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MANAGERIAL REAL OPTIONS PRACTICE IN LARGE SYSTEM ACQUISITION: EMPIRICAL DESCRIPTIONS AND COMPARISON WITH THEORY

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Managerial Real Options Practice in Large System Acquisition: Empirical Descriptions and Comparison with Theory

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Abstract

Effective and efficient development of large complex acquisition projects requires proactive management of uncertainties to meet performance, schedule, and cost targets. Flexibility in the form of real options can be an effective tool for managing uncertainty and, thereby, adding value to acquisition projects. But, real options can be both difficult to recognize, design and evaluate and expensive to obtain, maintain, and implement. Real options theory suggests a general approach and has developed precise valuation models that demonstrate the potential of options to add value. But, these models of simplified real options (compared to managerial practice) have failed to significantly improve practice, presumably because of a lack of knowledge and understanding of real options use by practicing managers. In contrast, practicing managers identify, design, value, and implement real options as a regular part of acquisition. Understanding the similarities and differences between current practice and theory is critical for developing operational real-option theories that can improve management practice. In the current work, an experiment using a simple uncertain acquisition project and a simulation model is used to capture managers' perceptions of real options. Subjects both valued flexibility and conceptually understood the impact of uncertainty on option values. Future needs for expanding real options theory into the operational management of acquisition and management implications are discussed.

Introduction

The uncertainty inherent in large acquisition projects makes increasing their value by improving development and acquisition performance difficult. Unpredictable development environments, immature technologies, and complex interfaces in integrated weapons systems, research laboratories, energy infrastructure, and other large complex systems often generate performance that varies widely from project targets. Uncertainties can be primary causes of cost overruns, delays, and substandard product performance. Effectively managing uncertainty can increase project value by reducing the likelihood of not meeting targets as part of risk management, adding benefits beyond original targets (Ford et al., 2002; Ng & Bjornsson, 2004; Reinschmidt, 2004), or both. Whether uncertainty management is viewed as a form of risk management or performance enhancement can depend primarily on the targets. For example, postponing equipment purchases can add value to the purchaser if future prices are uncertain and happen to fall. A lump-sum contractor will likely perceive managing this uncertainty as risk management if the bid is close enough to costs that the value addition is required to have costs not exceed the bid. But, the same lump-sum contractor may perceive managing the same uncertainty as a means of boosting profits if the bid far exceeds costs. Researchers and some practitioners recognize the potential of managing uncertainty to improve performance beyond targets as well as for risk management (Amram & Howe, 2002; Yeo & Qiu, 2002). The same basic management theories, tools, and methods can be applied to increase development project value through the management of uncertainty regardless of the levels of performance targets. Therefore, increasing project value can be a useful metric for either uncertainty management purpose.

Both the amount and nature of project uncertainty make it difficult to plan for and to manage. Miller and Lessard's (2000, p. 90) study of sixty large ($985 million average cost and 10.7 years average duration) engineering projects concluded that project success depended largely on the amount of uncertainty and how these uncertainties were managed. Ceylan and Ford (2002) investigated the complex nature of uncertainty in a single, large ($2.4 billion) Department of Energy acquisition project; they concluded, in part, that the complexity of managing uncertainty in practice currently exceeds the ability of available tools and methods. Proactively planning for and managing of uncertainty requires forecasting both performance under uncertainty and the impacts of potential decisions. Frequently, a lack of data or understanding of historical experience for prediction, long project durations, and complex interactions between project components (including decisions) make this difficult (Ceylan & Ford, 2002). Managers of large complex system-acquisition projects need decision-making theories, methods, and tools to use uncertainty to increase project value. Miller and Lessard (2000), Ceylan and Ford (2002), and others have found managerial flexibility to be a primary tool for managing uncertainty.

