INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI

A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600

THE UNIVERSITY OF NEW HAVEN

GRADUATE SCHOOL

THE APPLICATION OF REAL OPTIONS TO THE INFORMATION TECHNOLOGY VALUATION PROCESS: A BENCHMARK STUDY

A DISSERTATION
submitted in partial fulfillment
of the requirements for the degree of
DOCTOR OF SCIENCE in MANAGEMENT SYSTEMS

BY
Jerry P. Flatto
West Haven, Connecticut
1996

THE APPLICATION OF REAL OPTIONS TO THE INFORMATION TECHNOLOGY VALUATION PROCESS: A BENCHMARK STUDY

APPROVED BY

Dr. Robert Rainish, Chair, Dissertation Committee

Dr. Edward George, Member, Dissertation Committee

Dr. William Pan, Member, Dissertation Committee

Dr. Ben Judd, Director of Doctoral Program

Dr. Linda Martin, Dean, School of Business

Dr. Jerry Allen, Dean, Graduate School

ACKNOWLEDGEMENTS

Even though my name is the only one on the cover page, this dissertation would not have been possible without the help of a number of people over the past few years. While it is not possible to identify all these people by name, you know who you are. I specifically wanted to thank Dr. Carol Davis, Dr. Myron Robinson, and Dr. Thomas Skrmetti at the Electric Boat Division of General Dynamics who provided support as I was trying to survive the coursework, written comprehensives and oral.

I want to thank my fellow faculty members at North Carolina A&T State University for the greatly appreciated assistance and support as I wrote my dissertation. I specifically want to thank Dr. Mary Lind, Dr. Joanne Sulek, and Dr. Melvin Johnson.

I also need to thank Mrs. (soon to be Dr.) Beverly Buckta, my fellow doctoral student, for all the support we gave each other over the years. I am not sure we fully comprehended how much work and sacrifice would be required when we started, but we finally made it.

This dissertation would have much harder without the support of Ann Purr and Janet Smith at the Life Office Management Association. Ann has read and provided valuable comments on this dissertation over the course of its evolution. Her support and assistance in the questionnaire development and distribution has been invaluable. Ann became an "ex-officio" member of my dissertation committee.

I also need to thank my committee, Dr. Robert Rainish, Dr. William Pan, and Dr. Edward George for their guidance and support over the course of this dissertation. They were always happy to review my work, answer my questions, and provide suggestions.

Finally, I need to thank my parents, Helene and Jerry, for their support and help over the years. Unfortunately, my mother Helene is not alive to see me wear my doctoral cap and gown, but I am sure she would be proud. I also need to thank my sister and brother-in-law, Linda and Eddie Zuker, for their support, along with the support of my in-laws, Dr. George and Janet Lowry, and my brother-in-law, Dr. Robert Lowry. Most importantly, I need to thank my wife, Gretchen, for her love and support over the years. Even though she knew the work and sacrifices that would be required for me to obtain my doctorate, she decided to marry me anyway. For that I will be eternally grateful.

ABSTRACT

This dissertation focused on the problem of mismeasurement of benefits provided by information technology. Specifically, this dissertation examined the potential of "real options" to assist in measuring the flexibility provided by information technology. What differentiates the concept of real options from the concept of flexibility is that flexibility is typically treated qualitatively while the goal of real options is to express the flexibility in quantitative terms (i.e., dollars). The value of the real options associated with any project can be included both qualitatively in the system development models and quantitatively in the cost and benefit analysis process.

This dissertation developed a three level integrated model detailing how real options fit into the information technology valuation process. The top level of the model describes how real options fit into the overall cost and benefit framework. The next level describes the components that determine the total value of the real options for a single project. The third level describes the components that determine the value of any particular real option.

This dissertation performed a benchmark study to establish the existing and potential use of real options in the insurance industry. The study performed in this dissertation was the first large scale effort to determine how real options are being used in any industry to evaluate any type of real project. The benchmark data was gathered by the use of a questionnaire. This questionnaire was developed from scratch since no previous work has been done in this area. The questionnaire was sent to the chief information officers of over four hundred insurance companies. Additionally, telephone interviews were conducted with some of the respondents to the questionnaire.

This research has found that very few companies are aware of the concept of real options and even fewer have any formal process to include the value of the real options in their existing analysis process. Based upon the responses to the questionnaire and the non-response rate, more "marketing" of real options must be accomplished before companies will expand their existing analysis tools to include real options. The existing system development and cost analysis models must be expanded to include the value of real options. This is especially important for strategic projects.

This dissertation added to the growing knowledge concerning the application of option pricing theory to real projects. Little work has been done in applying real options to actual industry situations. More effort and education is needed to transfer real options from the academic arena to industry use. This effort is vital since existing analysis tools such as net present value underestimate the value of real projects.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Statement of the Problem

This dissertation examined the information technology valuation process. It focused on the problem of the mismeasurement of benefits provided by information technology. This measurement problem is believed to be one of the largest hurdles that must be overcome in the search for analysis techniques that allow the costs and benefits of information technology to be compared directly (Accola 1994; Baily and Gordon 1988; Barua, Kriebel, and Mukhopadhyay 1995; Brown, Gatian, and Hicks 1995; Brynjolfsson 1993; Brynjolfsson and Hitt 1993; Denison 1989; Gillin 1994b; Kaplan 1986; Krohe 1993; Noyelle 1990; Panko 1991; Roach 1994b).

At present, many of the costs (e.g., hardware, software, labor, etc.) can be estimated using a number of established techniques that yield a tangible (i.e., dollar) figure. However, many of the benefits (e.g., competitive advantage, increased customer satisfaction, etc.) of information technology projects are intangible and there are few techniques available to put a dollar value on the intangible benefits. Therefore, the decision maker has to balance tangible costs with both tangible and intangible benefits. In many cases, the value of these intangible benefits are not included in the analysis of a project. This tends to result in an underestimate of the benefits associated with a project (Bacon 1992; Brealey and Myers 1991; Brennan 1995; Brookfield 1995; Busby and Pitts 1995; Hayes and Abernathy 1980; Hayes and Garvin 1982; Kogut and Kulatilaka 1994b; Ross 1995; Sercu and Uppal 1994; Smith and Nau 1995; Trigeorgis 1993b; Weaver et al. 1989).

One of the intangible benefits provided by information technology is flexibility. Real options provide the ability to measure the flexibility that management has to alter their decisions as more information becomes available. What differentiates the concept of real options from the concept of flexibility is the techniques by which the concepts are measured. Flexibility is typically treated qualitatively (e.g., very flexible, not enough flexibility, etc.). The goal of real options is to evaluate the flexibility and convert it into a quantitative value (i.e., dollars).

Objectives of this Dissertation

The area of real options is a relatively new area and there has not been much previous work done on this topic. The majority of work that has been done is conceptual. This was the first research study to examine industry's existing use of real options and their attitudes towards the potential benefits provided by real options in any industry and for any type of real project. The specific objectives of this dissertation were:

- Perform a benchmark study of the existing use of real options to evaluate information technology in the insurance industry.
- Evaluate the potential of real options to assist in valuing information technology.
- Evaluate the different factors that determine how valuable real options are to information technology projects.
- Design and test a survey instrument that can be used to gather the data required to evaluate the other objectives.

The data was gathered through the use of a mail questionnaire and follow-up telephone interviews. Information gathered for the research study included: how industry is presently incorporating the value of the real options (i.e., qualitatively or quantitatively), the different types of real options utilized, and the value of real options to different types of information technology projects. It also gathered information

concerning managements' opinions on further research needed to ensure that real options will be valuable in evaluating information technology projects.

A review of the literature determined that there were no existing survey instruments available to perform this benchmark study. Therefore, another objective of this dissertation was the creation of a survey instrument to gather the benchmark data. The usefulness of this instrument was evaluated as part of this dissertation.

