SOFTWARE COST ESTIMATION THROUGH MARKET TRADING: AN EXPLORATORY STUDY OF A NEW TOOL FOR PROJECT MANAGEMENT
Software Cost Estimation Through Market Trading: An Exploratory Study of a New Tool for Project Management

Donald J. Berndt and Joni L. Jones
College of Business
University of South Florida

Abstract
Project management markets aim to harness the wisdom of project teams through trading and continuous price discovery of project outcomes. Information or prediction markets have been used for a variety of tasks, from predicting presidential elections to identifying successful technologies. These market mechanisms are an interesting alternative to many of the typical information aggregation mechanisms used in project management. The challenge is to adapt market mechanisms for use in the project management context. Project management markets are a natural fit for estimation tasks, such as predicting effort, overall cost, delivery dates, or even quality levels. However, markets could also be used for requirements gathering, technology selection, or staffing needs. For instance, software cost estimation remains a difficult challenge, despite decades of attention from both researchers and practitioners. Predictions are often inaccurate and characterized by very wide confidence intervals. Direct approaches rely on “expert” estimates drawn from detailed requirements, along with the experience and intuition of the estimator. The Delphi method seeks a consensus estimate among a group of expert estimators. Still other approaches use historical project data to fit estimation models, such as COCOMO, while hybrid techniques like COBRA combine aspects of several methods. This white paper proposes a very different approach—the use of project management markets to continually aggregate the individual estimates of diverse software project stakeholders. Markets offer a cost-effective method of obtaining continuous feedback on current tasks, providing an independent and complementary perspective on critical milestones.
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1 Introduction

“The ultimate good desired is better reached by free trade in ideas and the best test of truth is the power of the thought to get itself accepted in the competition of the market.”

Oliver Wendell Holmes Jr. (1841–1935), Dissent, Abrams v. United States, 1919

Estimation tasks are central to managing any type of project. Strategies for developing estimates can range from trusting a single expert to running formal group decision-making activities. Software projects are among the most complex projects to manage, because the materials and requirements are so malleable. From the inception of software engineering as a discipline, researchers and practitioners have struggled to develop effective methods for estimating the required development effort and overall cost of projects. The track record has been inconsistent at best. Software, as the ultimate in malleable building materials, makes the estimation of effort a real challenge. For instance, Lederer and Prasad (1998) found that approximately two-thirds of all major software projects substantially overran their estimates. This can result in millions of dollars of unexpected implementation costs and loss of productivity. Over several decades, numerous software cost estimation models have been proposed and tested in practice, but the problems persist (Kemerer, 1987). Software cost estimators and project managers often rely more heavily on their personal memory of similar projects than on more structured methods. However, guessing and expert intuition have also been found to be highly positively correlated with large software projects overrunning their estimates (Maxwell, Wassenhove, & Dutta, 1999).

Conversely, a number of studies claim expert estimates are more accurate than formal estimation models (Kitchenham, Pfleeger, McColl, & Eagan, 2002; Kusters, 1990; Pengelly, 1995). In fact, expert judgment-based estimation is the most commonly used approach today (Jørgenson, 2004). In this white paper, we explore an alternative method for software estimation models, an approach that supports the use and aggregation of multiple, independent, and diverse expert assessments to form composite estimates based on information markets.

Research in group dynamics has demonstrated that, in general, the consensus of a group is often better than any one individual (Treynor, 1987). Evidence from such experiments suggests that the simplest way to get reliably good answers is to harness the “wisdom of crowds” (Surowiecki, 2004). One well-tested technique for exploiting the power of groups is to establish an open market, such as a stock exchange, to accumulate the knowledge of many different stakeholders. It is a widely held belief that prices in free markets convey information held privately by individuals regarding the value of goods (Hayek, 1948). More recently, information markets have emerged that aggregate and collect individual insights, and have been shown to be an effective way to make forecasts and predict future events. This is precisely the problem facing project managers as they struggle to combine the individual opinions of software engineers into a reasonable cost estimate.

In this white paper, we explore the use of project management markets to bring together the many different perspectives of software development stakeholders (from designers to end users) to produce more accurate estimates of costs, overall effort, and other outcomes. For instance, Boehm, Abts and Chulani (2000, p. 177) found that “no single technique is best for all situations, and that the results of
several approaches is most likely to produce realistic results.” The ability of a market to aggregate information from a number of sources, who may in turn use a variety of models to assist in the formation of their expectations, may generate more robust software project estimates. Additionally, an information market gives immediate feedback that can reveal the level of uncertainty within a project and provide learning opportunities for participants. Markets are ubiquitous, simple to understand and use, and are a natural fit in the project management context.

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Any opinions, findings, conclusions, or recommendations expressed in this research are those of the authors and do not necessarily reflect the views of the Project Management Institute.
2 The Software Estimation Problem

“How does a project get to be a year late? One day at a time.”

Frederick P. Brooks, Jr.

The software industry has a long history of inaccurate or inadequate estimation of the effort required to complete projects. These poor estimates have translated into failed projects, or projects that exceed their budgets, their time projections, or both. Additionally, some projects may fall within their budget and time boundaries but not deliver the functionality promised. The Standish Group has tracked software projects for the last two decades and their findings are dismal. Its 2006 CHAOS report indicated that only 34% of software projects succeed, 51% came in late, over budget, or without the required functionality, and 15% failed—cancelled or finished but never used (The Standish Group International, 2006). Similarly, the Meta Group has estimated only a 28% success rate (McBride, 2005). The following section discusses a number of reasons for the lack of success.

2.1 Project Estimate Challenges

Considering that project success and failure are predicated on adherence to budget and time estimates, it is imperative that these initial estimates be as accurate as possible. Yet, there is a disincentive for accurate early estimates. Charette (2005) stated, “Frequently, IT project managers eager to get funded resort to a form of liar’s poker, over promising what their projects will do, how much it will cost, and when it will be completed.” Describing MIS projects, Hulme claimed that the incentive system “encourages overly optimistic estimates of what benefits … can be attained from doing the project” (1997, p. 2). Many project managers are confident that once initial funding is approved, the project can survive change requests that extend the costs and timeline without adding additional functionality. This is a recipe for project failure.

The structure of IT projects makes them inherently difficult to accurately estimate. “Too many projects fail because the average project is like an iceberg—9/10ths of it lay hidden from view” (Hodgson, 2002). Additionally, these estimate errors increase with the size of the project. “A project’s sheer size is a fountainhead of failure. Studies indicate that large-scale projects fail three to five times more often than small ones” (Charette, 2005). In fact, according to Charette, “The larger or more novel the project, the less accurate the estimates.” Recognition of our inability to handle complex projects has prompted phased development, where large projects are divided into more manageable modules. Success rate increases have been directly attributed to these smaller projects, and specifically, the use of agile methods (Attwood, 2006). Agile methods employ short, collaborative development cycles that result in releasable software (see “The Agile Manifesto,” 2001).