Background and Problem Description

Focusing on project value as a metric for managing uncertainty requires a project valuation method to compare alternative acquisition strategies. Traditional project valuation tools such as Net Present Value ignore or undervalue the potential for flexibility to be used to increase project value (Dixit & Pindyck, 1994; Amram & Howe, 2002; Ng & Bjornsson, 2004; Yeo & Qiu, 2002). Methods that explicitly address flexibility in managing uncertainty include decision tree analysis and real options. Decision tree analysis can be valuable in structuring uncertainty management, but is limited in the number of uncertainty evolution scenarios and strategies that can be valued, largely due to its use of discrete time steps (Lander & Pinches, 1998; Schmidt, 2003). Real-options theory can explicitly capture the value of flexibility and is the focus of the current work. An option is the right, but not the obligation, to change a strategy in the future depending on how uncertain conditions evolve (Amram & How, 2002; Ford et al., 2002; Ng & Bjornsson, 2004). For example, by building an expandable waste-to-energy plant, an owner purchases an opportunity to increase the plant’s capacity in the future if waste generation increases, but avoids expansion costs if waste production remains stable or decreases. The extra cost required to make the plant expandable is the cost of flexibility and an indication of a minimal value of the option, as perceived by the owner.

Real options theory formalizes this form of flexibility in the central premise that, if future conditions are uncertain and changing, the strategy later incurs substantial costs; therefore, having flexible strategies and delaying decisions can have value when compared to making all strategic decisions during pre-project planning. Real-options theory values alternative strategies by identifying available future alternative actions and when choices among them should be made to maximize value based on the evolution of conditions. Options typically include decisions to delay, abandon, expand, contract, or switch project components or methods. Trigeorgis (2000) and others categorize and describe these classifications. Methods for valuing options have been developed and analyzed (Dixit & Pindyck, 1994), applied to engineering (Park & Herath, 2000; Baldwin & Clark, 2000), and promoted as a strategic planning aid by both academics (Amram & Kulatilaka, 1999; Bierman & Smidt, 1992) and practitioners (Leslie & Michaels, 1997). Real options have been used to increase value in natural resources development, research and development, and product development (Brennan & Trigeorgis, 2000; Amram & Kulatilaka, 1999; Trigeorgis, 1993; Dixit & Pindyck, 1994). This work focuses on the understanding of real-options theory by practitioners.

Real options capture the value of managerial flexibility to address uncertainty in decision making (Amram & Kulatilaka, 1999) and can add value to acquisition projects (Yeo & Qiu, 2002). However, in contrast to the expectations of some real-options researchers (e.g. Copeland & Antikarov, 2001), the theory is not widely used by practitioners. In 2002, a survey of 205 *Fortune* 1,000 CFOs (Chief Finance Officer) revealed that only 11.4% use real options, while 96% use Net Present Value (Teach, 2003). Lack of knowledge about real options by practicing managers has been suggested as a reason for the low adoption of real-options theory to practice (Schmidt, 2003; Lander & Pinches, 1998; Teach, 2003). Fundamental knowledge would include recognizing the most important features of options that impact value and the direction of impacts of changes in those features on option values. If this explanation is correct, that practitioners lack a fundamental understanding of real options concepts and relationships, basic education about real options concepts and fundamental relationships is a required next step in improving the management of flexibility with real options. But, if practicing managers have this fundamental knowledge, then improving practice with real options requires a different focus, perhaps on the development of application tools and methods. Describing and evaluating managerial understanding of fundamental real-options value concepts is important for increasing the use of real options to manage uncertainty.

Some evidence suggests that managers do not understand real options well. Miller & Lessard (2000) conclude that managers *intuitively* manage uncertainty to gain the upside value. Based on a case study of options use in practice, Ceylan and Ford (2002) concluded that “Many acquisition project managers recognize the value of flexibility in managing dynamics uncertainties and use options. However, the practice is rarely structured into the frameworks developed by options theoreticians.” The tacit methods used by the majority of managers to identify, design, value, and implement options may hide or be used to obfuscate a lack of understanding of real-options theory fundamentals. Based on the plethora of publications demonstrating the potential benefits of applying simple real options in practice (including one by one of the authors), many real-options researchers evidently agree. But, other evidence suggests that practitioners do understand real-option theory fundamentals. Based on his interactions with managers dealing with uncertainty, Triantis (2001) claims that managers often consider how uncertainty will evolve and their potential strategies, both which are central to real-options theory. Ford (2001) observed managers’ use of options in the development of the National Ignition Facility, including the explicit identification and description of uncertainties, quantitative performance forecasting, option valuation, and strategy selection based on option valuation.