Relevance to Management Systems

Previous work has demonstrated that failing to include the value of the flexibility in discounted cash flow analysis will yield a result that underestimates the value of a project (Bacon 1992; Brealey and Myers 1991; Brennan 1995; Brookfield 1995; Busby and Pitts 1995; Hayes and Abernathy 1980; Hayes and Garvin 1982; Kogut and Kulatilaka 1994b; Ross 1995; Sercu and Uppal 1994; Smith and Nau 1995; Trigeorgis 1993b; Weaver et al. 1989). This may cause a project to be rejected when it should be accepted. Figure 1 indicates how including the value of real options could impact the results of a cost benefit analysis.

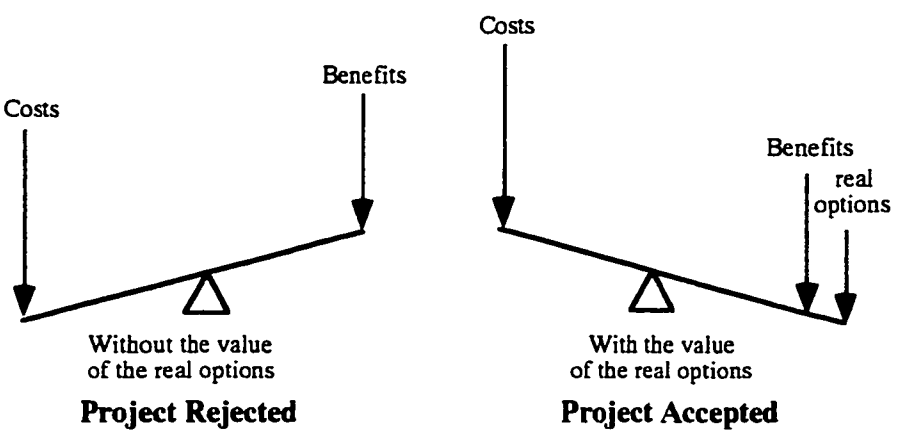


Figure 1: Potential impact of real options on a project's cost benefit analysis

Therefore, including the value of the real options in existing cost benefit techniques will improve the ability of these techniques to assist in the decision making process. The more accurate and realistic the analysis technique, regardless of the project type, the better the decisions made from the results. Improving the evaluation process is especially critical in the evaluation of information technology projects since information technology is usually the largest slice of an organization's capital budget (Cliff 1990; Farbey, Land, and Targett 1993; Farrell 1995; Keen 1991; Maglitta 1993; Roach 1991; Roach 1994a; Schnitt 1993; Too Many Computers ... 1991; van Nievelt 1993).

Definitions of Terms

Since the area of real options is relatively new, the terms associated with this area may not be familiar to most people. This section defines some of the terms used in this dissertation.

Real option — The flexibility that you have to alter a decision as further information becomes available. A real option allows you to put a value on your ability to change a project's direction in the future as you receive additional information about future conditions.

Real option to defer — The option to defer occurs when management can put off a decision until some date in the future. This allows management to determine if resources should be spent on a project at that future date.

Real option for staged investment — The option for staged investments occurs when a project investment happens in a series of outlays that allows the project to be abandoned in mid-stream if conditions become unfavorable.

Real option to change scale — The option to change scale can result in the project being expanded, contracted, or shut down and restarted. Depending on market

conditions that prevail at a particular time, the rate of resource expenditure can be adjusted to meet the new conditions.

Real option to abandon — The option to abandon allows the company to abandon a project if the market conditions drop dramatically.

Real option to switch — The option to switch allows an organization to change either the input mix or output mix of a facility. If environmental conditions change, this option provides the flexibility to alter either the process (i.e., input mix) or product (i.e., output mix).

Real option to grow — The option to grow is used when an initial investment is required for further development. The project can be considered a link in a chain of related projects. Each project in the link is required for the future growth.

Strategic information technology projects — Those that change an organization's product or the way that the organization competes in the marketplace. These projects are typically concerned with long-term objectives.

Informational information technology projects — Those that provide information for the general management of the organization and have medium-length objectives.

Transactional information technology projects — Those that support management in their day to day operations.

Threshold information technology projects — Those that are required to simply compete in the marketplace. In most cases, threshold projects are implemented in response to competitors' actions or governmental requirements.

CHAPTER II

REVIEW OF THE LITERATURE

This dissertation is focusing on the problem of mismeasurement of benefits associated with information technology in the insurance industry. This chapter reviews the relevant literature in this area. The chapter is broken into four major sections. The first section examines the role of information technology and the problem with measurement of benefits. It also examines existing techniques from the fields of economics and management information systems that can be used to value information, either directly or indirectly. The next section examines the literature regarding the concept of real options and how they can be used. The third section examines the literature related to evaluating information technology in the insurance industry. The last section develops a model that integrates real options into the information technology valuation process.

Information Technology

Information Technology and the Mismeasurement Problem

This dissertation was focusing on the problem of measuring the value of information technology. However, it is not the technology that provides value but rather the information contained in the system since without data and information, the raw hardware and software provides no value. Second, the role of information technology in an organization was reviewed. The resources allocated to information technology provide the basis for the importance of the research proposed in this dissertation. Third, the difficulty associated with measuring the value of information

technology was reviewed. This measurement problem, and potential solutions, is the central theme of this dissertation.

Role of information

From a formal perspective, information can be defined as that which reduces the uncertainty which an individual perceives (Shannon and Weaver 1949). Information in isolation does not have value. It is the use of information that provides value to the organization. The value of the information from management's perspective comes from information's ability to reduce the uncertainty in which management decisions must be made (Hirshleifer 1973; Laudon and Laudon 1996; McKeown and Leitch 1993; Repo 1989; Schoderbek, Schoderbek, and Kefalas 1990). Fama and Laffer (1971) identified how information can reduce the risk for an organization and improve operating decisions by the firm. They state that with additional information, a firm will make decisions as good as, if not better than, if the additional information was not available.

Information is a unique commodity. Most commodities exhibit properties such as divisibility, scarcity, and decreasing returns from continued use. Information, on the other hand, is not easily divisible (i.e., more than one person can possess it at a time); is not scarce (in many cases, there is information overload); and may increase in value when used (Arrow 1962; Glazer 1993). Because of these unique features, information is very difficult to measure using traditional techniques.

Role of information technology

Information technology is being used for many applications and purposes in organizations. Information technology's importance stems from its potential to affect the organization's value chain and influence the "bottom line" (Ackoff 1981; Benjamin 1982; Bharadwaj, Varadarajan, and Fahy 1993; Cash Jr. and Konsynski 1985; Chang

and Lee 1992; Drucker 1995; Eby and Kufahl 1995; Freeman 1984; Glazer 1993; Ives and Learmonth 1984; Johnson and Vitale 1988; Kanter and Miserendino 1987; Keen 1992; Rackoff, Wisemann, and Ullrich 1985; Wisemann 1985; Wisemann and MacMillan 1984). Porter (1985) discusses how information technology can provide a mechanism to address each of the five competitive forces in an industry. Porter and Millar (1985) feel information technology is changing the rules of competition in three ways: changing the industry structure; creating competitive advantage; and creating completely new businesses.

Spending on information technology has increased. The share of information technology in the service sector's stock of capital equipment rose from 6.4% to almost 20% over the past twenty-five years. In manufacturing, it rose from 1.6% to 10.6%. The number of personal computers went from 3 million to 23 million as their sales climbed from $1.9 billion to $40.8 billion. Mainframes' sales went from $16.5 billion to $35.5 billion. The service sector accounts for 82% of the installed information technology base (Roach 1994a). Each worker in the service sector is now supported by an average of $9,000 of computing power. Overall corporate spending on technology is expected to rise 10% this year (Farrell 1995). Information technology is now the largest item in the capital spending budget of corporate America — almost a third of all expenditures (Roach 1991; Schnitt 1993). U.S. corporations spent more than $200 billion on computers, telecommunications and related services, making information technology the largest capital expense for business in 1993 (Cliff 1990; Farbey, Land, and Targett 1993; Keen 1991; Maglitta 1993; Too Many Computers ... 1991; van Nievelt 1993).