Another contributor to inaccurate estimates is poorly defined system requirements. Requirements define the scope of a project and thus are the cornerstone upon which estimates are formed. Large projects, incomplete knowledge, or an inability to understand and define customer needs contribute to deficient requirement specifications. When discussing failed projects, Tim Sheedy, IDC Research Director of Software and Services, said, “The managers of these (failed) projects set out requirements at the
beginning of the project and they got it wrong” (McBride, 2005). According to the Standish Group Chaos Report (1994), incomplete requirements was among the top two reasons for challenged or failed projects, while a clear statement of requirements was a factor contributing to successful projects. Deborah Weiss, Meta Group Program Director, identified poor project estimating techniques as one of the root causes of project failure (McBride, 2005).

2.2 Current Estimation Methods
Research into software effort estimation has produced an alphabet soup of models and techniques. Methods for estimation can be grouped into four major categories: model or algorithmic approaches, analogy/case-based methods, expertise-based methods, and dynamic techniques. Boehm, Abts, and Chilani (2000) surveyed the estimation approaches and concluded that “no single technique is best for all situations, and … a careful comparison of the results of several approaches is most likely to produce realistic result” (p. 1).

2.2.1 Model/Algorithmic
Since the late 1960s, researchers have been developing parametric models. These models have become more robust and complex over the years, but are challenged by the rapid changes in the development environment. A few examples include SLIM, Checkpoint, Price-S, ESTIMACS, SEER-SEM, and COCOMO (I and II) (Putman & Myers, 1992; Jones, 1997; Park, 1988; Rubin, 1983; Jensen, 1983; Boehm, 1981; Boehm et al., 1995). The models differ in the activities covered and input and output factors. Some of the models are proprietary, preventing a direct comparison of their attributes. All must be calibrated to data from past projects, limiting their use in unprecedented situations or for projects where comparable data is not adequate. In most cases, some form of regression is used to build and validate these models. The beta coefficients quantify the predictor variables that make up the model. Many models use simple ordinary least squares (OLS) regression due to its simplicity and wide acceptance. More sophisticated applications use multiple or “robust” regression designed to alleviate the outlier problem common to software project data (Boehm et al., 2000). COCOMO (COstruction COst MOdel) is arguably the most popular cost estimation model. The original model developed in 1981 has been updated to accommodate the rapid development issues (COCOMO II) and has sub-models to handle various advances in software development practices. The COCOMO model equation and parameter values are available at http://sunset.usc.edu/research/cocomosuite/index.html, along with recent extensions designed for off-the-shelf software, quality, and so forth.

2.2.2 Analogy/Case-Based Learning Techniques
Case-based methods or estimating by analogy is rooted in artificial intelligence. Data collected from previous projects, detailing the decisions, environment, conditions, constraints, and ultimate results, provide a repository of comparison cases, or projects that can be used to identify project costs and schedules. Case-based techniques automate the discovery of analogous projects that match or are similar across a variety of dimensions whose actual costs and schedules act as the basis for the new project estimates (Mukhopadhyay, Vicinanza, & Prietula, 1992).
A similar approach, which also originates in artificial intelligence, is the use of neural networks. Rather than use regression as noted above, historical project data is used to train estimation models based on machine learning. The model is developed and subsequently exposed to historical project data and the corresponding known schedule and cost values. The algorithm iterates until the model estimates fall within a predefined error or delta of the actual value. The predictive efficacy of the resulting model is strong for similar environments but may not be applicable to projects that deviate from the training set (Gray et al., 1996). Idri et al. (2002) obtained acceptable results using a neural network algorithm on a COCOMO dataset but found that interpreting the results was difficult.

2.2.3 Expert Techniques

The above techniques rely heavily on data about past projects that is synthesized to generate projections for similar projects. Unfortunately, reliable and representative data are not always available. Additionally, the models and techniques described above may not include important domain knowledge or account for environmental volatility. In these cases expert estimation has been shown to be a viable (and very popular) alternative, outperforming formal estimation models (Jorgensen, 2004; Lederer & Prasad, 1998). In reality, studies show that expert estimation is the dominant effort estimation method, but prediction errors of 32% to 1,107% have been reported (Lederer & Prasad, 1998; Jorgensen, 1995; Hihn et al., 1991; Heemstra et al., 1991; Paynter, 1996; Hill et al., 2000; Kitchenham et al., 2002). The accuracy of expert estimation is directly correlated with knowledge, experience, and the rationality of the expert estimator. The latter is affected by the perceived estimation goals. Lederer et al. (1990) identified two models: the rational model that emphasizes accuracy and the political model that identifies conflicting motives, differing goals, and power conflicts. Incentive structures and other human biases may influence the accuracy of the expert estimates. Jorgensen (2004) has synthesized the literature in this area and provided the 12 guidelines shown in Figure 1 to improve expert accuracy.

| 1. Evaluate estimation accuracy, but avoid high evaluation pressure. |
| 2. Avoid conflicting estimation goals. |
| 3. Ask estimators to justify and criticize their estimates. |
| 4. Avoid irrelevant and unreliable estimation information. |
| 5. Use documented data from previous development tasks. |
| 6. Find estimation experts with relevant domain background and good estimation records. |
| 7. Estimate top down and bottom up, independently of each other. |
| 8. Use estimation checklists. |
| 9. Combine estimates from different experts and estimation strategies. |
| 10. Assess the uncertainty of the estimate. |
| 11. Provide feedback on estimation accuracy and development task relations. |
| 12. Provide estimation training opportunities |

Figure 1. The 12 “Best Practice” Guidelines for Expert Estimation (Jorgensen, 2004)

Formal techniques have been developed to assist experts form their estimates. They include the Delphi Method (Helmer, 1966), Wideband Delphi (Boehm, 1981), Estimeetings (Taff et al., 1991) and the work breakdown structure (WBS) (Boehm, 1981). Delphi is a technique that attempts to aggregate expert
opinions as suggested in Item 9 of Figure 1. Expert judgments are gathered by some means, usually a survey instrument. Opinions are collected in rounds, then summarized, and the results and reasoning distributed to all participants. Subsequent rounds seek to narrow the gap between the participants’ perspectives. This process continues until consensus is achieved or a predetermined stopping point is reached. The process is fairly structured: a facilitator controls group interactions, which may be anonymous. Advances in this area include electronic versions that allow greater flexibility and a more distributed collection of participants. Wideband Delphi is a less-structured version of the traditional Delphi technique. Delphi has been effectively used in software development projects, especially for requirements discovery.

