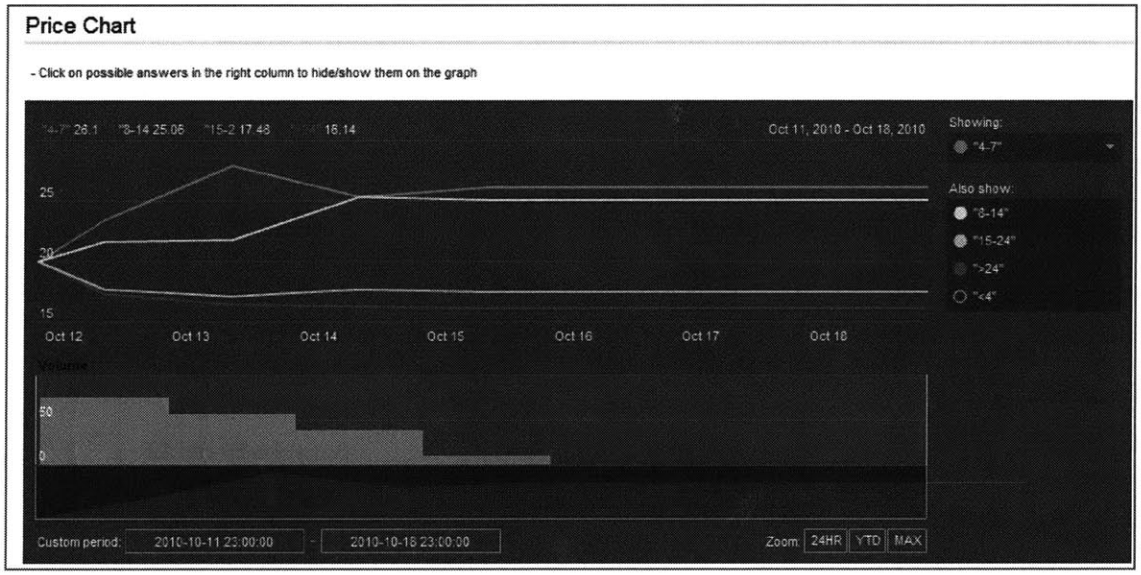


Figure 41: Market Prediction - Range 4-7

The game turned out to be quite close, with correct outcome being '<4'. It is interesting to note that the two extreme outcome ranges – '<4' and '>24' had the least predicted likelihood. Although it may not directly be linked to the long-shot bias observed in horse-racing, it still gives some indication of bias of traders in undervaluing events that seem unlikely.

	PREDICTED	ACTUAL
'<4" (closed)	15.20%	100.00%
	PREDICTED	ACTUAL
"4-7" (closed)	26.10%	0.00%
	PREDICTED	ACTUAL
"8-14" (closed)	25.10%	0.00%
	PREDICTED	ACTUAL
"15-24" (closed)	17.50%	0.00%
	PREDICTED	ACTUAL
">24" (closed)	16.10%	0.00%

Figure 42: Actual Result - Range <4

SURVEY RESULTS:

Out of the 16 traders, 12 participated in the before and after surveys. These surveys were voluntary and non evaluative. Some of the observations from the surveys were:

- All of the survey participants were students. Since the questions in the market were related to football and movies, they were asked to specify how much time they spent on each, thus giving an indication of their level of knowledge in the respective areas.
  Question: How many professional football games do you attend/watch every season?

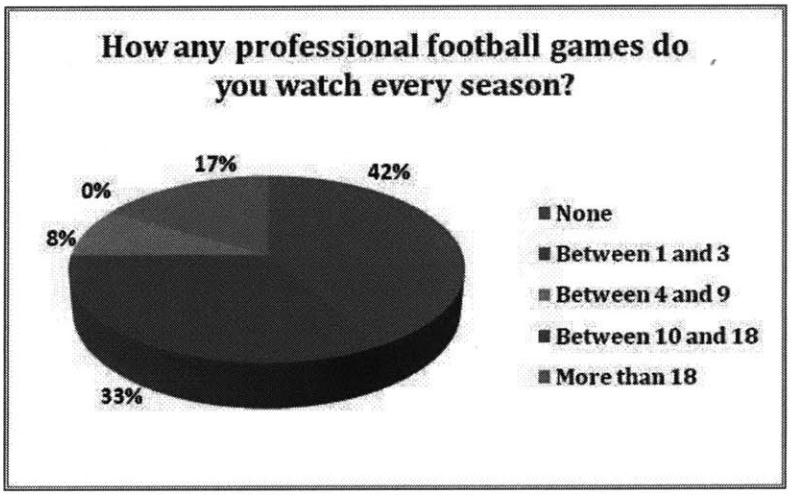


Figure 43: Survey results indicating level of knowledge of traders in football

As shown in Figure 43, about 42% of the traders did not have any prior knowledge of football (they did not watch any game) while about 17% of the traders could be considered as most knowledgeable in this area within the group (they watched more than 18 games every season). Majority of the traders had basic idea of football.

Question: How many movies on average do you watch at home/cinema in a month?

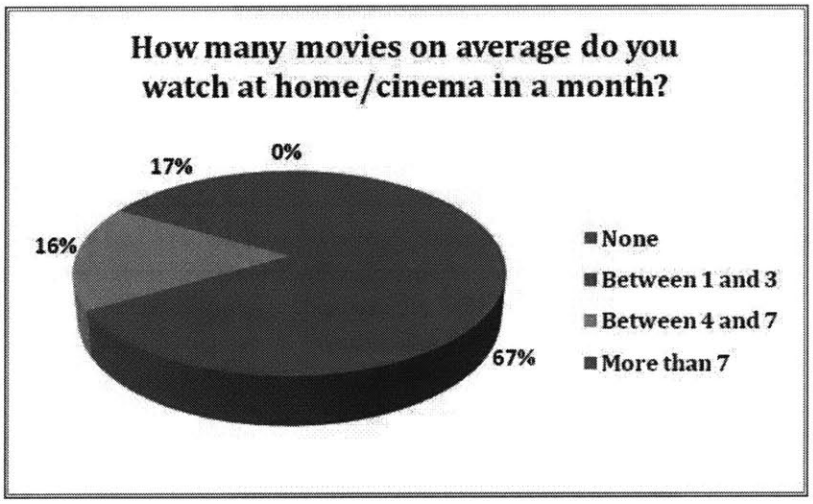


Figure 44: Survey results indicating level of knowledge of traders in Movies

As shown in Figure 44, majority of the traders had some basic knowledge of movies (about 67% watched 1-3 movies every month, while 16% watched 4-7 movies every month). 17% of the traders could be considered most knowledgeable in this area within the group as they watched more than 7 movies every month.

When participants were measured against the five questions that were asked in the before and after surveys, it was found that awareness of all the traders increased on those questions. While the accuracy percentage in the before-survey was 25%, it increased to 55% in the after survey.

Figures 45 and 46 also show the percentage of traders that were correct with respect to each of the five questions in the before and after surveys.