However, increased spending does not automatically equate to increased performance in the organization. It is estimated that U.S. industry and government organizations waste approximately twenty billion dollars annually on personal

computers by mismanaging the technology (Sagar 1995). One of the major concerns of top executives is the proper application of information technology in their organizations. They want to ensure that they are getting value for their money spent (Accola 1994; Campbell 1987; Cliff 1990; Cooke and Parrish 1992; Dyle 1995; Flatto 1992; Keen 1991; Keen 1992; Roach 1991).

Unfortunately, recent studies have shown little or no productivity gains from the investments in information technology. A study by Loveman (1991) showed that investment in information technology had minimal impact on output or labor productivity. Loveman concluded that the organizations involved would have been better off investing their money in worker training or more efficient boilers or bigger coffee cups — almost anything but computers. Another study by Morrison and Berndt (1990) found evidence that every dollar spent on information technology delivered on average only about $0.80 of value on the margin, indicating a general over investment in information technology. Other studies found similar results (Baily and Chakrabarti 1988; Bresnahan 1986; Brown, Gatian, and Hicks 1995; Osterman 1986; Strassman 1985; Weill 1990; Weill 1992).

These results are symptomatic of the computer productivity paradox. In 1993, Computerworld magazine and Andersen Consulting found that fewer than half of the 203 senior corporate officers surveyed thought they were getting good value from their information technology spending (Krohe 1993).

Mismeasurement problem

The most likely reason for this productivity paradox is the inability to properly measure the benefits associated with information technology[1] (Accola 1994; Baily and Gordon 1988; Barua, Kriebel, and Mukhopadhyay 1995; Brown, Gatian, and Hicks 1995; Brynjolfsson 1993; Brynjolfsson and Hitt 1993; Denison 1989; Gillin 1994b; Kaplan 1986; Krohe 1993; Noyelle 1990; Panko 1991; Roach 1994b). The first

information systems developed forty years ago provided their benefit through a direct reduction in costs (Parker, Benson, and Trainor 1988; Weill 1990). For example, the cost of a computer-based accounting system was balanced out by the savings resulting from a reduction in the number of bookkeepers and accountants required. Thus, both the costs and benefits of the accounting system were tangible and relatively easy to quantify.

Now many information technology projects do not only reduce costs but are also designed to produce other benefits. The benefits provided may include more accurate information allowing management to make better decisions; increased customer satisfaction; and changes in the organization's infrastructure which can yield benefits totally unexpected in the original analysis process.

Brynjolfsson (1993) states that the measurement problem is more severe in the service sector than in the manufacturing sector. The manufacturing sector is dealing with tangible products where changes in performance at the individual level, as well as the organizational level, can be measured using well-defined techniques. The service industry is typically dealing with intangible products, such as information, for which performance measures are not as clearly defined. The traditional measure of the relationship between inputs and outputs might not be able to account for intangible sources of value. (See also Baily and Gordon 1988; Denison 1989; Dirks 1994; Due 1994; Gillin 1994b; Howell et al. 1987; Mason and Merton 1985; Myers 1984; Noyelle 1990; Roach 1991; Thurow 1987).

This problem is exacerbated when dealing with long-term investments. The further out the expected return from a project, the more uncertainties the project faces. This increases the riskiness associated with a project which may make the project a poor prospect for investment. Management also tends to have a bias against long-term invesments (Accola 1994; Accola, Agrawal, and Holsapple 1995; Antle and Eppen

1985; Antle and Fellingham 1990; Brookfield 1995; Busby and Pitts 1995; Farbey, Land, and Targett 1993; Gehr Jr. 1981; Hertz 1990; Lohmann and Baksh 1993; Michel and Ostertag 1974; Ross 1995; Sarper 1993; Smith and Nau 1995). This bias results not only because of the uncertainties associated with a project but also because of the typical incentives associated with managers' performance (see for example Accola 1994; Antle and Eppen 1985; Antle and Fellingham 1990; Dertouzos, Lester, and Solow 1989; Kogut and Kulatilaka 1994b; Sullivan and Reeve 1988).

The measurement problem is also more severe when looking at benefits as compared to costs. While errors in measurement affect both the costs and benefits associated with an information technology project, measurement errors tend to be biased towards underestimating benefits because of their intangible nature (Accola 1994; Brynjolfsson 1993; King and Schrems 1978; Strassman 1988).

The measurement problem is also affected by the type of information technology project. Some types of projects are more amenable to existing quantitative techniques than others. Turner and Lucas (1985) proposed the use of a hierarchy based upon the objective of the information technology project. The hierarchy includes three types of projects: strategic, informational, and transactional. Strategic information technology projects are those that change an organization's product or the way that the organization competes in the marketplace. These projects are typically concerned with long-term objectives. Informational projects provide information for the general management of the organization and have medium-length objectives. Transactional projects support management in its day to day operations. Weill (1989) recommended adding a fourth type that he called "threshold projects". These projects are required to simply compete in the marketplace. Threshold projects may be required because of government regulation or competitors' actions. Strategic projects have the greatest potential to impact the competitive position of an organization. Unfortunately,

these projects have the greatest measurement problem associated with them that puts them at a disadvantage in the capital budgeting process.

Thus for many information technology projects, there is only qualitative justification that benefits exceed their costs (Agarwal, Tanniru, and Dacruz 1992; Eby and Kufahl 1995; Hogue and Watson 1983; Keen 1981). There is also a very strong feeling that techniques to eliminate this mismeasurement problem must be developed (Accola 1994; Badiru 1990; Brynjolfsson 1993; Brynjolfsson and Hitt 1993; Davenport 1989; Davis 1976; Dirks 1994; Eby and Kufahl 1995; Flatto 1992; Gillin 1994b; Keen 1981; Keen and Scott-Morton 1978; Melone and Wharton 1984; Money, Tromp, and Wegner 1988; Pant and Ruff 1995; Parker, Benson, and Trainor 1988; Pieptea and Anderson 1987; Repo 1989; Rivard and Kaiser 1989; Young 1984).

The development of quantitative methods to measure the benefits of information technology are especially important since the management review process tends to be biased against qualitative analysis. Management typically assigns greater weight in the decision making process to quantitative analysis (Agarwal, Tanniru, and Dacruz 1992; Farbey, Land, and Targett 1993; Hogarth 1980; Oxenfeldt 1979; Slovic, Fischoff, and Lichtenstein 1977).

Quantitative Analysis Techniques

This dissertation is focusing on how the use of real options to measure flexibility can assist in measuring one aspect of the intangible benefits associated with information technology. Real options are not the only method that has been developed to value information and information technology. There are a number of techniques developed from the field of economics that have attempted to directly value information. There are also a number of techniques in the field of management information systems that have been developed in an attempt to measure the costs and

benefits associated with information technology and thus indirectly attempt to measure the value of information.

Economic techniques

Lamberton (1971) defines the economics of information as the review of the process by which information is produced, distributed, stored, and employed. Marschak (1968) narrowed the definition slightly by calling it the economics of inquiring. Hirshleifer (1973) called the economics of information an outgrowth of the economic analysis of uncertainty.

While phrases such as "knowledge is power" and "the facts speak for themselves" acknowledge the importance of information (Stigler 1961), historically economists have been concerned with the allocation of resources such as land, mineral, and labor (McDonough 1963; Schoderbek, Schoderbek, and Kefalas 1990; Stigler 1961). Stigler (1961, p. 213) stated that information "occupies a slum dwelling in the town of economics. Mostly it is ignored ...".