The WBS employs the ideas of checklists and top-down, bottom-up estimation. The WBS defines and organizes the total scope of a project, using a hierarchical tree structure. High-level tasks are defined and then broken into subtasks. Tasks continue to be decomposed until each subtask can be realistically and confidently estimated, cannot be logically subdivided further, can be completed quickly, and will have a meaningful conclusion and deliverable. A well-designed WBS describes planned outcomes instead of planned actions. Outcomes are the desired ends of the project, and can be predicted accurately (Rose, 2006). Effort estimates can be assigned to each subtask and sequenced into the project work plan, resulting in an overall project estimate.

Finally, Estimeetings relies on estimators with detailed domain knowledge who review requirements specifications in a series of group meetings (Taff et al., 1991). All of these techniques rest on our intuitive view that experts know best. Project management markets offer a counterintuitive (and possibly complementary) view that it is better to aggregate everyone’s opinion.

2.2.4 Dynamic Techniques

The techniques discussed so far assume that a careful and thorough analysis of the elements of the project will result in accurate project estimates. The rationale is that using one or more of these traditional approaches will result in accurate calculations of the cost and duration of a project. Others have suggested that the traditional approaches ignore the interrelationships between project components. The concern relates to the notion that the whole may be greater than the sum of its parts (Rodriquez & Bowers, 1996, p. 214).

System dynamics is a more holistic approach to effort estimation that concentrates on the entire project, including feedback loops that facilitate adapting to new and changing environmental conditions. To employ this approach, first you identify the key feedback loops and the impact of various disruptive factors on the project. An influence diagram is used to depict the dynamic environment and is modeled as a continuous simulation. The project manager uses this model to assess the impact of changes in conditions over the life of the project. System dynamics models have been successfully employed to predict cost, duration, and staffing in software engineering projects as the projects progress (Abdel-Hamid, 1989a, 1989b, 1993; Abdel-Hamid & Madnick, 1991, 1993; Madachy, 1994).
2.3 Estimation Challenges

Accurate estimation faces several challenges. The modeling and analogy-based techniques require representative data, and expert estimates may fall victim to the expert’s experience and biases. The tremendous complexity of software engineering projects is an obvious challenge to accurate software estimation. Acquiring the information necessary for any of the techniques discussed can be difficult, and the aggregation and distillation could result in information loss. The assumption for the model and case-based techniques is that adequate representative data is available. Stutzke (2000) claimed that “constant and rapid changes mean that little relevant historical data will be available to help estimate future software projects and develop new cost estimation models.”

There are few endeavors that require such constant innovation and creativity during the construction process. In the face of such complexity, it is difficult for any one person to maintain a mental model with enough detail for project estimation and management. Most software developers bring localized knowledge of some components into the estimation process, but this does not guarantee that they also bring an accurate system-wide perspective. One of the reasons often cited for effort estimation error is the sole (or nearly complete) dependence upon the project manager’s viewpoint (Jørgenson & Moløkken-Østvold, 2004).

While experts are able to offer insights, recognize unusual circumstances and capitalize on experience, the collection and interpretation of information may be incomplete. As Stutzke observed,

> Expert judgment techniques tend to be informal and qualitative in nature, even though they often produce quantitative results. The main source of information is the estimator’s memory of past projects, products, or processes. Although the experts may consult historical records to refresh their memories, these techniques do not use historical data in an organized way, even though they may perform quantitative calculations. (2005, p. 104)

Expert estimates are subject to the knowledge and biases of the expert. Experiments using groups of experts have resulted in more accurate and less biased estimates than single expert estimates (Moløkken-Østvold & Jørgenson, 2004). This same idea, harnessing the collective minds of many experts, is the driving force behind the Delphi method.

No matter which approach is adopted, if more than one project manager or estimation technique is involved, the various opinions and judgments need to be assembled into a single estimate. There are many strategies for synthesizing estimates of effort or analogous projects to arrive at cost estimates, from expert “guesstimating” techniques to more structured approaches such as the venerable Program Evaluation and Review Technique (PERT). As depicted in Figure 2, the project manager must collect information from various stakeholders in the development process, including project team members and end users. Estimates are influenced by the interaction with human resources facilitated by formal and informal meetings, interviews, review sessions, Joint Application Design (JAD) sessions, and other less formal means. The gathered information is used to generate design artifacts such as diagrams, workflows, design specifications, and to populate analytic models that will further assist the project.
manager in forming cost estimates. The aggregation and communication process is subject to information loss.

Figure 2. Information Aggregation
3 Information Markets

“The market is not an invention of capitalism. It has existed for centuries. It is an invention of civilization.”

Mikhail Gorbachev, June 8, 1990

Berg, Nelson, and Rietz defined information markets “as those run for the purpose of using the information content in market values to make predictions about specific future events” (2003, p. 79). Harnessing the collective wisdom of the crowds through markets is the topic of a recent book by Surowiecki (2004). He claimed that groups of people are smarter than an elite few, no matter how brilliant any individual may be. Groups are better problem solvers, innovators, decision makers, and predictors of the future. Extensive research has shown that information markets effectively aggregate the opinions of participants with vastly different backgrounds, holding localized knowledge, who may be geographically dispersed (Sikora & Shaw, 1998; Plott, 2000). There is a large body of evidence that information markets are effective at estimating the probability of future industrial or political events, such as shifts in monetary policy, predicting the next U.S. Supreme Court Justice to leave the bench, and assessing various forms of geopolitical risk (Berg & Rietz, 2003; Brüggelambert, 2004; Gruca, 2000; Herron, Lavin, Cram, and Silver, 1999; Oliven & Rietz, 2004; Wolfers & Zitzewitz, 2004). The Iowa Electronic Market (www.biz.uiowa.edu/iem), perhaps the most well-known example, has compiled an impressive record of predicting presidential elections (Berg et al., 2001; Berg & Rietz, 1996; Forsythe, Nelson, Neumann, & Wright, 1992). Plott and Chen (2002) successfully applied information markets in a more business-oriented experiment to forecast sales volume and the level of profit sharing at Hewlett-Packard Laboratories. Their market results consistently outperformed official internal forecasts. Ortner (1998) used an information market to predict a software project’s late delivery, directly contradicting traditional estimation methods. In light of their success, a number of commercial prediction markets have recently emerged (TradeSports.com, EconomicDerivatives.com, NewsFutures.com, Foresight Exchange [iedosphere.com], Hollywood Stock Exchange [hsx.com]), trading on political, financial, current events, sports, and entertainment. Several informal explanations for the success of these markets are presented in the prediction market literature. Most notably, financial incentives for accurate predictions, better-informed traders self-selecting to participate, the ability to aggregate information, and the feedback provided by market price (Plott, 2000).