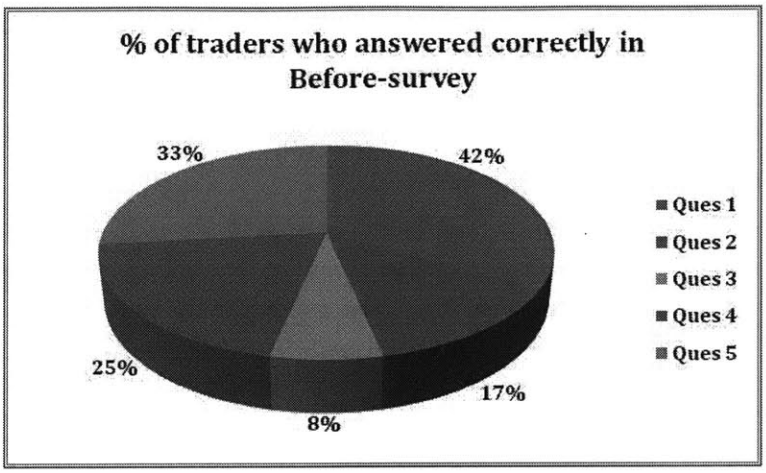


Figure 45: Percentage of Traders who answered correctly in the Before-Survey

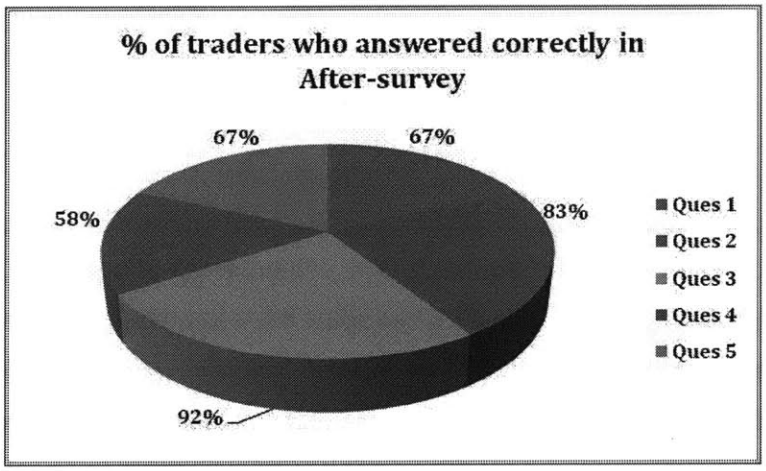


Figure 46: Percentage of Traders who answered correctly in the After-Survey

Figures 45 and 46 indicate that while question 1 was answered correctly by only 42% of participants before trading, about 67% of the traders were able to answer it correctly post trading. Similarly, traders getting question 2 correct increased from 17% to 83%, while for question 3, increase was from 8% to 92% of traders. The corresponding increase in traders for question 4 was from 25% to 58%, while for question 5 it was from 33% to 67%.

This increase indicates an increase in level of awareness of participants due to participation in the trading activity. Most of the traders researched online on the market topics or consulted with family or friends to get knowledge on the market questions, which supplemented their knowledge regarding the five survey questions too.

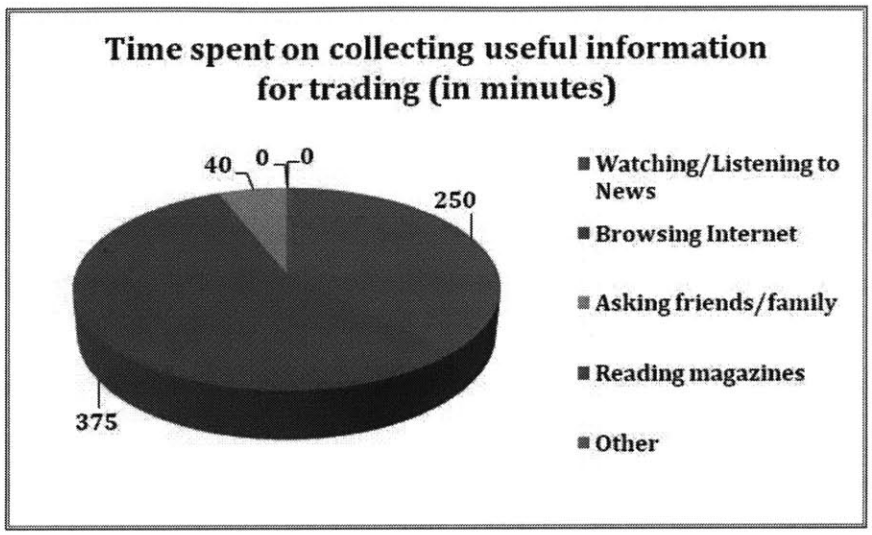


Figure 47: Time spent on collecting useful information on market questions for trading

Figure 47 shows the aggregate time spent by traders over the 7 day period, to gather information for trading through various sources. It indicates that the main source of information to traders was through browsing the internet (375 minutes or about 6 hours) followed by watching or listening to news (250 minutes or about 4 hours). The third source was through family or friends (about 40 minutes).

- Various strategies were adopted by traders to win in the market. Some of the strategies as reported by the participants are noted below:
    - "Quick research" and "Short-selling"
    - "Searching for information on the internet"
    - "shorting unlikely possible outcomes"
    - "Selling stocks whenever there was a possibility of profit"
    - "Diversify, take gains and even them out over other investments"
    - "Bidding only on questions for which I knew the answers"
    - "invested all my money in the question that I was most confident in. and continued to revise my predictions for that question as the market close approached"
    - "Put more money on one question for which I collected more data"

Around 5 traders reported that they changed their trading pattern after observing other traders or his/her trading pattern.

The winner of the market had the following comment: "Originally I spread my investments based on sports spreads, current hurricanes, and my guess of the movie. Before you sent out the information about Hereafter being a limited release, I found that out on my own and so shorted it

and reinvested in Red and Jackass 3D. Finally, I liquidated most of my sports holdings (since I had lower confidence on those outcomes) and in Red, and invested heavily in Jackass 3D, because there was a lot of online discussion about it being a top performer. Thanks! I had fun investing in the markets".

The above comment clearly shows that the trader was able to take advantage of the information that one of the movies was a limited release (which he found out himself), and was able to realize the benefits.

One of the other traders complained that he was not able to participate further in the market as he invested all the money on the first day itself. Thus, he did not have any money left to trade. This could be a good factor to account for in future markets; by keeping tab on how much 'money' the traders have left. Additional play money in form of bonus etc can be distributed to keep the traders involved throughout the trading cycle.

4.5 KEY OBSERVATIONS AND LESSONS LEARNED FROM PILOT SIMULATION 3

Some of the key observations from pilot simulation 3 are:

- The market was able to predict correctly the outcome of 3 out of 4 events.
- It should be made sure that information updates regarding the events are provided at regular intervals to the traders. In the pilot simulation 3, when new information regarding the events was made available to the traders, it was absorbed quickly and the market trading changed to reflect that information. Trading activity was also increased due to information updates.
- Traders with insider information on certain events can take advantage of the fact and can get an upper hand on other traders in the market. The winner of the market for example, was able to gain significant amount because he was aware that one of the movies was a limited release. None of the traders seemed to have that information at that point of time.
- Participation in the market helps increase the knowledge and awareness of participants on related topics. When participants were measured against the five questions that were asked in the before and after surveys, it was found that awareness of all the traders increased on those questions. While the accuracy percentage in the before-survey was 25%, it increased to 55% in the after survey.
- It is important to keep tabs on how traders are performing. If some traders are becoming inactive due to loss of 'money', it might be better to distribute additional amounts or bonus to ensure participation.

- Some traders had difficulty regarding trading concepts like "short-selling". Such terms need to be explained to traders during the initial training sessions.

4.6 SUMMARY OF OBSERVATIONS AND LESSONS LEARNED

The observations and results from the pilot simulations confirmed some of the observations from the case studies discussed before, and also provided some useful insights in other aspects. We summarize the observations and lessons learned from these simulations:

- An unbiased, incentivized market piqued their interest and motivated them to remain involved throughout the market duration. Some other behavioral observations were:
    - Increased participation due to Internal competition
    - Attempts at market gaming
    - Trying to make use of First mover advantages
    - Forming alliances to manipulate the market
    - High incentive to participate led participants to gain more knowledge on the subject.
    - Use of statistical models by some participants to forecast ratings
- It should be ensured that adequate numbers of participants are present in the market for trading. Otherwise volatility related problems can affect the result. For example, the number of participants was lesser in the second study leading to volatility and resulting significant error in the prediction. The market needs to be less volatile, so that it is not easily influenced by a single trader.
- A significant contribution of prediction markets in the field of cost or schedule estimation is to keep the participants involved and make the process exciting. Participation in the market helps increase the knowledge and awareness of participants on related topics. When participants in simulation 3 were measured against the five questions that were asked in the before and after surveys, it was found that awareness of all the traders increased on those questions. While the accuracy percentage in the before-survey was 25%, it increased to 55% in the after survey.
- Some people just executed the minimum required four trades and stopped. Although there was high trading, some people did not care to do all the research. One reason for this was due to incentives not being aligning directly with the objectives of these participants (They did not feel the need for additional grades or for the book).
- It should be made sure that information updates regarding the events are provided at regular intervals to the traders. In the pilot simulation 3, when new information regarding

the events was made available to the traders, it was absorbed quickly and the market trading changed to reflect that information. Trading activity was also increased due to information updates. In simulations 1 and 2, there were not enough information updates during the trading duration to sustain participants' interest due to which trading pattern was infrequent and some traders lost interest after some time.