Marginal analysis is a technique used to determine whether it is viable to produce additional goods or services. Under marginal analysis theory, the demand curve is generated by adding together the varying amounts of the good that all the buyers in the market will buy at varying prices. Similarly, the supply curve is a summation of the varying amounts of the good that all the producers in the market will sell at varying prices (Hirshleifer 1973; McDonough 1963; Stigler 1952). Under marginal analysis, an organization will continue to acquire information until the cost exceeds the value. There is a point where the maximum value of information can be acquired for the minimum cost. This is the optimal point.

One of the problems with marginal analysis is that it assumes the costs and benefits provided by the information are quantifiable. This is the same basic problem

with evaluating information technology. If the costs and benefits were easily quantified, there would not be a measurement problem.

Central to the idea of decision theory is the determination of the value for perfect information. Under decision theory, the best information is that which would eliminate all uncertainty and allow the decision maker to determine the actual state of nature that is to occur. If there is more than one possible state of nature, the value of information is the difference between the maximum expected value without additional information and the maximum expected value in the presence of additional information (Carter 1985; Feltham 1968; Hilton 1979; Hilton 1981; Schoderbek, Schoderbek, and Kefalas 1990).

One of the most widespread applications of decision theory is in the construction of decision trees. A decision tree is a display of a sequence of actions, states of nature and their associated probabilities and payoffs. The decision tree includes the probabilities associated with all random events and the value of the payoff if an event occurs.

Unfortunately, the usefulness of the decision theory approach is diminished when all the data requirements are determined because of data collection difficulties (Lacava and Tull 1982; Repo 1989). The decision tree also assumes the probabilities associated with each branch are known and constant, neither of which are typically valid assumptions.

The whole idea of equilibrium in the market has been the starting point for many avenues of analysis in economics. It is based on the idea of equilibrium in the marketplace (i.e., total supply equals total demand). The basic idea under equilibrium theory is that if people under uncertainty do not have perfect information, they may allocate resources to collect enough information to make a decision. Price information

is then studied to describe the role of the imperfect information (Radner 1968; Spence 1976).

Unfortunately, the equilibrium theory approach is more useful in theory than in practice. Models generated tend to be very specific and abstract from actual practices (Hirshleifer 1973; Repo 1989). Radnor's (1968) example had two consumers, one producer and two commodities.

The multidimensional value approach is used with information needs inside organizations where information markets are not developed or not of importance (Cristie 1981; Mason 1979). The approach tries to assign quantitative values based upon qualitative feelings (e.g., consumer confidence studies).

Epstein and King (1982) have studied how management uses information in an attempt to determine the value placed on information by various managers. More specifically, they tried to evaluate the impact a number of attributes had on the value of the information. Some attributes were: reliability; understandability; freedom from bias; and decision relevance. The actual value was determined through surveys with the respondent indicating relative satisfaction percentages.

The drawback with this approach is that the costs and benefits are valued using qualitative techniques. The results are subjective depending on the respondent and will have the same drawbacks that many of the information technology valuation techniques have.

Glazer (1991; 1993) has developed a method called "Components of Value" to determine the value of a firm's information assets. The technique focused on the "transaction" as the basic unit of analysis which was defined as the exchange between a firm and consumer of goods or services for money. Additionally, information is also exchanged. The information gathered could provide increased value from three sources: increased revenues from subsequent transactions because of more

personalized service; lower costs because of more economical distribution; and direct sale of the gathered information.

The value for each of these sources is determined qualitatively by people involved with the process. As in previous techniques, the results are subjective depending on the respondents and will have the same drawbacks that many of the information technology valuation techniques have.

Management information system techniques

The previous section detailed some methods that could be used to value the actual information itself. This section examines how information is measured from a macro perspective by examining the costs and benefits of the information technologies that are the receptacles for the information.

There are a number of methods available to analyze the value of information technology. There are also many opinions on the need for the methods. These opinions range from no analysis is required to those which state that existing discounted cash flow techniques are adequate to evaluate any type of information technology project (Bonczek, Holsapple, and Whinston 1980; Dyle 1995; Heenan 1976; Lembersky and Chi 1984; McLean and Riesing 1977; Waldman 1992).

The techniques from the field of management information systems are designed to evaluate the costs and benefits associated with the information technology and indirectly value the information. The techniques categorized into three major groups. One group, which includes cost revenue analysis, cost-benefit analysis, discounted cash flow, value analysis, analytical hierarchy process, and information economics, attempts to generate a quantitative analysis with dollar values being assigned for both the costs and benefits. The second group, which includes return on management and spending ratios, evaluates information technology projects after the fact. The last

group, which includes multi-objective multi-criteria and critical success factors, looks at valuing information technology from a qualitative perspective.

The first analysis method is cost revenue analysis. This method uses conventional cost and management accounting practices. It is used when benefits directly result from information technology and are in the form of cost savings or revenue improvement (Brealey and Myers 1991; Copeland and Weston 1992; Farbey, Land, and Targett 1993; Horngren and Sundem 1991; Shillinglaw 1982).

The analysis is fairly straightforward to perform. It is also a universally recognized and accepted method to evaluate capital asset acquisitions. However, it tends to look at only cost savings or revenue improvement and ignores intangibles.

Closely associated with cost revenue analysis is a technique called cost-benefit analysis. It overcomes the problem of intangibles by assigning a value to each cost and benefit (Abrahams, Flowerdew, and Smith 1978; Boczany 1983; Ghandforoush 1982; King and Schrems 1978; Kleijnen 1984; Litecky 1981; Stern 1976; Vaid-Raizda 1983; Willcocks and Lester 1991). However, the values assigned to the intangibles are subjective with the different people involved coming up with differing values. It also does not deal well with projects that have a high degree of uncertainty.

Discounted cash flow techniques are one of the most popular analysis techniques for evaluating information technology projects, along with many other types of projects. These techniques examine the cash flow of a project putting the costs and benefits in some form of constant dollars (Bacon 1992; Brealey and Myers 1991; Copeland and Weston 1992; Due 1989; Horngren and Sundem 1991; Kaplan 1986; Sassone 1986; Sassone and Schwarz 1986; Shillinglaw 1982; Thurow 1987; Trigeorgis 1993b; Weaver et al. 1989). Among the most popular of these techniques are net present value and return on investment.

These analyses are fairly straightforward to perform along with being universally recognized and accepted methods to evaluate capital asset acquisitions. They also allow direct comparison to other projects and allow management to determine if projects meet or exceed the hurdle rate. However, these techniques typically assume clear, measurable and reliable returns and are oriented to cost saving, productivity oriented projects. They also ignore intangible benefits and ripple effects and do not deal well with projects that have a high degree of uncertainty or have very different time horizons.

Value analysis emphasizes an information technology project's benefits rather than its costs. It examines the work patterns throughout the organization and then uses a work profile matrix to shift work to lower cost employees or to increase quality of decisions using the information system under evaluation (Greis and Materna 1993; Keen 1981; Menon 1993; Money, Tromp, and Wegner 1988; Parker and Benson 1987; Parker, Benson, and Trainor 1988; Rivard and Kaiser 1989; Sassone 1992; Schwartz 1987; Sievert 1991).

Value analysis is useful in a white collar environment where the amount and type of work varies. It allows intangibles to be converted into tangibles and the values obtained can be used for monetary evaluation such as cost benefit analysis or discounted cash flow analysis. However it concentrates on the reduction of labor costs and does not look at higher level benefits such as strategic fit. Also the labor reduction calculations are subjective.