3.1 Market Participants

Participant selection is a critical factor in any market, especially if the market is small or the knowledge is specialized. Factors such as domain expertise and trading experience may influence market behavior. Therefore, it is important to incorporate individual traits, evolving trading experience, and other factors specific to the particular context into market design. However, involving the ideal set of market participants is not as critical as one may expect. The “no-trade” theory suggests that adverse selection will prevent rational uninformed agents from trading if they believe their counterparts are all informed agents (Milgrom & Stockey, 1982). Including somewhat less informed, or even completely uninformed, traders in a market adds liquidity, as they may buy and sell contracts at prices that more informed participants would hold (Plott & Chen, 2002). In fact, the attraction of markets is that they display high
levels of efficiency, even though individual traders may have biases and make mistakes (Forsythe et al., 1992; Oliven & Rietz, 2004; Forsythe, Rietz, & Ross, 1999). Participant traits that support an effective information market include decentralization, diversity, independence, and the number of interconnections among participants in the market (Holland, 1998; Johnson, 1999; Knight, 1921).

3.1.1 Decentralization
Market mechanisms are well suited to environments where there is distributed, local knowledge, privately held by many potential market participants. Decentralization may lead to information silos, which create areas of localized knowledge. Information markets are an excellent mechanism for bringing together many decentralized “experts” or team members and subsequently sharing the group consensus through market prices. This is especially true as we move toward global development teams and geographic dispersal. By harnessing the power of information markets to aggregate diverse knowledge and expertise, the limitations of single expert decision making can be avoided.

3.1.2 Diversity
Diversity of backgrounds and opinions are characteristics of successful markets. Greater variety in group experience and domain knowledge leads to better decisions (Surowiecki, 2004). If everyone held the same ideas or beliefs, there would be no trading. All traders would desire to buy and sell the same items, therefore no trades would occur. To facilitate a market, participants must have differing expectations regarding the value of a stock. The old adage, “one man’s trash is another man’s treasure,” exemplifies this notion. Without trader diversity, everyone would have the same belief and thus value their trash and treasure the same.

3.1.3 Independence
Another critical ingredient of successful information market participants is independence. That is, participants are free to act independently and express their personal opinions through trading behaviors. Participants need to be free from group pressures when forming their valuations. Independent value formation reduces the influence of dominate opinions. A market-based approach has the advantages of continuously available trading and the possibility of anonymity, which promote independence.

3.1.4 Interconnections
While independence is necessary to foster a unique perspective, it is also desirable to have interconnections between market participants to foster the exchange of individual information. The market provides a platform where general connections can be facilitated, but a common knowledge core is necessary to develop and refine value estimates.

3.2 Market Size
Berg, and Rietz (1996) found that larger, more active markets with fewer contracts are more accurate. However, reasonable performance has been demonstrated with small (or thin) markets with as few as 8 to 30 participants (Plott & Chen, 2002; Ortnner, 1998). For instance, Chen, Fine, and Huberman (2001) successfully ran laboratory experiments using information markets with fewer than 15 participants.
However, small markets do present some unique market design challenges. A small market is more susceptible to intentional market manipulation or the subtle dominance of shared beliefs. Additionally, market liquidity may suffer due to a limited number of trades offered given the number of participants involved.

3.3 Information Aggregation and Feedback

For information markets to be successful, contracts must be clear, easily understood, and easily adjudicated. As participants buy and sell contracts in a market, the price of the individual contracts forecasts the probability of each event occurring (Berg et al., 2001; Malinvaud, 1974). This equilibrium property of information markets acts as an opinion aggregation mechanism, with supply and demand principles illuminating the group consensus. The feedback provided by the prevailing market prices of the contracts allows bidders to learn from the actions of other traders and possibly modify their initial estimates. This concept is well defined in the literature on common value auctions (Kagel & Levin, 1999; Rothkopf & Harstad, 1994; Dyer & Kagel, 1996). Finally, Wolfers and Zitzewitz suggested that prediction markets “provide three important roles: (1) incentives to seek information; (2) incentives for truthful information revelation; and (3) an algorithm for aggregating diverse opinions” (2004, p. 125).

3.3.1 Incentives to Participate

A market must provide some motivation to induce accurate trading behavior. Market participants must have the proper incentives to fully engage in the market, as well as to trade in a forthright manner. That motivation is normally in the form of a monetary payoff. Payoffs can be real money or play money. The “real-money” markets follow the principle that forecasts will be better if traders risk their own money. However, due to regulatory issues mainly surrounding state prohibitions on gambling, many commercial information markets have adopted the concept of play money. Servan-Schreiber, Wolfers, Pennock, and Galebach (2004) compared the accuracy of information markets with real-money and play-money payoffs and found no difference. Their conclusion is that real money is only one of many possible motivators such as the thrill of competition, reputation, and community bragging rights, or prizes for the best forecasters.

3.3.2 Payoff

There are a number of potential payoff functions that can be applied to the market. For example, participants can be rewarded for holding the most winning contracts. Other payoff methods can be based on the level of a participant’s bank. One such method, referred to as the winner take all method, specifies that the payoff for owning a share of the winning contract at the close of a market is always a dollar ($1.00). By using this strategy we can interpret the prices of contracts as the probabilities that it will be the most likely outcome at market close (Jørgenson, 2004). Thus if a participant owns any contracts in \( v^* \) at market close and 0 otherwise, a participant’s payoff will be:

\[
\sum_{b=1}^{B} (1 - p_b) s_b
\]

where:

\( B = \) the set of contracts bought in estimate \( v^* \),
$p^b_i$ = the price in any contract purchase of $v^*$, and
$S_b$ = the number of shares in any contract purchase of $v^*$.

A participant will incur a loss equal to the amount they paid for shares in non-winning contracts:

$$\sum_{b=1}^{g} (p^b_i) S_b$$

The bank is adjusted by the previous formula and participants are either rewarded for having the largest bank or given a monetary reward that is some fractional percentage of their bank.