- Traders with insider information on certain events can take advantage of the fact and can get an upper hand on other traders in the market. The winner of the market in simulation 3 for example, was able to gain significant amount because he was aware that one of the movies was a limited release. None of the traders seemed to have that information at that point of time.
- It is important to keep tabs on how traders are performing. If some traders are becoming inactive due to loss of 'money', it might be better to distribute additional amounts or bonus to ensure participation.
- Some traders had difficulty regarding trading concepts like "short-selling". Such terms need to be explained to traders during the initial training sessions. It might also be useful to perform a 'dry-run' before the actual launch of the market.
- Traders should be encouraged to post comments while trading. These comments can provide a very useful dimension to the trading activity, and also help the decision makers in getting information on the though process of traders while trading.

5 CONSIDERATIONS FOR DESIGNING A MARKET

There are various components of a market that need to be considered prior to designing and implementing a prediction market for a project.

A prediction market is composed of the following:

- **Traders:** These are the participants or team members in a project that will be trading information in the form of stocks or contracts in the market.
- **Marketplace:** This refers to the software environment which contains the market or the questions for trading. It also encompasses the market maker which facilitates trades among the traders and manages the information distribution process.
- **Stocks:** These are the outcomes or possibilities of the market that are collectively exhaustive and mutually exclusive. These act as stocks and securities for the traders to trade against, with a 'buy' indicating a belief of occurrence of that particular outcome and a 'sell' indicating a belief of non-occurrence.

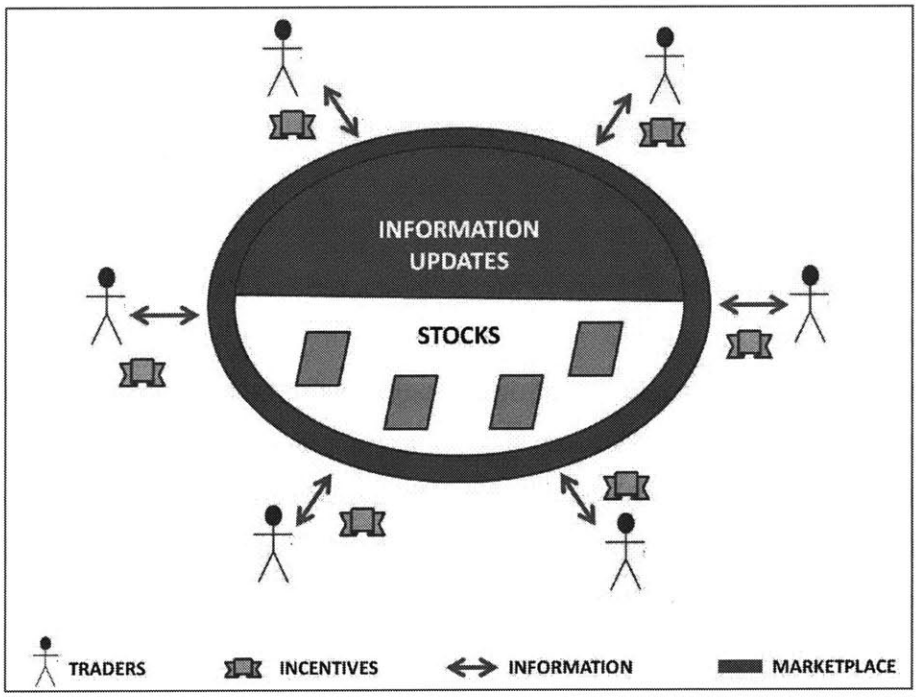


Figure 48: Components of a prediction market

Figure 48 shows the various components of a prediction market. There needs to be a continuous flow of information for the traders to base their decisions on and trade throughout the market duration. The arrows in the figure denote the information flow, which occurs from trader to the market, as well as from the market to the trader.

Incentive structure is another important factor that should be considered during market design, as it acts as the motivating factor for the traders.

Below is some of the discussion on the design parameters:

5.1.1 STOCKS

The stocks or the outcomes traded in the prediction market form the most important component of the market. The stocks traded will give us an indication of the beliefs of the participants, and the number of stocks traded will show us the level of confidence in their beliefs.
Hence the questions that are asked in the market are very important.

5.1.1.1 CATEGORIZATION BASED ON HOW THE QUESTION IS ASKED

There are mainly two categories of questions that can be asked:

- **Type I questions:** Asking these questions can directly provide the required information. i.e. $Q_1 = A$
- **Type II questions:** Asking these questions can indirectly provide the required information, and a series of questions might be required for getting the information directly. i.e. $Q_2 \rightarrow Q' \rightarrow Q'' \rightarrow A$

This is similar to another perspective where the questions can be divided as (Healy, Ledyard, Linardi, & Lowery):

- **1st Dimension questions:** i.e. based on an unobservable factor whose value can impact realization in second dimension, e.g. Monetary policy of Central bank
- **2nd Dimension questions:** i.e. based on an observable factor e.g. Interest rate each quarter.

In the latter definition, 1st dimension questions correspond to Type I questions, while 2nd dimension questions compare to Type II questions.

The distinction of questions based on these categories is important because these allow us to focus more carefully on the 'stocks' or outcomes of Type II questions, so that the required information is available.

- The suitable approach with the Type II questions is to ask multiple questions in the first round of prediction market, and subsequently drill down to specific questions in further rounds.

- If we consider one question as a single market, then one approach can be to run multiple markets at a given time, and then add follow up questions based on the responses. New markets (i.e. questions) can be run every week, and questions can be updated weekly based on new information. The important factor with this approach is to decide which questions need to be deployed first.

5.1.1.2 CATEGORIZATION BASED ON THE TYPE OF INFORMATION SOUGHT

Information required in a project or program can be either related to factors impacting the cost and schedule of the project, or can be related to the current or future decision processes within the project. Based on the information required, we have further categorized the market questions:

- **Questions of the First Order:** These are the questions that give us the information about the program of interest. Example:
    - Will the product be launched by January 2012?
- **Questions of the Second Order:** These are the questions that give us the information about traders and the trading process. Example:
    - What is your motivation for trading? (e.g. to win/ to solve the problem/ to validate my knowledge)
    - What are useful sources of information about the project?
- **Questions of the Third Order:** These questions give us information of the behavior outside of the prediction markets. Some of the questions are:
    - How have you used the prediction market in your job? If you notice a change in a contract price, how have you used that information?
    - Did trading improve your confidence in your opinion?
    - Did Prediction Markets encourage you to change your communication habits?

The first order questions will be asked in the prediction market for trading. The second order and third order questions are more of profiling questions which can help decide how to improve the markets, or how the participants are gaining from the market information. These questions can be sent to the participants as a survey and can be tied to incentives so as to encourage them to participate.

Another important aspect is to mix some fun questions (like who will win the Monday night game, etc) along with serious questions to keep the participants involved.

Care should also be taken to consider any legal issues depending on the participants of the market. If traders from outside an organization are to participate, then questions should be designed in such a way that they do not reveal any sensitive information.

5.1.2 MARKETPLACE

There are two important aspects of design for the marketplace – the software environment in which the participants perform trades, and the market manager which facilitates the trading process.