Another approach that attempts to incorporate the intangible benefits in the analysis process is the analytical hierarchy process. The intangible benefits are incorporated into the tangible costs and benefits using subjective estimates. The decision makers quantify the perceived importance of the intangible benefits using a qualitative weighting system (Accola 1994; Canada and Sullivan 1989; Harper Jr.,

Apostolou, and Hartman 1992; Liberatore, Monahan, and Stout 1992; Neises and Bennett 1989; Stout, Liberatore, and Monahan 1991; Wind and Saaty 1980).

Information economics looks at information technology valuation using a range of financial techniques including traditional cost benefit analysis, value acceleration, value linking, value restructuring, and innovation and investment valuation. Value acceleration is when information technology allows benefits to be received more quickly than otherwise possible while value linking looks at the ripple effects caused by information technology in an organization. Value restructuring looks at how information technology can restructure the way an organization performs its tasks. Innovation and investment valuation looks beyond the financial issues and examines how an information technology project will impact the organization from a competitive and strategic perspective (Fisher 1995; Parker and Benson 1987; Parker and Benson 1989; Parker, Benson, and Trainor 1988; Pastore 1992; Semich 1994).

Information economics breaks benefits into six major classes of value: enhanced views on return on investment, strategic match, competitive advantage, management information, competitive response, and strategic information technology architecture. It also looks at five potential risks associated with new system development: strategic uncertainty, organizational risk, information system infrastructure risk, definitional uncertainty, and technological uncertainty.

Information economics also provides a comprehensive method of the treatment of benefits and risks and is able to assign dollar values to costs and benefits, tangibles and intangibles. It also recognizes many types of values such as strategic or competitive advantage along with recognizing a number of different types of risks and uncertainties. However, it requires considerable knowledge to use and can be expensive and time consuming to acquire all the needed information.

Information economics is not a single technique to evaluate information technology projects. Rather it is a framework that attempts to tie together other analysis methods into a coherent structure. Therefore any new techniques to evaluate information technology, or a particular aspect of information technology, will not replace the concept of information economics but be integrated into its overall framework.

Return on management assumes information costs are the cost of managing the organization. The method uses discounted cash flow techniques to determine the value left over after everybody has been paid. This residual value is value of management. The return on management is the value of management divided by cost of management (Strassman 1985; Willcocks 1992).

Return on management does concentrate attention on the management process and how management uses information technology. Another advantage is that the data required is relatively easy to obtain since the same data is needed for required financial statements. On the other hand, it assumes all information in the organization is used only by management and it ignores any use of information by non-management personnel. There are also many other factors that may influence the value determined which have no relationship to information technology use such as changing environmental conditions. Thus it does not provide any causality relationships and can not be used to evaluate competing projects.

Using spending ratios, one compares spending on information technology to other internal values (e.g., total sales, labor costs, profits, etc.) and determines the ratio of the two values. Alternately, one can compare money spent on information technology from one company to another in the same industry or compare bottom lines before and after spending on information technology (Belcher and Watson 1993; Bender 1986; Gold 1993; Martin 1989; Strassman 1985; Thomas and Edwards 1993).

A spending ratio can be easily and quickly performed with minimal problems gathering data. However it provides no explanation for results and does not help when evaluating the implementation of new systems. More importantly, it does not measure the effectiveness of information technology usage. Additionally many other factors besides information technology can influence ratios, especially "before and after" ratios. It also does not provide, or prove, any causality relationships between the use of an information technology project and the spending ratio outcome.

The multi-objective, multi-criteria method assumes that there are other measures of worth besides monetary value. The approach handles the fact that many users can not assign a monetary value to their desires but can express relative needs (e.g., timeliness is more important than neatness). It attempts to define a measure of utility where utility is defined as the satisfaction of users' preferences. This is typically done through the use of focus groups and survey techniques where the various attributes of an information system are placed in a rank order (Gregory and Jackson 1992; Kenny and Raifa 1976; Land 1976; Vaid-Raizda 1983).

The multi-objective, multi-criteria method allows users to evaluate systems in terms of wants and needs rather than monetary values. It can also help build consensus among the stakeholders on the desired system requirements as an outcome of the focus groups. However, it does not provide any type of monetary evaluation. This makes it extremely difficult to compare alternate projects. This is especially important when trying to compare information technology to non-information technology projects. Also, without a monetary outcome, there is no basis to determine whether a system is economically worthwhile and helps the organization meet financial objectives. Finally, reaching a group consensus can be very difficult and time consuming.

The critical success factor approach is used to establish key business objectives and then decompose these objectives into critical success factors. These critical success

factors are then evaluated to define the information technology needs that support these factors (Baker 1993; Boynton and Zmud 1984; Broadbent and Lofgren 1993; Byers and Blume 1994; Carey 1993; Fortin 1993; Kehoe, Little, and Lyons 1993; Pellow and Wilson 1993; Pollalis and Frieze 1993; Rockart 1979; Shank, Boynton, and Zmud 1985; Slevin, Stieman, and Boone 1991; Willcocks 1992; Zahedi 1987; Zink 1993).

This approach focuses on criteria that are considered important to management and allows them to be evaluated more deeply than criteria not considered important. It also helps define a consensus of what the important criteria are from an organizational perspective. This can offset an imbalance between monetary costs and benefits. However, critical success factors are subjective based upon the respondent and the output of a critical success factor analysis does not directly provide input for monetary analysis.

Analysis Techniques Used

The previous sections discussed quantitative techniques that are available and could be used to evaluate capital budgeting projects, including information technology projects. This section examines the techniques actually being used by industry.

A survey of capital budgeting techniques, regardless of whether the project was an information technology project or not, used by the Fortune 500 companies (Cooper, Cornick, and Redman 1992) found that the primary techniques used were internal rate of return – used by 56.9% of the companies, payback – 20.6%, and net present value – 12.7%. The secondary criteria used were internal rate of return – 20.6%, payback – 23.5%, and net present value – 20.6%. Also found was that 19.6% of the firms fail to perform feedback and review of their capital budgeting process. Interestingly, many of the firms that use payback as their first method and don't review the results are larger firms in the billion dollar category. Evans and Forbes (1993) believed that the primary reason for the use of internal rate of return over other

techniques such as net present value was that the results from an internal rate of return analysis could be more easily interpreted.

Another survey (Freeman and Hobbes 1991) found results similar to the first. The results also indicated that 76% of firms accept projects that fail quantitative analysis. Strategic reasons were cited in 94% of the cases. The study noted a negative relationship between the sophistication level of the analysis technique and the firm's performance. The authors felt that analysis sophistication was related to the firm's evolutionary stage. Thus firms involved in mature industries tended to be more sophisticated in their analysis than high growth firms. Other surveys (Baksh 1986; Cooper and Petry 1994; Pike 1989) found similar results to previous studies.

Looking at information technology projects, in 1987 only 23% of information technology projects had any quantitative analysis performed on their costs and benefits (Green 1980; Hogue and Watson 1983; Keen 1981; Pieptea and Anderson 1987; Wagner 1980). By 1992, quantitative methods were being used by 75% of companies, with discounted cash flow techniques being used to evaluate 40% of information technology projects (Bacon 1992). By 1994, 95% of the companies indicated that discounted cash flow analysis was either very important or somewhat important in getting a project accepted (Gillin 1994a). Also found was that in the analysis process, there is a tendency to use discounted cash flow techniques to prove how new systems will reduce costs rather than increase benefits (DiRomualdo 1990; Framel 1993; Greis and Materna 1993; Nairn 1988; Quinlan 1990; Zottola 1991).

Conclusion

This section examined three topics that are woven together. Information technology has evolved over the years from a tool that handled routine record keeping to an integral part of the business process. Information technology now provides a number of benefits that can assist an organization in obtaining and maintaining

competitive advantage. However, the use of information technology has come at a price. Organizations must allocate a number of resources to maintain and update their information technology infrastructure.