3.3.3 The Voice of the Market

One of the most difficult challenges in using information markets is determining exactly what the market is saying since there are many ways to aggregate the trading behaviors and prices (Pennock et al., 2001). Plott and Chen (2002), used a volume-weighted price average (VWPA) to determine the most valuable contract and a single estimate—the voice of the market. The volume-weighted price average was calculated for each contract ($c_i$) in a market with a set of contracts ($C$). Let $q_i$ be the quantity of contracts purchased and let $p_j$ be the price (the number of credits paid for each contract) in a single trade ($t_j$). The total cost of any trade is then $p_j q_j$. Finally, the VWPA ($v_{ci}$) for each contract is found by summing the cost of all trades in a contract over the sum of the share quantities (as shown below).

$$v_{c_i,C} = \frac{\sum_{j \in T_i} p_j q_j}{\sum_{i \in T} q_i}$$

where:

$C$ = set of contracts in the market,
$c_i$ = the $i^{th}$ contract in $C$,
$v_i$ = the volume-weighted price average for contract $c_i$,
$T$ = set of trades in the market,
$T_i$ = set of trades involving contract $c_i$ ($T_i \subset T$),
$t_j$ = the $j^{th}$ trade in $T$,
$p_j$ = price per share in trade $t_j$, and
$q_j$ = quantity of shares in trade $t_j$. 

15
4 Project Management Markets

“Despite the naïve faith many people have in the effectiveness of market forces, the superiority of disorganization over organization is deeply counterintuitive. Businesspeople who recognize the weakness of centralization and planning when undertaken by a state authority do not understand that centralization and planning will fail in their own organizations, and for the same reasons. The truth about markets is not that businessmen are cleverer than bureaucrats: mostly they are not. The genius of markets is that they are not dependent on the genius of any individual. They do not rely on knowledge that no one can hold or depend on information that is impossible to collect.”

John Kay, Culture and Prosperity, 2004 (p. 19)

In our culture of expertise, where we value specialists and professionals (often irrationally), from Wall Street to the sports arena, it is difficult to accept that insightful information can arise from the messy interactions of market mechanisms, nicely summarized as prices, rather than the prognostications of a gifted few. This is perhaps the most surprising message from the growing body of research projects and applications of prediction markets. Distrust in the messages embodied in market prices runs deepest where there is an existing hierarchy of pundits, a well-established status quo, or the news is something we would rather not hear. The current run-up in oil prices is certainly an unfortunate series of events, especially when coupled with other financial crises. The Wall Street Journal Review & Outlook (Editorial) column succinctly addressed the issue of market distrust:

Futures markets aren’t some shadowy dangerous force, but are essentially a price discovery mechanism. They allow commodity producers and consumers to lock in the future of goods, helping to hedge against future price movements. In the case of oil prices, they are a bet about supply and demand and the future rate of inflation. Democrats nonetheless now argue that these futures markets are generating the wrong prices for oil and other commodities. (June 10, 2008; p. A-16)

While it is doubtful that the mistrust is confined solely to the Democratic Party, the underlying message of mistrust in market forecasts is hard to ignore. High oil prices are inconvenient economic messages that may reflect a changing landscape of energy use. How better to discover that message than through a market mechanism? Centralized planning? Government price controls? The enduring success of market mechanisms makes the choice seem obvious.

4.1 Estimating Continuous Functions

One of the most intriguing differences between general information markets and estimation markets is the continuous nature of most outcomes, rather than the discrete events that characterize many prediction markets. Project effort estimation focuses on delivery dates over some time interval, the number of labor hours required, or budgeted amounts for materials, labor, and other inputs. All of these critical estimation tasks involve picking a point along a continuous interval, whether represented in units of time or cost.
We typically make these continuous estimation tasks discrete by simply selecting points across a given interval, often quite arbitrarily. This simplification allows traders to concentrate on a small set of choices rather than every overly precise incremental change possible. However, one of the challenging aspects of estimation market design is finding the right balance between the number of contracts or outcomes for trading, while still covering the necessary range and offering reasonable precision for the estimates. Past research, as well as our current experience, has shown that a reasonably small number of outcomes improves trading activities, though there has not been much attention focused on estimation tasks. The current Milestone Market described in this paper typically uses a dozen or fewer contracts to represent discrete estimates. These contracts target outcomes such as labor hour estimates, outright costs, or even quality levels. While a set of discrete contracts is a straightforward method of handling continuous estimation tasks, more natural interface designs are possible. Representing the outcomes as continuous functions and allowing traders to select points along the continuum could lead to innovative methods for supporting estimation tasks.

4.2 Market Makers
For people unfamiliar with markets, the idea of posting bids or asks can be an obstacle to participation and therefore, price discovery. One method of making the market simpler to use is to have automated agents or specified traders play the role of market makers, fulfilling small orders as needed to keep the market liquid. Traders under this scenario buy and sell, at times with a market maker and not other traders. Many of the prominent stock exchanges employ specialists or market makers. For instance, the NASDAQ uses several competing market makers that “are required to maintain two-sided markets during exchange hours and are obligated to buy and sell at their displayed bids and offers” (see www.wikipedia.org – Market Makers). This allows trades to execute even when there are short-term imbalances between buyers and sellers. A basic automated market maker is being incorporated within the Milestone Market as an optional feature. It has only been used for a few markets, but seems to be a possible strategy to add liquidity and encourage participation by keeping the market moving, avoiding lulls that can cause traders to tune out.

4.3 Thin Markets
As noted in the prior discussion of information markets, markets can often be quite small, yet still remain effective. This is an important consideration in project management markets. Project teams may be somewhat small and result in thin markets, despite the recruitment of other stakeholders. For instance, agile methods typically rely on small teams to accomplish development tasks. There are also many software development companies that are simply small in size. In these situations, participants can be recruited from other development teams, quality assurance areas, marketing, internal end-users, and external clients. One positive feature of the project management context is that participants are often naturally divided by area of specialization. There are business analysts, project managers, database administrators, data stewards, programmers of various types, testers, and users that all bring different localized knowledge to the market.
4.4 Market Transparency

Market transparency “is defined as the ability of market participants to observe the information in the trading process. Information can be related to current or past prices, offers, volume, and the identities and motivations of market participants” (Bichler, 2001, p. 5). Clearly, online markets have many advantages with respect to transparency. Information about offers and trades is easily captured and made available to participants. Advanced features for searching and analyzing trade data can also be supported, with downloads for more customized analytic investigations.

Transparency of market participants is another matter. The Milestone Market is setup to support various levels of anonymity, from the display of individual trader names at a transaction level to nearly complete anonymity. Intuitively, it is natural for us to expect anonymity in these marketplaces. But in the project management context, a mixture of trader transparency models may be appropriate. Clearly, recognition among peers is a primary motivation for market participation, so being identified as a market winner—an accurate estimator—is a reward that must not be given anonymously. However, naming a winner does not necessitate disclosing the trader’s identity in a particular milestone or event, or require treating all traders uniformly. In financial markets, executives and other insiders are often scrutinized and must meet mandated reporting requirements. Project managers and technical staff who might directly manipulate the outcomes of milestones could be considered insiders in the project management context. It seems appropriate to adopt a hybrid transparency model, where project managers, estimators, or technical leads who assign task priorities trade by name, while other stakeholders remain anonymous.