5.1.2.1 CONSIDERATIONS FOR THE SOFTWARE ENVIRONMENT

Following are the design considerations for the software environment, based on observed behaviors in case studies, pilot simulations and requirements of a corporate environment:

- The software environment should be easy to access and use.
- The software environment should be commercially available (if in-house development is not required) or should be built within available budget so that there is no impact on the financial resources of the project.
- The IT environment should satisfy the security considerations – like secure login, user access rights, data security etc. The market should also be immune to threats like phishing, Trojans etc.
- The software environment should have dashboard and administrative capabilities to analyze the data and generate reports based on the user behavior.
- It should be possible to communicate with traders, share new information and/or close or open new markets whenever required.
- Several commercial prediction markets allow functions similar to social networking tools like Facebook etc. Such functionalities can increase the adoption of the prediction market software and attract more traders.
- The prediction market software should be either available through intranet or publicly via internet based on the requirements of the organization.

5.1.2.2 CONSIDERATIONS FOR THE MARKET MAKER

The matching mechanism in prediction markets has most often been a continuous double auction in which computer software matches buyers offering bids with sellers and their asking prices. Most of the case studies discussed previously have used this method. Prediction markets have been successful using real world money, purely "play money" with no economic value (beyond the

satisfaction of "winning), and "prize money" that can be exchanged for prizes and entries in prize drawings.

A scoring rule is a technique that is used to reward forecasters for accurate predictions in trading (Nikolova & Sami, 2007) . 'Market Scoring Rule (MSR)' invented by Professor Robin Hanson at George Mason University should be used in the Prediction Market. MSR involves a trading process in which traders can buy and sell shares with the help of an automated market maker which continuously adjusts the price of the contracts based on the trading activities (Hanson, 2003). This will ensure that fewer traders can be present in the market, and lot of concepts related to stock markets that are difficult to understand (like bid-ask spreads etc) can be avoided (Siegel). The price of the stock represents whatever the last trader was willing to pay for shares and is set automatically according to the volume and sentiment in the question. For example, if someone buys 10 shares of an answer, we increase the price according to an algorithm. It is important to note that the automated market maker here acts as a trader who is willing to undertake losses so as to facilitate trading.

5.1.3 TRADERS

Surowiecki (2005) stated that in order to ensure that the crowd is really 'wise' and to avoid any irrationality, the following traits should be present:

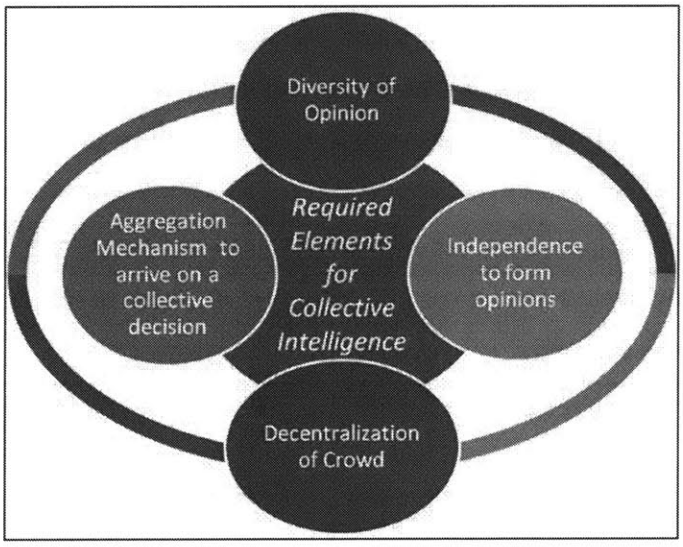


Figure 49: Characteristics for a 'Wise Crowd' (Surowiecki, 2005)

- The crowd should have **diversity of opinion**: Traders should be selected from multiple departments and different functions. This will also help eliminate any correlation biases which were observed in case of Google (Cowgill, Wolfers, & Zitzewitz, 2009). However a

balance view should be maintained when selecting the traders. While prediction markets require some disagreement among potential traders over forecast, else no trades would occur; excessive information heterogeneity can be harmful to the markets functioning. If some traders posses significant private information (and hence become insiders), the outsiders may refuse to participate, ultimately killing the market.

- **Independence to form opinions** among members: Traders should be able to form and express opinions of their own without additional pressure or constraints. Prediction markets are most likely to be successful if traders hold sufficiently balanced information about the event but have differing beliefs about the meaning of common information.
- **Decentralization of Crowd:** Traders should be decentralized with respect to location and function. This will facilitate the above two factors and help in elimination of any biases due to proximity. This will also help in capturing information from different sources much more easily.
- **Good Aggregation mechanism:** It is also critical that when new information becomes available, it becomes widely known throughout the market to all the traders. Using prediction markets, traders should be able to understand new information expressed by others, and also should be able to convey their opinions.

In a large organization setting, traders can comprise of either the employees working directly or indirectly with the organization or general public. Depending on which approach is taken, 'Infosurv Concept Exchange[2]' categorizes them as 'Enterprise prediction markets' or 'Public prediction markets' (Heyman, 2010). Key features of each approach are shown in the below table:

Table 5: Enterprise prediction markets vs. Public prediction markets

ENTERPRISE PREDICTION MARKETS	PUBLIC PREDICTION MARKETS
• Easier to select targeted employees or groups within the company	• Difficult to target selected groups of people
• Non-monetary incentives can work well	• Higher incentives or monetary rewards might be required to attract traders
• There are limited concerns regarding protection of intellectual property or sensitive information	• Intellectual property and confidential information needs to be protected through NDA's etc
• It can be challenging to maintain high	• High participation can be maintained, as

[2] http://www.icepredict.com/

participation over time	new traders can join in if old traders are inactive.
• It can be challenging to maintain diversity of trader opinion	• Higher probability of diverse opinion
• High probability that traders will be able to make educated guesses regarding the event to be predicted	• Not all traders will have relevant information regarding the event to be predicted.

The choice of traders will depend on the purpose of the market. Typically if the organization is using prediction markets for idea generation or market research, public markets can be a good option, while enterprise markets can be useful in case of events where specialized knowledge is required. For example, sales forecasting etc.

5.1.4 INCENTIVES

The incentive structure is perhaps the most important component of prediction market in the DOD environment. Incentives should be such that they are non-biased and encourage participation independent of any hierarchical considerations. "As with any business incentive system, a considerable challenge exists in choosing incentives that motivate the right behavior. . . With information markets, incentives must serve a dual role: to motivate participation and to motivate participants to provide truth-revealing opinions. Incentives that satisfy both criteria can be difficult to define." (LaComb, Barnett, & Pan, 2007).

While other components of the market need to be decided by keeping the 'crowd' in mind, this component needs to focus on an individual's needs and the factors that impact the motivation of the individual.

The 'Self-Determination Theory' (Deci & Ryan, 1985)is a theory of motivation that gives an insight into the factors that motivate people. It deals with the interplay of extrinsic factors and the intrinsic motives that influence an individual's behavior to act in a certain way.

5.1.4.1 INTRINSIC MOTIVATION

As per the theory, the three psychological needs that foster the most "volitional and high quality forms of motivation and engagement for activities, including enhanced performance, persistence, and creativity" (Deci & Ryan, 1985)are:

- **Autonomy:** Research suggests that intrinsic motivation is increased when people are fee to do activities that they wish to do (Deci & Ryan, 2000). Constraints and pressures can sap the energy from them leading to lesser motivation. When extrinsic rewards are introduced for an activity that an individual found intrinsically interesting, they have an impact on the individual's behavior and can lead to less motivation. Thus, it is important while deciding the incentive structure that the rewards or competition resulting from the same does not undermine the perceived autonomy of the participants.
- **Competence:** Positive feedback that supports the effectiveness of an individual's competence increases intrinsic motivation, compared to negative feedback which can foster perceived incompetence (Deci & Ryan, 2000). Thus, an important aspect of incentive structure is to make sure that the traders are rewarded or recognized for good performance, but also do not get penalized heavily so as not to undermine their motivation.
- **Relatedness:** People feel more motivated if they can relate personally to the work or to the people they are working with. For example, research has indicated that students who consider their teachers as warm and caring are more intrinsically motivated (Deci & Ryan, 2000). This factor however is less central to intrinsic motivation, compared with autonomy and competence. This factor can help us focus on the manner in which incentives should be conveyed so as to make the traders feel more related with the organization and their senior management.