One of the concerns that management has is ensuring that the resources spent on information technology are wisely allocated. Studies evaluating the productivity associated with information technology investments have found minimal productivity improvements. It is believed that the major problem in this evaluation is the proper measurement of the benefits associated. Unfortunately, many of the benefits provided by information technology are intangible and difficult to quantify.

A number of different techniques in the fields of economics and management information systems have been developed over the years to evaluate the costs and benefits associated with information technology. The techniques from the field of economics are designed to measure the value of the information directly. However, the techniques are better suited for examining the concepts than they are for performing detailed analysis.

The techniques from the field of management information systems are designed to evaluate the costs and benefits associated with the information technology and indirectly value the information. The techniques categorized into three major groups. One group, which includes cost revenue analysis, cost-benefit analysis, discounted cash flow, value analysis, analytical hierarchy process, and information economics, attempts to generate a quantitative analysis with dollar values being assigned for both the costs and benefits. The second group, which includes return on management and spending ratios, evaluates information technology projects after the fact. The last group, which includes multi-objective multi-criteria and critical success factors, looks at valuing information technology from a qualitative perspective.

Each of these three groups has drawbacks associated with them. The first group attempts to provide a quantitative evaluation of a project's costs and benefits. However, these techniques have limited success in quantitatively capturing all of the benefits associated with a project. The second group is not able to evaluate potential projects but only provide feedback after the fact. The third group evaluates projects from a qualitative perspective. While this can capture some of the intangible benefits associated with a project, it does not allow the direct comparison of competing projects. This is especially crucial when comparing potential information technology projects to other non-information technology projects. Therefore, there is still a great need to develop and evaluate new analysis techniques that can help quantify the intangible benefits.

Real Options and Option Pricing Theory

The previous section examined the techniques presently being used to evaluate information technology projects. The majority of the organizations use some form of quantitative analysis technique (Bacon 1992; Gillin 1994a). The three most common techniques used are internal rate of return, net present value, and payback (Baksh 1986; Cooper and Petry 1994; Cooper, Cornick, and Redman 1992; Freeman and Hobbes 1991; Pike 1989). Of these three techniques, net present value provides the "best" answer[2].

However, net present value analysis as described in the textbooks (i.e., traditional net present value) has some associated limitations that can result in the value of an investment being underestimated. A traditional net present value analysis makes implicit assumptions concerning an expected scenario of cash flows. It presumes management's passive commitment to a certain "operating strategy" (e.g., to initiate the project immediately, and operate it continuously at a set scale until the end of its pre-specified expected useful life). It also ignores the synergistic effects that an investment project can create. Traditional net present value analysis usually

underestimates investment opportunities because it ignores management's flexibility to alter decisions as new information becomes available (Bacon 1992; Brealey and Myers 1991; Brennan 1995; Brookfield 1995; Busby and Pitts 1995; Hayes and Abernathy 1980; Hayes and Garvin 1982; Kogut and Kulatilaka 1994b; Ross 1995; Sercu and Uppal 1994; Smith and Nau 1995; Trigeorgis 1993b; Weaver et al. 1989).

Because of the limitations of traditional net present value, Myers (1974) proposed the use of an analysis technique he called "adjusted present value". The original purpose of the technique was to provide a generalized analysis method to evaluate the interactions of corporate investments and associated financing decisions. He determined that for the case of interacting financing and investment decisions, the adjusted present value of a project equaled the base-case net present value plus the net present value of financing decisions. (For further information, see also Ashton and Atkins 1978; Bar-Yosef 1977 and Myers' response to Bar-Yosef.)

The concept of adjusted present value is not limited to evaluating the interaction of investment and financing decisions. The concept was expanded to include the impact of any other effects of accepting the project. Myers (1974) stated that the adjusted present value model he developed was static and did not reflect how future events would affect the investment decision. However, the adjusted present value approach is flexible and the impact of dynamic decision-making could be incorporated into it. One approach to including the value of dynamic decision-making in the adjusted present value model is by the use of option pricing theory and real options.

Real Options

The birth of quantitative option pricing theory comes from the works of Black and Scholes (1973) and Merton (1973). Options allow an investor to determine a dollar value for an event that is to occur in the future (Brealey and Myers 1991; Copeland and Weston 1992; Cox and Rubinstein 1985; Fitzgerald 1987; Ritchken

1987). Historically, options have been used to value future possibilities associated with financial assets such as stocks.

Real options are based upon Myers' (1977) initial discussion of discretionary investment opportunities as growth options. Kester (1984) expanded Myers' work and talked about the competitive and strategic uses of growth options. (For further discussion, see also Brookfield 1995; Busby and Pitts 1995; Dixit and Pindyck 1994; Dixit and Pindyck 1995; Kamrad 1995; Kogut and Kulatilaka 1994b; Kulatilaka and Marcus 1988; Kulatilaka and Marcus 1992; Mason and Merton 1985; Ross 1995; Sanchez 1991; Sercu and Uppal 1994; Smit and Ankum 1993; Smith and Nau 1995; Trigeorgis 1988; Trigeorgis and Mason 1987). The value of the real options can affect the overall value of a project and should be included in the adjusted present value analysis.

The concept of real options is based upon the fact that management does have the flexibility to alter decisions as further information becomes available. If future conditions are favorable, a project may be expanded to take advantage of these conditions. On the other hand, if the future is unfavorable, a project may be curtailed or even canceled as the conditions warrant. A traditional net present value analysis does not take these factors into account. The difference between a traditional and dynamic valuation approach can be seen by examining the probability distributions of the expected value of a project.

A traditional net present value analysis generates a range of probable expected values with the most likely value in the center of a symmetric normal probability distribution as shown in Figure 2 (Trigeorgis 1988, p. 147). An adjusted present value analysis, including the value of the real options, incorporates into the analysis process management's flexibility to improve a project's upside potential while limiting the impact of the project's downside losses. This results in a project with a higher

expected value and causes the distribution to be skewed to the right as shown in Figure 3 (Trigeorgis 1988, p. 147). The difference between the expected values is the value of the real options and is called the option premium.

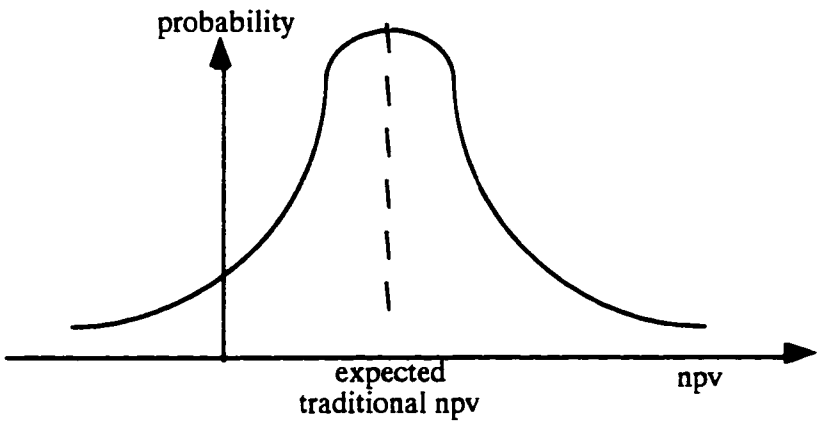


Figure 2: Project under traditional net present value

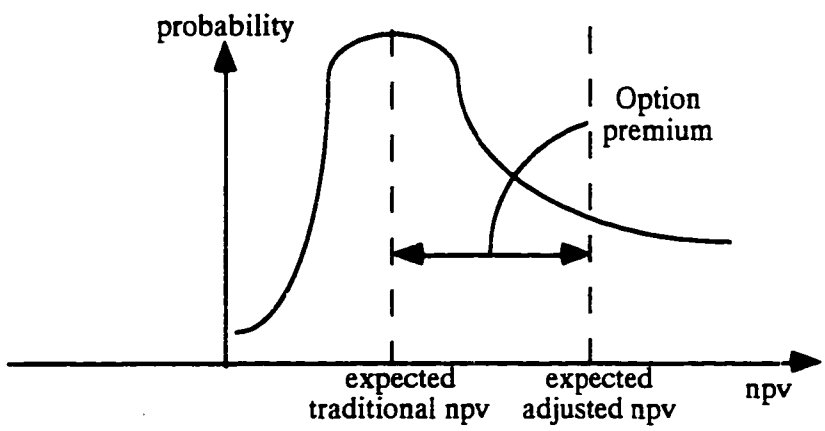


Figure 3: Project under adjusted present value, including the real options

Previous work in real options (Trigeorgis 1986; Trigeorgis 1988; Trigeorgis 1993b) has generated a taxonomy that has broken down real options into six categories based upon the type of flexibility provided. The six categories are: the option to defer; the option for staged investments; the option to change the existing scale; the option to abandon; the option to switch use; and the option to grow. It is also possible for a project to have more than one category of real options be applicable that leads to multiple interacting real options.