4.5 Messaging and Notifications

One fairly direct way to motivate traders is to issue a variety of messages and e-mail notifications. Several mechanisms for messaging are being incorporated into the next version of the Milestone Market in order to experiment with different messaging schemes. Trading activity in project management markets typically includes many milestones over extended periods of time. The ongoing nature of these markets, plus the relationship to day-to-day project tasks, could lead to markets fading into the background as a low priority activity.

What strategies would keep interest in the markets high? Certainly, the most important factor is utility. Markets mechanisms will be used if they prove to be cost-effective methods of estimating key project milestones. However, designing engaging and easy-to-use markets can go a long way toward fostering trader participation. The current development goals for e-mail notifications include daily or weekly market summaries, trader position information, trade execution receipts, and price-level notifications. These notifications are very low cost features that can include embedded tables and hyperlinks for “one click” trading or more detailed information. Just as in online shopping applications, driving toward very streamlined processes seems to overcome some barriers to interaction. Overall, having a “push” capability for information provisioning nicely complements the “pull” of actually logging into the market to monitor prices and trade.
4.6 Starting Positions
As discussed earlier, project management markets such as the Milestone Market can use a group of contracts to represent a continuous outcome. Even in naturally discrete situations, there may still be a number of contracts to represent distinct alternatives for price discovery. Setting the initial prices for a set of outcomes with a small number of market participants can be a challenge. One way to start the process is to include initial estimates from project managers or other key participants. The input from such experts could be a single estimate, probabilities for all outcomes, or a hybrid approach where initial prices are derived from given estimates.

Another strategy to encourage early pricing is to provide each trader with a portfolio of shares and cash as a starting position. This provides some incentive for traders to offer unwanted shares in the market, establishing initial prices. The more traders who feel shares in a given outcome are undesirable, the lower the initial price. Of course, bids for desired shares serve the same function on the buy side. Having an initial portfolio forces some liquidation of positions in order to raise capital for future investments, thereby helping to establish prices quickly. This strategy is available in the Milestone Market and has provided a reasonable stimulus in many markets.

4.7 Direct Incentives for Participation
An overt strategy for encouraging market participation is to supply some reward for logging into the market, posting bids or asks, or completing a trade. Some sports-oriented markets have offered such rewards, but these markets may want to encourage high website traffic as much as accurate predictions. Nevertheless, some type of direct reward can certainly be effective. In a recent market experiment focused on the Euro Cup for 2008 (www.euro2008.uefa.com), we employed a direct incentive in the form of market currency for each day that a user visited the market. These experiments continue in the GolEx soccer market (www.golex.es). While the evidence at this moment is anecdotal, the market developers became hooked in a way that was truly unexpected. In the project management context, such direct incentives unrelated to predictive performance may serve to undermine accurate estimations. Investigating the possible tradeoff between accuracy and direct incentives for participation is an interesting avenue, especially since the effect of such incentives seems strong.
5 Milestone Market

“So everybody has some information. The function of the markets is to aggregate that information, evaluate it, and get it incorporated into prices.”

Merton Miller

The Milestone Market (www.MilestoneMarket.org) is a prototype project management market built by the University of South Florida (funded in part by the Project Management Institute). The market is being used to experiment with many of the market design issues discussed in this paper. The market is also available for others to use, with the eventual goal of providing an “open web service” that is accessible to the project management community. The current version being developed includes market administration facilities that will allow end-users to create and customize markets for specific purposes, with built-in support for many typical project management activities. The following sections include screenshots of the current interface and discuss some of the design features.

The Milestone Market is a bid/ask-based double auction, so there are many simultaneous buyers and sellers trading shares of outcomes, such as specific delivery dates or project effort estimates. The markets are typically open, which means that the buyers and sellers can see the current bids and asks, re-posting offers in response to current market prices. The market is typically formulated with a series of contracts representing various outcomes of the project task. As discussed earlier, the Milestone Market is an estimation market that aims to predict project costs, effort levels, or delivery dates. While the market infrastructure can be customized for many other uses, the default markets are tailored for project-related estimation tasks. A series of contracts represent individual estimates, such as specific delivery dates, one of which will be the actual result in the future. At the close of the market, whoever holds shares of the winning contract receive payouts (typically 100 credits or “fruppees” to keep prices simple to interpret). The Milestone Market uses a fake currency called “fruppees” to conduct business. Variants of the market can accommodate different payoff amounts, or pay holders of nearly winning contracts to reward pretty good (but not winning) estimates.

Again in the default market, traders begin with equal-sized portfolios of shares in all contracts, along with a cash bank balance. Traders begin the market by making adjustments to their starting positions, liquidating shares in contracts or outcomes that they feel are unlikely to occur, and buying shares at prices that reflect their beliefs. The use of an initial position has proven to be a bit of an incentive to start trading. Only two actions are required, posting bids (to buy) and posting asks (to sell). The market automatically matches bids and asks (at the lowest asking prices) and executes a trade, including partial executions based on the number of shares available. This simple set of actions makes the market easy to use, asynchronous, and a natural fit for geographically dispersed participants. Essentially, there are two ways to make a profit: hold the winning contracts until the market closes and a payout is made, or buy low and sell high.
5.1 Milestone Market Primer
Selling shares of a contract involves posting an ask, which includes the number of shares you want to sell and the price that you are asking. If there is someone with a pending bid for those shares with a price at or above your asking price, a trade will execute at the asking price. The seller’s bank will increase by the price paid multiplied by the number of shares traded, with a corresponding decrease in the contract position. Partial trades will also execute. For example, if a trader wanted to sell 5 shares at 20 frupees (f) and a bid exists for 2 shares at 25f, the trade would execute for 2 shares at 20f and the bank would increase by 40f, with a pending ask for 3 shares at 20f. Traders cannot sell more shares than they own in any contract.

Buying shares of an outcome involves posting a bid, which includes the number of shares you want to buy and the price that you are willing to pay. If there is someone with an ask pending for those shares with an asking price at or below your bid price, a trade will execute at the asking price. The buyer’s bank will decrease by the price paid multiplied by the number of shares traded, and the number of shares owned in that contract will increase. As above, partial trades will also execute. In addition, traders cannot post a bid for more money than they have available in the bank.

The winner of the market is the trader with the largest bank at the end of trading (though other models are also supported). At the close of the market, traders are given 100f for each share held in the winning contract. This amount is added to the existing bank and the total bank is then evaluated. Traders receive no compensation for holding shares in non-winning contracts. Therefore, the net gain for buying a share in the winning contract is 100f, less the amount paid for the share.