5.1.4.2 EXTRINSIC MOTIVATION

Several external factors can provide participants with extrinsic motivation. A sub theory[3] of 'Self-Determination Theory' describes four different types of extrinsic motivations (Deci & Ryan, 2000):

- **External Regulation:** This case of extrinsic motivation includes scenarios when people have to behave in a certain manner so as to avoid punishment, satisfy external demand or to obtain a tangible reward. Such a motivation is considered controlling and is least autonomous in nature. Thus, any external pressure on traders in the market should be avoided and they should be able to trade in anonymity.
- **Introjection:** While the external regulations are administered by others to control the behavior, introjected regulations are administered by the individuals to themselves in the form of pride, ego or threats of guilt and shame (Deci & Ryan, 2000). These behaviors are not entirely intrinsic and although they are internal to a person, they remain external to the

[3] Organismic Integration Theory (OIT)

self. Thus, incentives should be distributed in a way that does not undermine the feelings of traders who did not win.

- **Identification:** If people are able to recognize and identify with the underlying value of their behaviors, they can be more acceptable and thus motivated. For example, recognizing the importance for exercising for one's own good health can make the individual exercise more voluntarily (Deci & Ryan, 2000). This is a more autonomous form of motivation. Thus, traders need to be made aware of how the results of the market will potentially benefit them.
- **Integration:** This is the most autonomous form of extrinsic motivation and involves identification with importance of behavior as well as integrating those identifications of the self.

An organizations' culture will determine which extrinsic motivations will impact the participants and to what degree. However, keeping these factors is mind can help design better incentive structures for prediction market participants.

Performance based incentives can also be provided to motivate participation in prediction markets. For example, participants can be rewarded based on the portfolio value at the closure of the market. Awards can also be given to the most active traders, or the traders contributing the most valuable information.

Non-monetary awards can be as effective as monetary awards when used as incentives. For example, Google found that in their internal markets, participants cared more about non-cash prizes like T-Shirts rather than cash prizes (Coles, Lakhani, & McAfee, 2007). Similarly, by announcing user rankings, the play-money markets in Christiansen's field experiment (Christiansen, 2007) were successful even without monetary incentives.

Other factors like social competition, recognition and opportunity to contribute towards the project can also act as important motivating factors.

A report by McKinsey (Dye, 2008), mentions six important decisions that need to be taken for building a prediction market:

1. **Defining the variable to be forecasted:** The variable to be forecasted should be defined clearly and expressed in precise manner. This factor is related to the design of the 'stock' component of the market.

2. **Defining how the results will be shared:** The results from the market should be in a form that is useful for the organization. Management should be prepared for any embarrassing results or negative feedback. This factor is also related to the design of the 'stock' component of the market. Questions should be designed correctly, keeping in mind the result required.
3. **Deciding who should participate:** Markets can comprise of traders within the organization or from outside. Markets with internal participants will be easier to organize, while markets with external participants will have more participation. This factor is related to the 'traders' component of the market.
4. **Deciding on the nature of market:** This factor is related to the 'marketplace' component of prediction market. Functionality and behavior of the market need to be decided.
5. **Deciding on Incentives:** Choice of incentives is important and should depend on the culture and policies of the organization.
6. **Deciding on role of experts:** In some cases, departments or individuals concerned with decision making might not be receptive to prediction markets. It is important to make them realize the benefits of the market and incorporate it as a part of their decision process. This can be a challenging task but is also the most important step for implementing prediction markets.

5.2 PREDICTION MARKET FOR DEFENSE ACQUISITION- CASE STUDY IN PROGRESS

A recent study by RAND (Arena, Leonard, Murray, & Younossi, 2007) performed an analysis of data in the Selected Acquisition Reports (SARs) for a sample of 68 completed programs. The results showed that the average cost growth (including both cost overruns and cost under runs) for these programs was 46 percent over the baseline estimate made at Milestone B and 16 percent over the baseline estimate at Milestone C. While cost growth occurred earlier in acquisition projects, the development cost growth at completion for programs initiated in 1970s, 1980s and 1990s remained relatively steady. (Arena, Leonard, Murray, & Younossi, 2007)

The DOD's ability to meet its acquisition targets is becoming increasingly critical as defense budgets are reduced and expectations to deliver on time and on budget remain high. Costs overruns are one aspect of this issue. Please refer to table 7 for a sample of cost overruns in large federal projects.

Table 6: Sample of Cost Overruns in large federal projects (downsizinggovernment.org)

Defense Development Costs ($2008)[63]	*Original Estimates*	*Final Estimates*
Global Hawk surveillance plane	$989m (2001)	$3.7b (2007)
Expeditionary Fighting Vehicle	$1.6b (2000)	$3.6b (2007)
C-130J Hercules	10.9m (1996)	430.3m (2007)
Extended Range Munitions	86.9m (1997)	500.1m (2007)
DDG 1000 destroyer	2.2b (1998)	9.3b (2006)
V-22 Osprey helicopter	4.0b (1986)	12.5b (2006)
Armed Reconnaissance Helicopter	388.3m (2005)	750.9 (2007)
Space Based Infrared System High	4.2b (1996)	8.5b (2006)
Armed Reconnaissance Helicopter	388.3m (2005)	750.9 (2007)
NPOESS Satellite System	5.0b (2002)	7.9b (2007)
Other Defense		
Coastal Patrol Ships[64]	$220m (2004)	$350m (2007)
Joint Strike Fighter[65]	$232b (2001)	$337b (2008)
Marine One (VH-71) helicopters[66]	$6.1b (2005)	$11.2b (2008)
Coast Guard, NSC ships, per unit[67]	$250m (2002)	$536m (2007)

A recent GAO report (Edwards, 2009) concluded that "weapon programs are taking longer, costing more and delivering fewer capabilities than originally planned." It also noted that "systematic problems both at the strategic and at the program level" (GAO, 2008) were to blame. The GAO also noted that military branches "overpromise capabilities and underestimate costs to capture the funding needed to start and sustain development programs." (GAO, 2008)
In 2008, GAO reviewed cost and schedule of 72 weapons programs and found that the average cost overrun for systems development was 40% (GAO, 2008) and concluded that "DOD's acquisition outcomes appear increasingly suboptimal" (GAO, 2008). A study by Deloitte consulting also agrees that defense cost overruns are getting worse (Irwin, 2009), (Edwards, 2009).

As part of an ongoing research project sponsored by Naval Postgraduate School Acquisition Research program, the author along with Dr. Valerdi, Prof. Potoski have been aiming to address some of the above mentioned deficiencies in defense acquisition programs by implementing a prediction market across such projects in parallel to existing cost estimation methodologies being used. If used correctly, prediction markets can supplement the existing tools and also help track any trigger events that can have an impact on the project.

This case study is meant to demonstrate some of the considerations required for implementing a prediction market in a new environment (Aggarwal, Valerdi, & Potoski, 2010).

OBJECTIVE:

To identify design principles for prediction markets for a defense acquisition program, and prepare for the implementation in a naval weapons acquisition project.

EXECUTION STRATEGY:

Preparation for implementation of prediction markets comprised of following three phases:

- Initial research and preparation
- Defense program selection
- Market component selection

Phase I: Initial Research and preparation

As part of the first phase, research on the success of prediction markets was done and pilot simulations were conducted to establish confidence. Collaboration with MITRE, an established organization already employing prediction markets for defense programs, helped in identifying best practices and important factors to be considered for a defense environment.