In summary, acquisition project managers use real options widely, but rarely knowingly apply real-option theory that has been demonstrated to have the potential to increase project value. Understanding similarities and differences between managerial perceptions of real options and real-options theory is critical for developing operational real-options theories that can improve management practice. The current work investigates the consistency between perceptions of real options and real-options theory. Few descriptions of real-options practice (that reveal managerial understanding) exist as a basis for such an assessment. This research developed an uncertain acquisition project exercise and simulation model as the basis for an experiment to reveal how subjects perceive options and to compare those perceptions with real-options theory.

Hypotheses

The most fundamental concepts and relationships of real-options theory are captured in the Black-Scholes equation (1973), which values flexibility in a financial asset (e.g. common stock). They value an option based on five factors: 1) variance of returns on stock, 2) stock price, 3) Time to expiration of the option, 4) exercise price, and 5) the risk-free rate of return. Corresponding components of a large acquisition project could be: 1) uncertainty in performance, 2) asset value, 3) duration that flexibility is available (option life), 4) costs to change strategies, and 5) discount rates (Ford & Sobek, 2005). Increasing uncertainty, asset value, option life, or the discount rate increases option values, while higher costs to change strategies decreases option values (Brealey & Myers, 2000). This research investigates perceptions of real options by testing the consistency of human understanding of fundamental drivers of option value with options theory. Due to its importance to option value and the potential for them being influenced by managers (Alessandri, Ford, Lander, Leggio, & Taylor, 2004; Bhargav & Ford, 2005), the current work focuses on the relationship between uncertainty and option value.

H: Perceived option values are positively correlated with perceived uncertainty.

This hypothesis reflects real-options theory. The adjective “perceived” is used to clarify that the concepts being measured are those understood by humans and to distinguish them from actual or optimal values. Support for the hypothesis would suggest an understanding of this fundamental real-options concept.

Research Methodology and Design

To test the hypothesis, the Rig Installation Project, a simulated simple uncertain acquisition project was developed. Research subjects were required to manage this uncertain project without and then with managerial flexibility being available. Subjects repeatedly valued an option to avoid a slow and expensive system-integration failure. To collect multiple types of data, subjects were interviewed (after managing the project) about how they made decisions during the project without and with flexibility, about how they valued flexibility, and other questions related to their perception of flexibility. Performance and interview data were analyzed to describe how subjects perceived and valued flexibility in an uncertain project. A system-dynamics simulation model (Sterman, 2000) of the experimental project was also developed to help test the hypothesis. Decision-making policies described by subjects during interviews and used during the experiment to manage uncertainty and extreme policies were built into the model. This allowed the management of many projects under a wide range of conditions and policies to be simulated. The hypothesis was tested using data collected from the experiment, subjects’ answers to the interview questions, and simulation results.

The Rig Installation Project Experiment

The Rig Installation Project without flexibility (the Rigid Project) is the basis for management with flexibility and will be described first. The Rig Installation Project represents the installation of a semi-submersed, deep water exploration and production rig for oil and gas in the Gulf of Mexico. A rig is composed of multiple systems—such as the sea floor anchors, support cables, flotation can, topsides, drill rig, etc. The project simplifies the complexity of rig installation and system integration into sixteen interacting systems arranged as shown on the right side of Figure 1. Systems are represented by playing cards numbered 1-16. Each system moves from fabrication (left side of Figure 1) to a dock and through one of three paths to the project site.