If a trader is completely confident that a particular contract will be the final outcome, holding the shares is a reasonable strategy. However, as the price rises there may be a point at which it makes sense to take a profit and remove risk. For instance, if shares were purchased at 20f and the price rises to 90f, it might be wise to forgo the possible extra 10f per share and take a certain profit of 70f per share, keeping the cash for subsequent purchases as market conditions change. Of course, traders can sell shares of unwanted contracts at any time.

5.2 An Example Effort Estimation Task
As an example, consider a market to estimate the number of labor hours necessary to complete a website development project. In fact, one of the experimental tasks used in our experiments was to estimate the effort need to translate a section of a website from English to Spanish as part of a localization project. An estimation market can start with an initial estimate from a project manager, derived from expertise, or a more formal approach. Though an initial estimate is not necessary, it does seem to provide a context for subsequent trading and is helpful in formulating the market contracts. Assume in our example market that an expert estimate is 75 labor-hours. Contracts are set up to span the range from 55 hours to 105 hours, with 11 contracts in total (this fits the screens shown in the following figures). One of the design decisions is how to bracket the initial estimate. In this case the right tail larger than 75 hours is longer than the left tail. A reasonable approach, because software development projects are typically underestimated rather than overestimated. Each trader starts with a portfolio of shares in the contracts, in this case 10 shares in each contract, and 1000f in cash.
5.3 Milestone Tab

In order to present the current interface, as well as a more detailed discussion of the example, screenshots of the major tabbed pages follow. The main Milestone page provides a summary of market trades using a histogram (see Figure 3). As noted in the legend, the translucent red bar indicates the minimum ask and maximum bid in the market for each contract. The smaller the gap, the closer traders are to reaching an agreement to trade. The black line indicates the highest and lowest past trade prices to provide a quick historical context. More detailed tabular information on bids and asks is presented below the graph (see Figure 4). Detailed data items include the minimums, maximums, averages, standard deviations, counts, and volumes for bids and asks. Finally, at the bottom of all pages are the bank balance, cash exposure based on the trader’s outstanding bids, and the difference, which is the available cash. In the current market, you cannot borrow or leverage your position, it is cash only. Because a trade could execute against any current bid, the cash is considered obligated while the bid is active. This page is the default landing page, providing an overall market summary and quick links to the individual contracts.

![Figure 3. Milestone Tab with Summary Histogram](image-url)
The Contract page provides a much more detailed view, as well as the input area or form for entering bids and asks. Figure 4 shows the graphical data on past trades, both price and quantity, while the minimum current ask and maximum current bid are above. This is the most important information a trader would need before posting a new competitive bid or ask. Quick links to all the other contracts are listed down the left of the screen. Below the graphs are detailed listings of all the trades for the specific contract, as well as all outstanding bids and asks (see Figures 5 and 6). This information can be presented using various levels of anonymity; in this case, trader logins are shown. However, unique identifiers without names or even complete anonymity are other options. This feature has been used for experiments on anonymity and is now an administrative parameter that can be modified to suit market tasks.
Figure 5. Contract Tab with Trend Data and Bid/Ask Entry
The Contract tab is also the single point for taking market action by posting bids or asks. The left side of the page includes some simple forms and buttons for buying (posting bids) or selling (posting asks) for a specific contract. Figure 7 is a closeup look at this part of the page, where you specify the number of shares you are offering to buy or sell, along with a price. You may also retract any outstanding bids or asks on a contract. So, interacting with the market consists of expressing your beliefs in certain outcomes by monitoring prices and periodically refining your offers by posting, retracting, and re-posting bids and asks. Using the market at an individual level is quite straightforward. The really interesting results arise from the interactions of many traders expressing their beliefs and aggregating them in the form of prices in a market.
5.5 Position Tab

The Position tab (see Figure 8) displays a table with the current holdings in each contract or outcome, along with the bank balance at the bottom of the page. A second table details each trade by a user, whether on the buy or sell side (ordered chronologically). This provides a detailed summary of a trader’s position in a particular milestone.
5.6 History Tab

Figure 9 shows the History page, which provides trend lines based on the trading prices for all of the contracts available. This allows traders as well as project managers to look at the rise and fall of contract prices and understand which outcomes are being viewed as most likely through higher pricing. The graphs are color-coded and have a mouse-over feature that displays the contract label. Below the graph is a chronological summary of all trades, presented at varying levels of anonymity (controlled by the market administrator).
5.7 Information Tab

The Information tab is a place for customized text and hyperlinks to additional sources of information. Using the web localization task described in the example, hyperlinks to country-specific information might be provided, along with information on various aspects of the localization process. Everything from direct language translations, color schemes, images, to currency conversions must be considered for local website deployments.

5.8 Market Help

Figure 10 is a quick look at the online help feature, which includes a selection of frequently asked questions that comment on simple trading features, such as retracting bids and asks. Other questions consider higher level issues, like how to win the game or different trading strategies. All of these pages present an easy-to-use trading framework with plenty of detailed information to support decision-making. The interface continues to evolve, but this version of the market is available for evaluation by potential users of project management markets.
5.9 System Architecture

The Milestone Market is deployed as a web application, with client interaction requiring only a browser. The prototype market was built using PHP and the current (MM2) version is implemented in Microsoft ASP.Net and the C# programming language. As illustrated above, the main web pages are presented as tabs, with most contract names and other text entries as shortcuts to appropriate pages. The web server does relatively little computing, rather focusing on presentation-level tasks.

The backend database (currently an Oracle platform) includes the database tables for persistent storage, as well as a collection of stored procedures that accomplish most of the computing tasks, from trade execution to market administration. Most data is returned to the web tier through a set of standard database views, acting as a layer of separation between interfaces and market mechanisms. The stored procedures and views are intended to serve as a public programming interface, so that other tools can be built to provide market access. For instance, desktop platforms could provide market access coupled with more advanced analytic capabilities, or lightweight trading tools could be implemented for mobile devices.
6 Conclusions

“The only relevant test of the validity of a hypothesis is comparison of prediction with experience.”
Milton Friedman

Research into the use of information markets to assist with business decisions is rich with opportunities. This white paper explores some of the potential research areas as they apply to effort estimation in software projects. However, information markets have unlimited potential for use in providing decision support for business problems. Figure 11 depicts the research landscape that could be explored to expand our understanding of markets in business settings and more specifically, to software effort estimation.