Phase II: Defense Program Selection

The successful execution of prediction markets for a defense acquisition project hinges on identifying an acquisition program that is willing to participate. The ideal characteristics of the program require:

- uncertain cost and schedule components that can be specified clearly in a contract
- a sufficiently large program community to ensure a liquid market
- ample "soft" relative to "hard" information and information is broadly and unevenly held by diverse actors
- one-of-a-kind program or a program with limited relevant historical information
- susceptible to performance impacts as a result of external events (i.e., political landscape, policy changes, personnel attrition, technology maturity, design modifications)

Based on initial pre-screening, a naval weapons acquisition project was identified as a suitable project, with a plan to implement the prediction market for duration of 3-6 months.

It is important to convey the importance of markets to the senior management of the program in which prediction market is to be implemented. To explain what prediction markets were, and to demonstrate the benefits that their use could bring, a research protocol (Appendix C) was submitted to the senior team of the naval program. More details were also conveyed through meetings and conferences.

Phase III: Market Component Selection

As discussed previously, there are four main components of prediction market that need to be considered as part of the design and implementation process. The composition of the market with respect to defense acquisition program is discussed below:

STOCKS

The first order questions will be asked in the prediction market for trading purposes. The second order and third order questions will be more of profiling questions which will help in getting information on how to improve the markets, or how the participants are gaining from the market information. Some of these questions will be asked at the time of registration, while some questions will be sent to the participants as a survey and will be tied to incentives so as to encourage participation. Incentive can be additional bonus money (like, earn $100 play money for answering 5 questions)

- **Questions of the First Order:** Some of the sample questions to be used in market:
    - Will <Naval project> be certified by <insert desired date>?
    - The cost of the first unit will be $x <initial estimated cost>.
    - The final cost of the program will exceed the baseline estimate by x%.
    - The 2011 Fiscal Year appropriation for the <Naval project> will be $x
    - Will the <Naval project> program be adequately resourced to meet its milestones?
- **Questions of the Second Order:** Some of the sample questions:
    - What is your motivation for trading? (e.g. to win/ to solve the problem/ to validate my knowledge)
    - What is your role in the Organization?
    - What are useful sources of information about the project?

2. **Questions of the Third Order:** Some of the questions are:

- How have you used the prediction market before? If you notice a change in a contract price, how have you used that information?
- Did trading improve your confidence in your opinion?
- Did Prediction Markets encourage you to change your communication habits?

It will be useful to map each first order question to the type of information they provide, and the risk that can be measured using that information. A risk mapping prepared for the acquisition project, showing the risk covered by a specific question of the first order, along with the modified version of the question is shown below in Table 8. Note that the first four questions are of type I, while the last question is of Type II.

Table 7: Risk Mapping for First Order questions

Question Type	First Order Questions (Information about the program of interest)	Measured Risk	Alternate way of asking the question	
Type I	Will SWCS be certified by August 1, 2010?	Schedule Overrun	When will SWCS be certified?	Or
			By how many days will the certification date be exceeded?	
Type I	The cost of the first unit will be $x.	Cost Overrun	What do you think is the most significant cost driver for the first Unit? Follow up question: Based on the below ranking of cost drivers for the first Unit, what do you think the cost of first Unit will be?	
Type I	The final cost of the program will exceed the baseline estimate by x%.	Cost Overrun		
Type I	What will be the 2011 Fiscal Year appropriation for the SWCS?	Cost and Schedule		
Type II	The SWCS program will be adequately resourced to meet its milestones?	Resource Allocation Errors	By how many days/months will the milestone be missed?	Or
			Which resource do you think is most necessary to meet the program's schedule objective?	Or
			Given the available resources, will the project be able to meet its planned schedule?	

In addition to the program related questions, there will be additional questions related to current events, sports and entertainment. Most of the case studies and simulations before have proved that inclusion of fun questions can improve participation and add to the experience of the market.

MARKETPLACE

Considerations for the Software Environment:

Following are the design considerations for the software environment, based on observed behaviors in pilot simulations and requirements for a defense project:

- A software environment which is commercially available and with prior success in defense related environment will be used for the project. For this purpose, 'inklingmarkets.com' was selected as the prediction market website.
- The software environment will be easy to access and use. The software will be accessible via internet and there will be provision of technical support in case of any issues.
- Security is of utmost importance in a defense project. Special precautions need to be taken to ensure that the software environment is secure and prevented against events like phishing, Trojans, etc. There will be an option to assign different roles to different users and a secure login and password capability. The access to the market may be limited to participants with a specific email address domain (for example, '@navy.mil') to security.
- The software environment will have dashboard and administrative capabilities to analyze the data and generate reports based on the user behavior.
- It will be possible to share new information with the traders via communication channels (like emails, messages) through the software.

Considerations for the Market Maker:

To ensure sufficient liquidity, we will use a prediction market with automated market maker ,based on the market scoring rule , which means that the buying and selling of stocks will happen between traders and the market and not between the traders themselves. A 'winner-take-all' format will be used for evaluating contracts. It may be necessary to provide an upper bound for the market maker on the play money amount, so as to avoid any excessive losses that may arise due to less liquidity.

TRADERS:

Market participants will be selected such that the acquisition project will have sufficiently broad following to attract participants from inside and outside the government.

- The traders in the defense project will comprise of the different team members across different cross-functional areas. These can include administrative personnel, sub-contracts, engineers, end users, consultants etc from within the program as well from other programs with which it has synergies. There will be many people in a project who will have limited

information as to what is going on with a program at large, and they might be biased to their individual projects. Hence, it will be ensured that participants from all smaller projects, as well as people from other departments are included in the trading process. The markets will be implemented for duration of 3 to 6 months, giving ample trading time to the participants.

- Sometime, due to fear of hierarchy or work environment pressures, people do not reveal uncomfortable information related to the project. In the prediction market, anonymity of traders will be maintained so that they can disclose useful information without hesitation.

INCENTIVES

The defense acquisition project will have incentives for most active traders and traders with most accurate predictions. Additional incentives will be provided for survey participation or for posting most user comments in the market.

Non-monetary rewards like social recognition and appreciation for the effort are more conducive for the defense environment. Specifically, following steps will be followed for distributing incentives:

- Winners will be declared based on the maximum portfolio value at market closure.
- A leadership board will maintained to display the top performers in the market. Only the user names of the traders will be displayed and the identity of the traders will be kept confidential.
- The results of the prediction market will be included along with regular status reports to track any new or less visible information.

6 CONCLUSION AND RECOMMENDATIONS

In his book "The Wisdom of Crowds" (Surowieki, 2004) Surowiecki argued that if we take a crowd of diverse people and correctly aggregate their judgments, we will be able to get more accurate results using the collective intelligence of the crowd. This wisdom of crowds can be seen in action every day (Coles, Lakhani, & McAfee, 2007) with the collective intelligence also driving Wall Street – the probabilities generated from the market displayed through the stock prices.

The prediction markets can be implemented in large organizations to aggregate the dispersed information across different functional areas. This information can help keep track of any cost or schedule variances, and also identify any potential risks (direct or indirect) that can impact the project.

In his book Enterprise 2.0, author Andrew McCafee talks about the Enterprise 2.0 bull's eye (McAfee, 2009), which represents the ties that a leader or worker has within the organization, on which he/she relies for information. These ties can be represented in the form of four concentric circles as shown in Figure 50, the circle size indicating the relative volume of each tie.