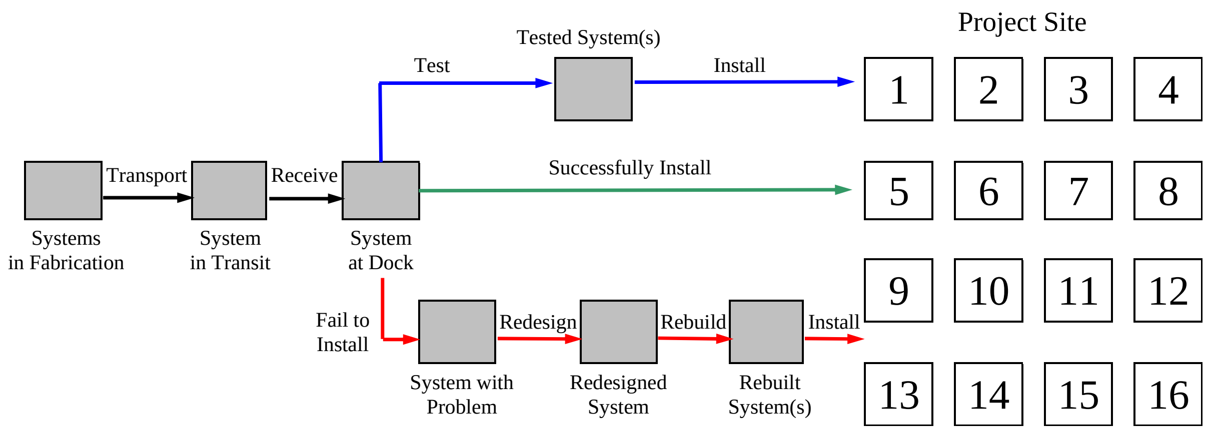

Figure 1. Rig Installation Project

Systems are built in different yards by different contractors and leave fabrication at a rate of one system per week. Systems arrive at the dock two weeks after leaving fabrication. Uncertainty is introduced through the random order of systems leaving fabrication. Before each system leaves fabrication, subjects choose between reserving the yard to test the system or trying to install the system directly without testing. If a subject decides to install the system without testing and the system meets the interface constraints (described next) then the system is successfully installed at the site, the middle path in Figure 1. Successful installation costs $10,000. Alternately, a failed installation attempt must be redesigned and rebuilt before installation (the bottom path in Figure 1) costs $40,000, and requires three additional weeks. Testing a system before installation costs $20,000 (the top line in Figure 1), but assures installation by holding systems until interface constraints are met. Performance was measured by the total cost; lower total cost indicates a better performance strategy.

The first system can always be installed successfully. Each system after the first system can only be installed when installation will create a shared-system interface (card edge) with a previously installed system. For example, if only system 5 is installed, then only systems 1, 6, or 9 can be installed. Each system number, and, therefore, the availability of a shared system interface, is not revealed until the system leaves the dock after the decision to test or attempt installation has been made. The task is difficult because the system number is unknown when the decision is made and because the conditions that determine whether installation will succeed or fail evolve from the time of the decision (at fabrication) to the time when the uncertainty is resolved (at the dock). As described so far, managing the Rig Installation Project is an exercise in uncertainty management to minimize costs, but does not include flexibility in the form of a real option.

In the flexible version of the Rig Installation Project (the Flexible Project), managerial flexibility is provided by allowing subjects to delay decisions about whether to test a system or send it directly to the site until the system reaches the dock where the system number is revealed. This delay allows subjects to make decisions when they know whether the system meets the interface constraints. Therefore, delaying decisions allows a subject to avoid slow and expensive installation failure by testing systems that would fail installation if installed directly. Subjects decide to purchase or decline flexibility for each system. This form of flexibility is an option to avoid a high cost and delay (i.e., a put option). Delaying the decision about a system incurs an additional cost, the amount which is set by the experimenter. Option costs were adjusted to identify the subject's perceived value of the flexibility, as reflected in the maximum cost each subject was willing to pay for the right to decide later. Option costs started at $2,000 and were increased by $1,000 for the next system's delay if the subject accepted delaying the current system decision and were decreased by $1,000 if the subject declined the option to delay the current system, with a minimum of $0. See Wu (2005) for additional details on experiment design and operation.

Research Subjects and Experiment Protocol

The target population is practicing acquisition managers. However, differences in education, training and professional experience in real options vary widely across practicing managers and may disguise perceptions of real options. Therefore, to partially control these factors and due to subject availability, time, and resource constraints, graduate students (mainly from the Civil Engineering Department of Texas A&M University) were chosen as the subjects. The simplicity of the Rig Installation Project and clarity of the decision-making task suggest that differences in technical knowledge or experience between practitioners and students will not impact results (i.e., students and project managers were assumed to have the same level of knowledge necessary to manage the Rig Installation Project). Students and managers are expected to perform similarly on an information-processing task such as the task in this experiment (Ashton & Kraner, 1980; Khera & Benson, 1970; Singh, 1998). If the hypothesis (that subjects' perceptions are consistent with options theory) is supported for civil engineering graduate students, then support for practitioners would likely be stronger, considering they have equal or more education, training, or experience in real options.