The option to defer occurs when management can put off a decision until some date in the future (Grenadier 1992; Ingersoll and Ross 1992; Lund and Oksendal 1991; McDonald and Siegel 1986; McGahan 1993; Morck, Schwartz, and Stangeland 1989; Paddock, Siegel, and Smith 1988; Pickles and Smith 1993; Quigg 1991; Quigg 1993; Stiegert 1993; Titman 1985; Williams 1991). This allows management to determine if resources should be spent on a project at that future date. For example, a company who owns an option to explore a potential oil site does not have to spend any resources if the cost of extracting the oil is greater than the existing value of the oil. If the price of oil rises or the cost of extraction decreases, the option to explore the site would be exercised. This option can be useful in evaluating natural resource extraction (e.g., lumber, oil, coal), urban land prices, farming, or the impact of potential interest rate decline.

The option for staged investments occurs when a project investment happens in a series of outlays that allows the project to be abandoned in mid-stream if conditions become unfavorable (Carr 1988; Childs 1995; Majd and Pindyck 1987; Trigeorgis 1993a). The development of a project can be considered a series of options. Each stage in development can be considered an option on the value of future stages. For example, choosing to build a pilot plant before building a full scale plant is considered an option for staged investments. This allows the company to determine if a process is

feasible and to work out any potential problems before spending the resources to build the full scale plant. This option can be valuable when looking at research and development or long term capital projects.

The option to change scale can result in the project being expanded, contracted, or shut down and restarted (Brennan and Schwartz 1985; Kogut 1991; McDonald and Siegel 1985; Pindyck 1988; Stiegert 1993; Trigeorgis and Mason 1987). Depending on market conditions that prevail at a particular time, the rate of resource expenditure can be adjusted to meet the new conditions. For example, a production plant might be built with extra capacity in case demand is higher than expected. This allows the company to immediately increase production without having to wait for new plant construction. In another case, a company may choose to rent office space rather than buy it. Thus if the scale of operation decreases, the company can vacate the space and not continue to pay a mortgage with the space sitting idle. This option is valuable with natural resource industries, facilities planning, or companies in cyclical (e.g., seasonal) industries such as clothes, toys or income tax preparation.

The option to abandon allows the company to abandon a project if the market conditions drop dramatically (Agmon 1991; Fung 1995; Kathan 1995; Myers and Majd 1990). The company can then sell off any assets available to offset the loss or switch those assets to other projects. For example, a company which produces major appliances may introduce a high-efficiency refrigerator. If there is no consumer interest, the company can abandon production of the new refrigerator and sell off any of the production assets or apply them to other major appliances. This option is valuable in capital intensive industries such as airlines or railroads, and in organizations that are involved in new product development.

The option to switch allows an organization to change either the input mix or output mix of a facility (Andreou 1990; Kensinger 1987; Kogut and Kulatilaka 1994a;

Kogut and Kulatilaka 1994b; Kulatilaka 1988; Kulatilaka 1993; Kulatilaka and Trigeorgis 1993; Margrabe 1978; Van Mieghem 1995). If environmental conditions change, this option provides the flexibility to alter either the process (i.e., input mix) or product (i.e., output mix). From the process perspective, a plant might be designed or purchased with a boiler that can burn either gas or oil. The decision of which to burn would depend on the relative market costs of the two fuels. From a product perspective, an organization may invest in a flexible manufacturing system that allows them to switch products as demand varies. This type of option is valuable for organizations where input mixes are likely to vary such as power plants, or chemical production facilities. It is also valuable where outputs are changing such as consumer electronics, automobiles or toys.

The option to grow is used when an initial investment is required for further development (Brealey and Myers 1991; Childs 1995; Kester 1984; Kogut and Kulatilaka 1994b; Myers 1977; Newton and Pearson 1994; Ott 1992; Pindyck 1988; Sanchez 1991; Solt 1993; Trigeorgis 1988). The project can be considered a link in a chain of related projects. Each project in the link is required for the future growth. An organization may invest in research and development even though it typically has a negative traditional net present value. It invests because of the future growth value of the results of that research and development. This option is valuable for high technology industries, industries involved in research and development, companies involved with competitive acquisition, or industries whose products are evolving, including computers and pharmaceuticals.

Many projects do not have only a single real option that is applicable to them. Depending on the type of project, more than one real option must be considered when computing the adjusted present value (Brennan and Schwartz 1985; Kathan 1995; Stiegert 1993; Trigeorgis 1986; Trigeorgis 1993a; Trigeorgis 1993b; Van Mieghem

1995). These options can interact in various ways. The value of the interacting multiple options may not be equivalent to the value of the individual options added together. The value of the interacting options is applicable to most industries and projects.

Application of Real Options to Information Technology

A review of the literature related to the application of real options to information technology produced only a few articles. Information technology infrastructure investments can be seen as providing real options. They can give management either the ability to create new applications not possible if the infrastructure is not in place (a call option) or the ability to replace existing applications quickly when they no longer meet needs (a put option) (Carlson and McNurlin 1992; Greis and Materna 1993; Trigeorgis 1993b).

An investment in electronic mail can be equated to a call option because it gives the company a way to create distributed systems more easily (Trigeorgis 1993b). An investment in standards-based equipment could be equated to a put option because it enables management to abandon software from one vendor without also having to abandon the hardware (Trigeorgis 1993b).

Actual Application of Real Options

The previous section categorized the literature on real options by the type of real option discussed in the article. This section breaks down the literature by the content of the article. Reviewing the contents of the literature allowed the articles to be broken down into three general categories — conceptual, simplified models, and industry applications. The first two categories encompass the vast majority of the literature.

The conceptual articles provide the basis for real options. Some of the articles formalize the theory underlying real options. Other articles expand upon the theory and give examples of how the real options could be used to increase the value of projects in a number of different industries such as pharmaceuticals, natural resource extraction, consumer electronics, etc. These articles do not develop any quantitative models but rather discuss real options from a qualitative perspective.

The second category is those articles that develop quantitative models that demonstrate how real options can impact a project's overall value. In many of the articles, the models developed are simple and examine only a few states of nature. The numbers entered into the models are created by the author(s) of the article. A few of the articles use input data drawn from actual projects. The quantitative models developed are not detailed enough for actual use by management.

The third category of articles is those that describe models sufficiently detailed to be actually used by industry to support decision making. A review of the literature found only four articles that fell into this category. The first two articles provide a comparison between the results of real options models and the results of "traditional" financial analysis (Paddock, Siegel, and Smith 1988; Quigg 1993). In these two cases, the real option models are not used by management for any decision making purposes. The third article discusses insights gained from the use of real options to assist in the decision making process at Shell (Kemna 1993). The fourth article discusses the use of real options at Merck Pharmaceutical Company (Nichols 1994). Merck has integrated the use of real options into their formal financial analysis process.