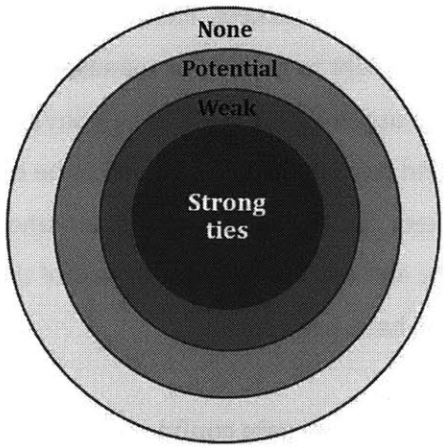


Figure 50: Relative volume of different types of ties of information for a leader or worker (McAfee, 2009)

The innermost circle represents the relatively small group of collaborators with which the worker has the strongest ties. These are the sources to which the worker might turn to before anyone else. The next circle represents the 'weak' ties or the set of people with whom leader might interact periodically. Then come the 'potential' ties, or the set of people who can be valuable for the leader if only the worker can know about them and interact with them. Finally the fourth and the largest circle labeled 'none' comprises of the strangers with whom the worker might not have any connection or way to interact with, but who might still possess some knowledge which might be

directly or indirectly beneficial for the worker. Current collective intelligence tools help strengthens these ties. Prediction markets can not only help the worker to interact with the 'weak' and 'potential' ties, but will also enable communication with the strangers or the 'none' ties (McAfee, 2009). For example, and organization can open the prediction market to public and get information on the basis of trading patterns of crowd.

We found that prediction markets can supplement the cost and risk assessment practices of an organization or program and help capture any trigger points which can directly or indirectly have an impact on the project. Apart from this, they can also provide secondary benefits like:

- Identifying informal and formal information channels within the company
- Engaging the employees and making them more aware about the organization
- Satisfying current need for a better forecasting tools
- Organizing and integrating tacit information

Despite being present for some time now, senior management of large organizations still need to be convinced about the efficacy of prediction markets. There is still a lot of push required initially in promoting the prediction market concept to the senior management, as well as to the employees of an organization. The experts in the organization need to be convinced why an additional tool is being introduced in the system, and participating staff need to be trained on how the markets work. Having said that, prediction markets do not require significant amount of effort in terms of understanding, financing and time and can easily become part of the process life cycle once the initial steps for its implementation have been taken.

One way to help organizations and workers gain confidence in prediction markets is to look at companies who have been using these for some time and study the results. MITRE has been implementing prediction markets for some time in large organizations and has a participant harvesting process to attract and maintain participants for prediction markets.
Figure 51 shows the participant harvesting process followed by MITRE (Henry, 2010). They use a combination of social networking tools like LinkedIn, facebook, twitter etc to connect with individuals, networks and organizations who work in the area of prediction markets, or who can benefit from its use. They invite people to participate in their markets, and promote awareness and supplement their knowledge through various conferences, groups and online forums.

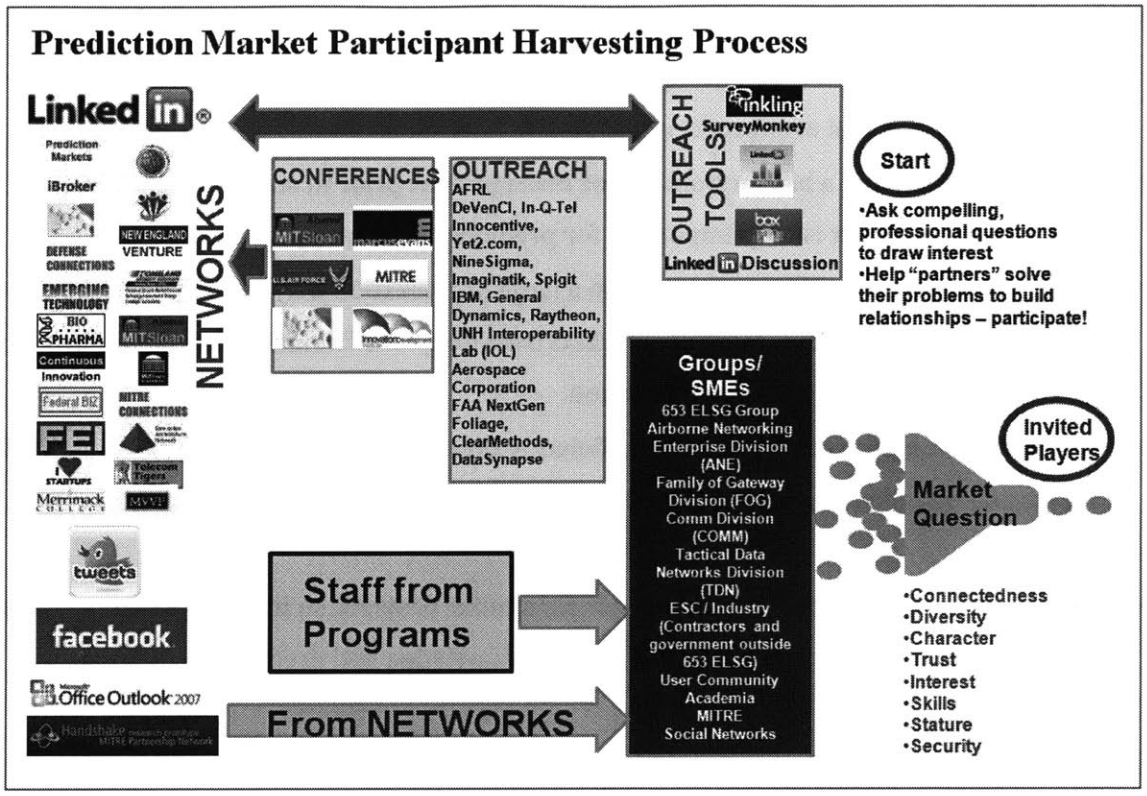


Figure 51: MITRE Prediction Market Participant Harvesting Process (Henry, 2010)

Once a participant group is established and ready for trading, they ask enough compelling and relevant questions to draw interest, and seed the discussion threads regularly with comments and updates. This is a continuous process and helps them build the required network and solve partner problems effectively.

6.1 RECOMMENDATIONS AND BEST PRACTICES

Based on the case studies, literature and pilot simulations, following are some of the recommendations for the use of prediction markets as a tool for cost and risk assessment.

Preparation for implementing prediction markets:

- Prediction market can be used in various ways – in terms of collecting data, predicting outcomes or for opinion formulation. It is essential to determine what purpose will best suit an organization's needs.
- Initial training on how the prediction software tools are to be used should be provided to the participants. This can help reduce participant's initial hesitation in participating and also help run prediction market more effectively.

- Depending on the information most relevant to an organization, prediction markets can be customized (like more subjective questions can be asked, scoring of market can be independent of actual event occurrence etc).
- It is important to get a buy-in from senior management prior to start of the market. Management support is very important for prediction market to succeed initially.
- Implementation of Prediction markets in a large organization may initially take time and effort to prove their value. Multiple markets over long time horizons may be required to get corporate acceptance and full-cooperation.
- The acquisition project should have sufficiently broad following to attract participants from inside and outside the government. These can include sub-contracts, end users, consultants etc.
- Ample historical data should be available for similar projects, so that participants who are new to the project have some basis of gaining knowledge and predicting.

Designing market questions:

- Markets need to be compatible with the political and regulatory contexts in which they operate. For example, federal regulations permit play and prize money prediction markets but has restricted real money markets.
- The questions for the market should be very carefully designed so that the required information can be revealed. 'Fun' questions should be mixed with 'hard' questions so that the participants remain involved.
- The right context for the market should be established from the beginning, so that participants are aware of what the goal is. This is particularly required when the questions revolve are of sensitive nature. Prediction market thrives on insider information, but such information in case of some scenarios (e.g. terrorism etc) can lead to negative reactions.
- Mix of long, medium and short questions is required in prediction markets. Questions should be continuously updated and relevant information should be provided frequently keep the traders interested.
- Questions should have a distinct answer and the contracts or the answer choices should be collectively exhaustive and mutually exclusive.
- First order questions should be supplemented with second and third order questions which can reveal more information regarding the traders and the sources of information to the

traders. These questions can be asked in form of survey during the trading period, or as profiling questions during user registration process.