Subjects sought to minimize total installation costs. Motivation for good performance was provided with $10 compensation to each subject for participation and monetary prizes for the top six performances. Each subject managed one Rigid Project (without flexibility) to become familiar with the Project and experiment processes and how performance is measured. Subjects then managed two Rigid Projects using their best strategies to achieve the lowest total installation cost. The experimenter verbally guided subjects through each project to ensure compliance with experimental protocol. Project conditions, costs, and subject decisions for each system were collected each simulated week by the experimenter and stored in an electronic data base. A semi-structured interview regarding how subjects made decisions was performed after the Rigid Projects. Subjects were then instructed concerning the use of flexibility in the Rig Installation Project (the Flexible Project). Three to six Flexible Projects were managed by each subject. A second semi-structured interview after the Flexible Projects was used to collect data concerning how subjects made decisions during the Flexible Project, with an emphasis on differences between the Rigid and Flexible Projects.

Simulation Model of the Rig Installation Project

Perceived uncertainty could not be directly articulated by subjects (e.g., with estimates of probabilities) with adequate precision and reliability. Therefore, the simulation model was used to describe the perceived uncertainty based on interview responses and decisions during the experiment. With few exceptions, subjects described the likelihood of success or failure of an attempted installation as their basis for decision-making. In addition, most subjects described those likelihoods as being dependent on conditions that evolved in response to the uncertainty (system sequence) and management strategy (subject decisions).

A simulation model of the Rig Installation Project was developed that can reflect Project processes, system uncertainty, subject strategies, and perceived uncertainty in the form of the likelihood of installation success or failure. The model consists of three sectors: installation, strategy, and cost. The installation sector operates exactly like the experiment by mimicking the flows of systems through a project (Figure 1) and random sequences of systems arriving at the dock. The strategy sector represents the policies that subjects used to make the test/to-site decision for each system based on project conditions. Interview results indicate that subjects perceive uncertainty as high when their ability to predict the outcome of a test/to-site decision is low, and visa versa. For example, 62% of subjects said they would not purchase flexibility in the beginning nor the end of a project when the probability of either success or failure was high; at these times, they felt better able to predict outcomes. Therefore, perceived uncertainty is modeled as low when either the probability of successful installation (p(s)) is high or the probability of failed installation (p(f)) is high:

Equation 1. Perceived Uncertainty

$$U = \min(p(s), p(f))$$

Where: U = Uncertainty

p(s): Probability of successful installation if system is sent directly to site

p(f): Probability of failed installation if system is sent directly to site

The cost subsystem adds operation costs (testing, installation, redesign, and rebuild costs) and flexibility costs together. See Wu (2005) for details of the simulation model.

Results

Data from 125 simulated projects (42 Rigid Projects and 83 Flexible Projects) managed by twenty-one subjects were collected. Subjects spent an average of two hours on the experiment. One Flexible Project was deleted from the results because of the subject's misunderstanding of flexibility. Performance results suggest that the data accurately reflects real options and subject perceptions. Performance with flexibility was expected to be better than without flexibility. Yet, variances of the Rigid and Flexible Projects are not significantly different based on F-tests. Therefore, one-sided t-tests were used to test whether total costs of Flexible Projects were less than total costs of Rigid Projects (Table 1). As expected, flexible project performance is significantly better than rigid projects based on both an analysis of aggregate project performance (p=0.0006) or pair-wise subjects performance (p=0.0002).

	Projects Costs		
Project Type	**Total**	**Operations**	**Flexibility**
Rigid Project (n=42)	270.0	270.0	0.0
Flexible Project (n=82)	247.0	235.2	11.8
Difference (improvement with option)	23.0	34.8	-11.8

Figure 1. Cost Performance of Rigid and Flexible Projects

Hypothesis Testing

H: Perceived option values are positively correlated with perceived uncertainty.