6.1 Trader Characteristics
All traders are not created equal. Diversity in market trader characteristics will have a direct impact on trader behavior. As noted earlier, diversity of backgrounds and opinions is viewed as positive for information markets, because differing ideas and beliefs will drive trading (Surowiecki, 2004). However, some individual differences may lead to trading behaviors that distort the market. Individual differences can be the result of cultural backgrounds, the participant’s role in the project, and their unique risk preferences. For example, there is a well-known difference between cultures in power distance, the extent to which individuals expect and accept the unequal distribution of power, and tolerate
differences in a hierarchy (Hofstede, 1991, 2001). Market participants from cultures high in power distance may be less reluctant to trade, or may follow the trades of individuals who have higher positions, rather than participate based on their own beliefs. Additionally, the mix of traders may be influential. A very diverse set of participants may interact differently than those with more in common. While diversity of mix may maximize the independence of market participants, it may reduce the interconnectedness of those participants, which could minimize the exchange of individual information. The impact of these influences on trading strategies, level of participation, and trading accuracy needs to be explored. Of particular interest in the project management area is how does the distinction between subgroups in a project impact the market. For example, will programmers act differently than system analysts? Do some groups have a better understanding of the overall process? If so, does that translate into more accurate trades?

### 6.2 Market Characteristics

Applying information markets to new and interesting problems generates a variety of market characteristics. The degree of task complexity of the problem being predicted can vary significantly. Unlike an information market predicting the outcome of a political event, where there is one correct choice among the choices, there are several contracts for an estimation task, representing either completion date ranges or effort required. Additionally, care must be taken in the choice and description of the alternatives in markets estimating effort. The market developer must decide on the granularity of the ranges, what the reference point will be (such as the initial estimate of the project manager), and whether to allow the estimates to grow as the project progresses. Particularly troublesome is the long-term nature of the market. Capturing the reaction to the changing project environment is a benefit of using information markets, but it also poses challenges to task description, due to the scope creep inherit in software projects. How various levels of complexity of the predicted task will impact trader behavior is an interesting and yet unexplored question.

The level of competition or the number of participants in the market should also affect trader behavior. Because software project teams are normally fairly small, concerns regarding thin markets must be addressed. Participants must be engaged and actively trading to generate enough data for accurate estimates. Future research is needed to discover if there is an effect on trading strategies, participation, and accuracy of trades with differing numbers of participants.

The type and level of incentives can vary from market to market. What is an adequate level and type of incentive to facilitate accurate trading and participation? The effort required to study a problem, apply an estimation technique, and make an informed decision regarding a software engineering task is not trivial. What level of incentive is necessary to prompt participants to expend the effort required to form accurate estimates? Are there any incentives for some market participants to trade in ways that influence the outcome in inappropriate ways, for example, to artificially inflate the time estimate for completion? Also, what impact do various incentive structures have on trading strategies and ultimately on the outcome of the market? Such unique knowledge or insights, reflected in trading behavior, is the advantage of the information market: it captures that new or additional information quickly and dynamically.
6.3 External Information
Markets do not exist in a vacuum. As the problems associated with information markets become more complex, the impact of external information that traders possess may be influential. This knowledge may be the existing expertise of the trader, the ability of the trader to adequately research and obtain publicly available information, and/or participants’ access to insider information. The notion of insider trading is particularly significant with small markets that can fall victim to intentional manipulation by a few influential traders. Also, in software projects some participants may have more domain knowledge regarding specific tasks. For example, a database developer may have insights about an upcoming change to the database management system that will affect the completion of the project and that is not known by the rest of the development team.

6.4 Market Design
The role played by information market design features is another important research area. Choices made by market developers during the design of the market mechanism may directly affect trader behavior, as well as moderate the effects of trader characteristics, market characteristics, and external information. We have identified five design considerations: (1) the choice of payoff functions, (2) feedback instruments and the notification frequency, (3) methods to aggregate the trading activity, (4) the level of anonymity afforded to traders, and (5) the determination of market closings.

Payoff functions are designed in conjunction with incentives to participate in order to reward traders, both intrinsically and extrinsically. Research needs to be conducted to test the difference between real-money and play-money rewards in new business problem domains. We expect that feedback mechanisms, such as e-mail alerts of changing market conditions, may have a significant impact on trader behavior. Additionally, creating innovative new feedback artifacts may prove to be a fruitful area to investigate. Similarly, the design of aggregation algorithms to transform trading activity into information that can be provided as feedback to both traders and sponsors has limitless potential. The prevalent data generated by the market shows trends, the degree of consensus among participants, and much more. The influence of the level of anonymity afforded to traders must be explored. This is especially important in markets with small business units where traders may be influenced by close association with other traders. Finally, software effort estimation markets will have soft closing dates. There is no exact date on which a decision will be made as there is with a presidential election. Market designers must choose how to accommodate this unique aspect. Should there be more general long-term estimates, with closing dates well in advance of the projected task, or should the close be dynamic? How do you account for scope creep in the choice-of-effort contracts? Should additional effort-estimate contracts be added to the market if it appears that the original contracts are no longer valid or as early estimate dates expire?

6.5 Trader Behavior
Trading behavior can be characterized by the strategies bidders choose, their level of engagement or participation, and how accurately they trade. As noted earlier, trader characteristics, market characteristics, access to external information, and market design all play a direct or indirect role in influencing the behavior of market participants. Additionally, traders also react to market outcomes, and
market outcomes are in turn influenced by trading behaviors. Future studies can attempt to identify the various trading strategies adopted by participants and what effect they have on market outcomes. Likewise, we need to discover what engages traders to actively participate in the market and the result of differing levels of participation on individual successes and overall market accuracy. Trades should represent the participants’ true beliefs. We need to investigate if bidders are behaving rationally when trading in business decision predictions. Does the level of trading accuracy translate directly into accurate market forecasts? To what degree do individual errors influence the voice of the market? Are trader values more elastic when predicting outcomes of future events as compared to purchasing a material good or service? How are changes in task scope and variability in the project environment captured by the market?

6.6 Market Outcomes
The ultimate goal of using a market is to gain knowledge regarding the consensus of the participants. This consensus is what Surowiecki (2004) referred to as the “wisdom of crowds.” The voice of the crowd or market is the accumulated prices of the representative contracts. Ideally, these prices should predict the true outcomes. As noted earlier in the market design section, additional data can be collected and manipulated to provide insights into participants’ beliefs. The activity or volume of trades may indicate the popularity of an estimate. Looking at the spread between pending bids and asks could be interpreted as the level of (dis)agreement between participants’ expectations. A longitudinal review of the trade/bid/ask history can display the belief trends. The interpretation of the data provided by an electronic information market is certainly a challenge with many potential solutions.

6.7 Summary
In summary, this white paper explored the use of project management markets as mechanisms for aggregating information from many project stakeholders. These techniques hold tremendous promise and can provide a very different perspective than most other project management processes. In order to explore this area, a prototype Milestone Market was implemented and is being used for ongoing experimentation at the University of South Florida. The ultimate goal is to provide this market as an open web service to the project management community.
7 References