Trading process and participants:

- The length of the trading period is important. Too short trading periods can limit the effectiveness of the markets, while longer periods can lead to decreased interest in participants in absence of any new information updates.
- Anonymity of participants should be maintained. If a market has less traders (for example a small project team), there is a probability of guessing the actual identity of a trader, To avoid such scenarios, scope of questions should be increased, and participants from other projects should be invited to participate.
- To ensure sufficient liquidity, prediction markets with automated market makers should be used, and at least 15-16 participants should be targeted for trading (Christiansen, 2007).
- Market maker should be designed in such a way that it is 'liquidity sensitive', i.e. takes into account the state of the market and frequency of trades in deciding the price impact of a particular trade.
- Care should be taken on selecting the traders for the market and their demographics should be kept in mind while analyzing the data. An organization can either choose to open the prediction market to public, or can limit it to its own employees.
- The participant comments should be recorded while trading and can prove to be a valuable asset for the business in filling data voids. It not only provides the employees with more information, but also provides an opportunity for the employees to express their opinions to senior management.
- Trading times for the employees can be limited in case there are concerns regarding the impact of the activity on regular office work.
- Regular information updates should be provided throughout the market trading cycle.
- It is important to keep tabs on how traders are performing. If some traders are becoming inactive due to loss of 'money', it might be better to distribute additional amounts or bonus to ensure participation.

Incentives and reward structures:

- A company's culture drives the incentives that motivate the employees. In some cases, the social incentives like recognition, t-shirts, etc can be much more effective than financial incentives.
- Some companies may not be very liberal in incorporating prediction markets results with their company policies. Hence, incentives for participants should be aligned with the company goals and project aspirations in mind.
- Play money should be used in the market and traders should be incentivized based on their constant participation and ability to predict accurate results. Additional bonuses etc can be provided during trading to keep the traders interested.

Continuous Improvement:

- A continuous 'harvesting process' should be employed to keep existing participants motivated and for attracting new participants.
- Prediction markets can be used along with collaboration tools like social networks, blogs etc. and can prove to be more valuable for an organization.
- Results from the market should be made part of the regular process life cycle of the organization. Based on any sudden price change in the market, cost estimation plans or risk mitigation plans can be revisited.

It is also clear from our research that a significant contribution of prediction markets, in the field of cost or schedule estimation and risk management, is to keep the participants involved and make the process exciting.

Yogi Berra once commented "It's tough to make predictions, especially about the future." By using tools like prediction markets correctly, we can keep a tab on the pulse of the organization and make sure that our predictions and estimates are as accurate as possible. This will not only help in avoiding any unforeseen risks but also help make the organization more agile.

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APPENDIX A: BEFORE SURVEY

PARTICIPANT SURVEY

Name: Date:

- How many professional football games do you attend/watch every season?
    - None
    - Between 1 and 3
    - Between 4 and 9
    - Between 10 and 18
    - More than 18

- How many movies on average do you watch at home/cinema in a month?
    - None
    - Between 1 and 3
    - Between 4 and 7
    - More than 7

- Who is 'Peyton Manning'?

- How many Atlantic tropic hurricanes have occurred so far this year?

- As of today, how many games have NFL New England Patriots won this year?

- Who won the recent game between Indianapolis Colts and Kansas City Chiefs?

- Which movie is based on Facebook's inventor Mark Zuckerburg?

APPENDIX B: AFTER SURVEY

PARTICIPANT SURVEY

Name: Date:

- For trading on the sports based questions, how much time (in Minutes/hours) did you spend on collecting information through:
    - Watching/listening to News
    - Browsing internet
    - Asking friends/family
    - Reading sports magazines
    - Other (please specify)
- For trading on the movie-based questions, how much time (in Minutes/hours) did you spend on collecting information through:
    - Watching/listening to News
    - Browsing internet
    - Asking friends/family
    - Reading Movie Magazines
    - Other (please specify)
- During trading process, was there any instance when you changed your trade after observing other trader or his/her trading pattern? (If yes. Please specify)
- What was your key strategy for winning in the prediction market?
- In your opinion, for what type of decisions do Prediction Markets add value?
- Did your perception of Prediction Markets change as a result of trading? How?
- Who is 'Peyton Manning'?
- How many Atlantic tropic hurricanes greater than category 3 have occurred so far this year?
- As of today, how many games have NFL New England Patriots won this year?
- Who won the recent game between Indianapolis Colts and Kansas City Chiefs?
- Which movie is based on Facebook's inventor Mark Zuckerburg?

Any Comments/Feedback:

APPENDIX C: RESEARCH PROTOCOL

Application of Prediction Markets to Cost Estimation of Weapon Systems: Research Protocol for <Naval Project>

Introduction:

"Application of Prediction Markets to Cost Estimation of Weapons Systems" is a collaborative research project between MIT and Iowa State University sponsored by the Naval Postgraduate School's Acquisition Research Program.[4] The project investigates ways to improve costs/completion schedules forecasts and techniques for identifying risks in defense acquisition programs. We propose to implement a prediction market[5] to generate cost/schedule estimates and surface potential program risks that can supplement to existing forecasting methodologies. A prediction market is a way to leverage the 'wisdom of crowds' by providing a mechanism for participants to vote on their opinion about certain issues through an electronic marketplace. Improving the accuracy of cost/schedule estimates and risk identification will in turn improve the DoD's ability to meet its acquisition objectives. For our research, we wish to implement a prediction market over a 3-6 month period using commercial prediction market software in a secure IT environment. The market may be extended if warranted by the early results.

Objective and Research Methodology:

<Naval Project> is an ideal candidate for our research because we are interested in programs that have significant short, medium and long term events so that prediction markets can be examined in a variety of settings. We will integrate our study with existing program procedures to minimize time impact on the project team involved. Our research team has two main objectives: (1) to compare the prediction market forecasts across with conventional forecasting techniques, such as parametric, analogy, activity-based approaches, to see if the initial prediction market forecasts are more accurate and determine how well these forecasts respond to new hard and soft information about the program; and (2) to provide a mechanism to expose unprecedented risks in the program by polling a broad set of individuals involved in the program. Senior Management support is required from the <Naval project> team, along with any specific constraints regarding IT security, participant profiles, timeframes etc.

<Naval project> will benefit from the prediction markets event forecasts in two ways. Not only will the study increase involvement of the participants in anticipating unforeseen events that may impact program performance, but the information can also help SWCS identify how informal information channels in their organization can serve as leading indicators for program performance.

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[4] http://www.acquisitionresearch.com/

[5] http://www.newyorker.com/archive/2003/03/24/030324ta_talk_surowiecki

For each market we will establish a set of questions that will be asked to all or a subset of participants. Questions will try to access information about specific events in the project and also regarding risk factors involved in various areas within the project. Each question is optional but the more activity that takes place in the market, the better information it will generate. Questions under consideration are:

- Will <Naval project> be certified by <insert desired date>?
- The cost of the first unit will be $x <initial estimated cost>.
- The final cost of the program will exceed the baseline estimate by x%.
- The 2011 Fiscal Year appropriation for the <Naval project> will be $x
- Will the <Naval project> program be adequately resourced to meet its milestones?

This research would require the following support and information from <Naval project>:

- Regular participation in the prediction market by team members
- Feedback by the participants on the usefulness of the market
- Ongoing use of the prediction market results in program reviews and/or status reports to senior leadership

We anticipate making the participation and data collection as unobtrusive as possible. The information of the participants and their responses will remain anonymous within the <Naval project> team members, but will be visible to the research team. The software prediction market tool, called Inkling[6], will operate in a secure IT environment, and we can ensure that the questions do not expose any proprietary project information. In addition, we will share all data that we collect during the <Naval project> study to help the program management team.

In other settings, similar prediction markets have generated valuable information for managers, while market participants have found the experience enjoyable. We hope to replicate this experience through the following timeline:

Proposed Timeline (notional):

Determine prediction market questions	Month 1
Launch prediction market	Month 2
Evaluate market activity	Month 2-4
Close market	Month 5
Evaluate results	Month 6
Provide report to <Naval project>	Month 7

[6] http://www.inkling.com