The hypothesis was tested with three types of data: subjects' decisions during projects, subject interview data, and simulation results. Graphs of the perceived value of options versus Rig Installation Project time and perceived uncertainty versus Rig Installation Project time were generated from the experiment and simulation results, respectively. Similarity in these behavior modes would show support of the hypothesis.

The option value is conceptualized here as the maximum that subjects are willing to pay for flexibility. Exact perceived option values could not be captured directly using the experimental protocol. However, the envelope of option values can be described with the data, as follows. Each week subjects either did not purchase the option, thereby describing a ceiling value[1], or purchased the option, thereby describing a floor value[2]. Perceived option values for the subject pool of each week must be between these ceiling and floor values. Costs of flexibility oscillate around perceived values due to the movement of option costs in response to subject decisions. To partially compensate for the experimental-protocol-induced oscillation in collected data, ceiling and floor values are the average of the data collected in each week and the data collected in the previous week (Figure 2).

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[1] Maximum cost subjects are willing to pay for an option may be less than (but not greater than) the cost offered but declined. For example, a subject declining an option costing $4,000 might also have declined it if the option had cost $3,000. Therefore, the ceiling values identified represent an upper limit on real-option values.

[2] Maximum costs subjects are willing to pay for an option may be more than (but not less than) the cost offered and accepted. For example, a subject purchasing an option for $2,000 might also have purchased it if the option had cost $3,000. Therefore, the floor values identified represent a lower limit on real-option values.

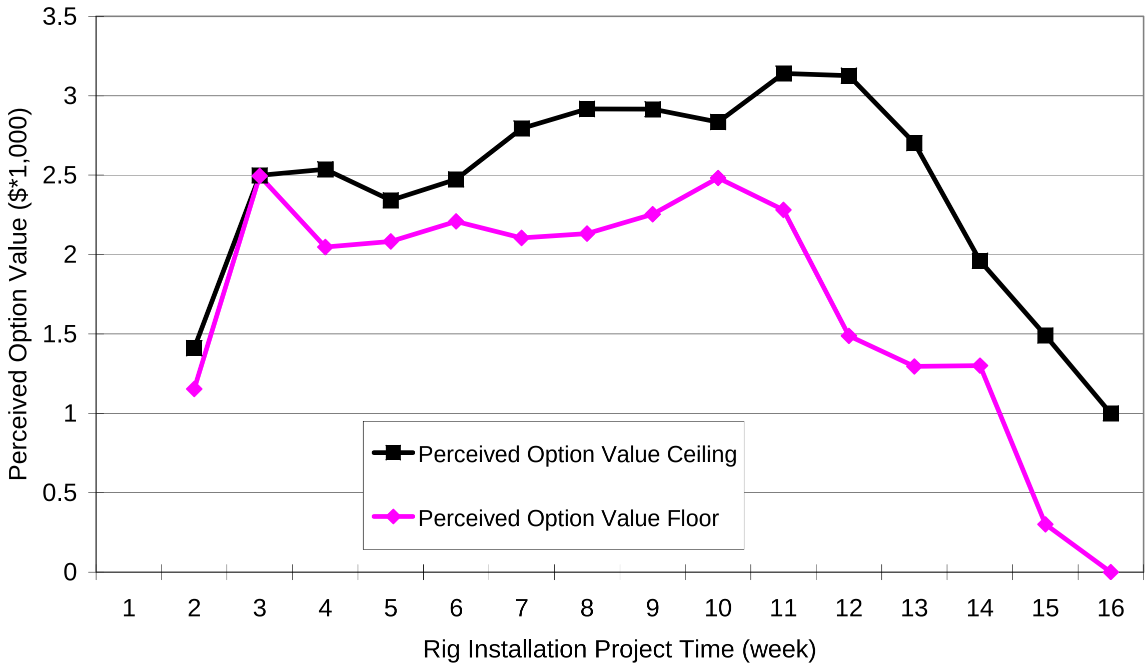

Figure 2. Envelope of Perceived Option Value vs. Rig Installation Project Time

The experimental protocol limits the rate of decrease in the rejected options costs to $1,000 per week. Therefore, the option value ceiling and perceived option values may drop faster and farther than reflected in weeks 11-16 in Figure 2. A generally concave shape of the perceived option value's envelope over time during the Rig Installation Project is observed in Figure 2. Subjects' answers to interview questions about their policies in Flexible Projects also support the concave shapes in Figure 2. Sixty-two percent of subjects (13 of 21) stated they would not purchase flexibility in the beginning nor end of the project, but would between these extremes. Fourteen percent of subjects (3 of 21) stated they would pay more in the beginning of the project even if the value of flexibility decreased over time. Fourteen percent of subjects (3 of 21) evaluated the flexibility value as constant over time and the remainder (10%) had no idea.

Perceived uncertainty was described with simulation results and supported by interview data. The simulation model was used to quantify perceived uncertainty. Perceived uncertainty was modeled using Equation (1). Perceived uncertainty is dependent on the decisions made during the project. Two extreme strategies were simulated to describe the envelope of possible perceived uncertainties[3]. An extreme risk-seeking strategy was modeled by sending all systems directly to the site. An extreme risk-averse strategy was modeled by only sending systems directly to the site that would install successfully and by testing all systems that might fail. The perceived uncertainty of 200 Rig Installation Projects with random system sequences were simulated for each extreme strategy (Figure 3). The shape of the simulated perceived uncertainty over time is generally concave.

[3] No subjects used either extreme strategy.

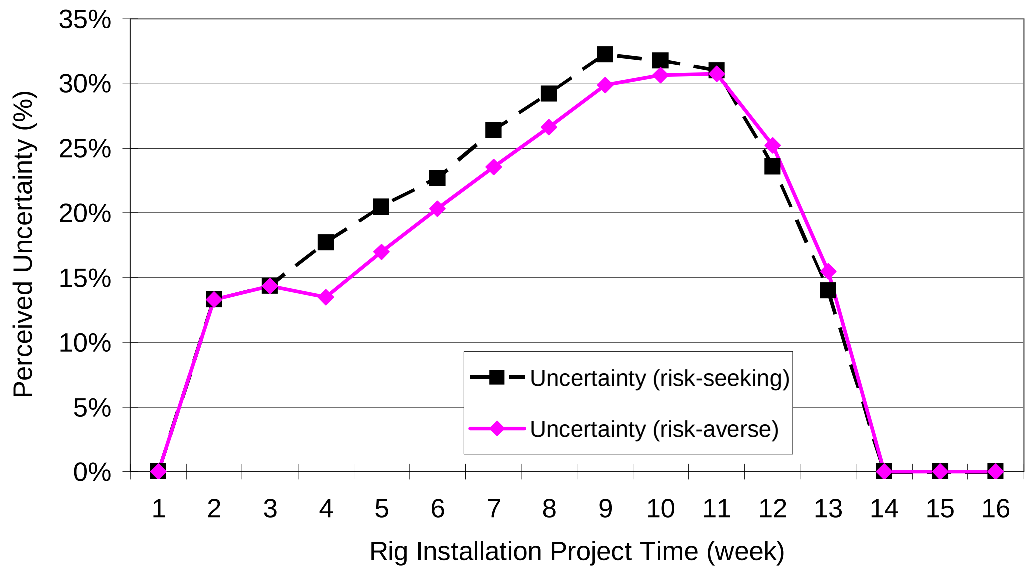

Figure 3. Simulated Perceived Uncertainty vs. Time

The behavior modes in Figures 2 and 3 are both concave. Differences between the consistency and precision of application of strategies in simulation (complete) and by human subjects (partial) can explain differences—such as in the timing of the peaks. Another possible reason is that subjects may overestimate uncertainty early in projects because a few systems have been installed (underestimate and with uncertainty) late in projects when most systems have been installed. The similarity in shapes in Figures 2 and 3 support the hypothesis.

The concave shapes in Figures 2 and 3 are also supported by interview data. The 62% of subjects that said they would not purchase flexibility near project beginnings or completion described their reasoning. Purchasing flexibility in the beginning of projects when the probability of failure was high was seen as unnecessarily adding cost because the system would most likely be tested anyway. Purchasing flexibility near the end of projects when most systems were installed and the probability of success was also high and, therefore, was seen as unnecessary. Subjects preferred paying more in the middle of the project when it was difficult to predict the outcome of attempting to install the system directly (i.e., when uncertainty was relatively high). Additional interview data also support the hypothesis. Subjects were asked, “If you managed the Flexible Project again exactly as we just did *except* that systems that would share a corner with a previously installed system can be successfully installed as well as systems that would share an edge, would you delay your decisions more often?” “Would you expect net savings to be the same, more, or less?” “Why did you answer as you did?” Twenty of twenty-one subjects (95%) believed flexibility would be worth less because the suggested change would reduce uncertainty. This is consistent with real-options theory. Therefore, the interview data also supports the hypothesis.

Interview data was also used to explore subjects' understanding of other portions of real-options theory with questions similar to the one above. For example, subjects were asked “If you played the Flexible Project again exactly as we just did *except* that it takes four weeks instead of two weeks to transport systems from Fabrication to the Dock, would you purchase flexibility more often, the same amount, or less often?” “Would you expect the net savings be the same, more, or less?" Subjects were also asked the basis for their response. This question tests subjects understanding of the relationship between option life and option value. No significant correlations were found. We suspect this is partially due to the relatively few data points available (n=21). However, evaluation of the data in a manner similar to Brehmer's adeptness (1998) using the consistency of changes and direction of differences in data suggest that subjects understand that increasing asset value and option-life increases option-value. See Wu (2005) for details.

Conclusion

An experiment and a simulation model of a Rig Installation Project was developed and used to capture managers' perceptions of uncertainty and the value of flexibility. The hypothesis that subject perceptions of the relationship between uncertainty and option value are consistent with real-options theory was tested and supported. Additional data suggests that subjects may also hold perceptions concerning the relationships between asset value and option life and the value of options that are consistent with theory.

The conclusions are limited by the nature and scope of the research. Additional subjects could strengthen conclusions through additional data and analysis. Experimental conditions (e.g. only one uncertainty) are significantly simpler than those experienced in practice, potentially allowing subjects to understand relationships more easily than is possible in practice. The subjects may not accurately reflect practicing acquisition managers.

Despite the preliminary nature of the results, some conclusions can be drawn. We conclude that subjects understand at least one of the fundamental drivers of option value and that they perceive flexibility in the form of options as effective tools in managing uncertain acquisition projects. If results are also applicable to practicing managers, who likely have equal, or more education, training, and experience in managing uncertain projects, the results would also suggest that practicing managers also understand at least some of the fundamental drivers of option value and that they perceive flexibility in the form of options as effective tools in managing uncertain acquisition projects.

This research contributes to the development of real options as effective operational tools for managing uncertainty. Previous research highlights real options' use in isolated anecdotal settings but does not objectively gather and describe perceptions of real options in controlled conditions. The current work is the first known real options research to collect and describe real options perceptions in controlled experiments. We used this data to describe and test subjects' understanding of fundamental option relationships, which can be used to assess and improve practice and build improved options theory for application. The results have implications for both real options research and practicing managers. They suggest that the subjects, and perhaps practitioners, conceptually understand fundamental options relationships. This implies that real-options research—seeking to develop effective tools and methods for applying real-options theory in practice—do not need to focus efforts on demonstrating the value of options or the fundamental drivers of option value. Real options research for application can be more effective if an understanding of fundamental real options concepts is assumed, and work focuses on developing tools to help managers apply options. Such managerial tasks might include recognizing opportunities to exploit options, structuring the complex circumstances faced in practice as options, designing and evaluating strategies, and implementing chosen flexible strategies. Despite the preliminary nature of the results, they also have potential implications for practicing managers. Although they valued flexibility, subjects in general found it difficult to articulate their strategies and the basis for the design, assessment, and selection of those strategies. Therefore, managers can potentially improve the management of uncertainty in acquisition projects by making their strategies and the flexibility in those strategies more explicit and available for evaluation and improvement.

Future research on the nature of human perceptions of options can test the consistency of perceptions with other fundamental real options relationships and the depth of that human understanding. Research and development of tools and methods for the application of basic real options in practice can build and test tools that bridge the gap between current real-options theory and uncertainty management practice. These tools may include means for making strategies more explicit and structured, measuring uncertainty, and evaluating options with complexities similar to those experienced in practice. Continued real-options research that links theory to practice can increase the breadth and effectiveness of real-options use to improve acquisition projects.

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