Paddock, Siegel and Smith (1988) developed a real option model to value offshore oil leases as a function of the price of oil. The model evaluated the flexibility of being able to defer actual exploration for oil until future demand and extraction costs

were better known. A real options model was developed which generated estimates for the expected bid prices for leasing twenty-one tracts of offshore land.

The estimates from the real options model were compared to estimates generated by a discounted cash flow model used by the U.S. Geological Survey. Both the real option model and the discounted cash flow model used the same underlying data so that differences in the estimates would be caused by differences in the financial analysis techniques. The results of the study found that the estimates provided by the real option model and the discounted cash flow model were highly correlated. However, neither of the estimates were correlated with the industry bids. The lack of correlation between government and industry estimates is a common occurrence and is related to differences in the way that the estimates are generated by the government and industry.

This effort demonstrated that real option models did have value in evaluating the option to defer. The real options approach had four advantages over the traditional discounted cash flow model. First, the real option model required considerably less data to estimate the bid prices since it more efficiently used market data. Next, it was easier to compute and less subject to error. Third, it provided a framework for the scheduling of development. Last, it provided insights into government policy and industry practice (Paddock, Siegel, and Smith 1988).

Quigg (1993) also examined the impact of the option to defer. The article determined the option premium associated with deferring the purchase of land and associated buildings until future conditions were better known. This research examined the empirical forecasts of a real options model using a sample of market prices.

The sample used consisted of 2700 real estate transactions within the city of Seattle, Washington. The real options model looked at a number of factors including

type of property (e.g., commercial, industrial, etc.), location of the property (e.g., southwest quadrant, etc.), age of buildings, and height of buildings. The real options model computed the adjusted present value of the land and building when the real option to defer is included. The results of the real options model were then compared to the results from a traditional model.

A comparison of the results found an average option premium of 6% when all the factors were combined. The option premium ranged from 1% to 30% in the various subsamples. The option premium was defined as the difference between the value computed by the traditional model and the real option model divided by the option model value. The conclusion of the article was that the option to wait does have a dollar value that can be attached to it.

The two real options models previously described were used to compare the results of a traditional financial analysis with a real options model. In both cases, the real options models were not used to support decision making.

Kemna (1993) reviews three case studies performed with Shell Oil Company as exploratory studies to determine how real options could improve their existing capital budgeting process. In order to use the option pricing theory techniques, the real world cases had to be simplified. The three cases examined were the option to defer development of an offshore oil field, the growth option provided by the construction of a pilot manufacturing plant, and the option to abandon a crude distiller in a refinery.

The major insight from the studies performed in conjunction with Shell was the development of seven steps to be followed when trying to develop option pricing theory models. First, convince management that traditional discounted cash flow techniques do not properly account for the flexibility inherent in a project. Second, distinguish between alternative courses of actions and the options embedded in a project. Third, determine the options that provide the greatest benefits since decreasing

the number of options in a model simplifies the model. Fourth, restate the investment decision to determine whether the benefits provided by flexibility outweighs the costs associated with including the flexibility. Fifth, determine the uncertainties inherent in the project and determine the most valuable option. Sixth, include the impact of competitors and other costs that may affect the value of the option since most options are not free to implement. Finally, concentrate on the value of the project and perform sensitivity analysis on the results.

Merck Pharmaceutical Company actually uses real options to evaluate projects and assist management in evaluating potential projects (Nichols 1994). Judy Lewent, chief financial officer, describes how real options are used to value research investments which typically are not amenable to traditional financial analysis techniques. Merck determines the values of the real options inherent in a project. Because of the nature of the pharmaceutical industry, development of new drugs takes a number of years before a return can be seen on the investment. In addition, development is a very risky business with many of the drugs never being marketed. Market conditions and cash flows so far in the future are difficult to predict. These factors tend to cause traditional financial analysis techniques to underestimate the value of a project.

Real options allow the potential profit that new drugs may provide to be better incorporated in the financial model. Because of the nature of the industry, large pharmaceutical companies typically farm out initial research and development to either small companies or universities. The large company funds the research as a series of payments (i.e., staged investment). These payments give the company the right, but not the requirement, to make further investments based upon the results of the research. If traditional financial analysis techniques were used, many of the projects that yield a positive net worth under options analysis would not be pursued since the

traditional net worth would be negative. Judy Lewent indicates that real options analysis is used for research and development projects, however, she would like to extend this type of analysis to "traditional" projects such as building new facilities or purchasing new companies.

Conclusion

The majority of companies use some form of quantitative analysis to evaluate the costs and benefits associated with information technology projects. However, the common techniques used do not account for the flexibility that management has to alter decisions over the life of a project as conditions change. This leads to estimates that undervalue the project's worth.

To measure the value of the flexibility, the concept of real options, an offshoot of financial options, was developed. Real options are relatively new and much of the work on real options is conceptual in nature. There has been little work done on applying real options to valuing information technology. The only literature in this area simply mentions in passing how a few types of information technology projects can be considered to provide the company with some real options.

There has also been relatively little work done in applying real options in actual industry settings. Merck Pharmaceuticals appears to be the only company formally using real options in their decision making process. There have been no benchmark studies of industry's existing use of real options for any industry, nor for any type of project. Nor has any study solicited industry's attitude towards integrating real options into their investment analysis process.

Information Technology in the Insurance Industry

This dissertation performed a benchmark study of the existing and potential use of real options to value information technology. For reasons discussed in the

methodology chapter, members of the insurance industry were chosen as the target participants. This section describes the insurance industry and their heavy dependence on information technology. It also discusses the existing studies that have been performed in the insurance industry to evaluate the benefits provided by information technology.

In the last fifteen years there have been a number of significant changes in the competitive nature of the insurance industry. The changes include deregulation of the industry, decreased demand for basic insurance policies, and a number of new entrants in the market. Coupled with these changes in the industry are changes in the buying habits of the consumers (A survey of ... 1990; Hoyt 1995; LOMA 1988; Mayewski and Albanese 1995; Schwartz 1995; Sippel 1989). Consumers are now more sophisticated and they look at insurance as an investment opportunity and want to maximize their return. The result is that buyers are more willing to switch companies.

All the changes have forced insurance companies to increase their product innovation and shorten the life cycle associated with these new products. They have also broadened their product horizons by expanding into businesses that were traditionally the domain of banks and brokerages. Insurers have been compelled to become more service and cost oriented (A survey of ... 1990; Bartling 1995; Burger 1995; Farinella 1995a; Farinella 1995b; Gagne 1994; Hamilton 1995; Hoyt 1995; Ingrassia 1994; Jones 1994; LOMA 1984; Mayewski and Albanese 1995; Nelson 1995; Schwartz 1995; Survey forecasts ... 1995; Wagner 1995; Wilcox 1995). A. M. Best, a company which determines and publishes ratings of the insurance companies, includes information technology as one of their factors when determining a company's rating (Best's Insurance Reports ... 1995a; Best's Insurance Reports ... 1995b; Technology and Ratings 1994).

Traditionally, insurance companies focused their information technology efforts on the automation of transactional-based functions such as policy underwriting, policy maintenance, billing and collection, claims transactions, personnel records and accounting (Daniele 1995; Harris and Katz 1989; Harris and Katz 1991a; Harris and Katz 1991b; Ingrassia 1994; Tucker and Wallace 1995). Recently, the insurance industry has used information technology to assist in decision making, improve the customer interface and create innovative products (Bartling 1995; Gagne 1994; Hammer 1990; Hoyt 1995; Ingrassia 1994; Jones 1994; LOMA 1988; Morrissey 1995; Nelson 1995; Schwartz 1995; Sippel 1989; Survey forecasts ... 1995; Van Gilder 1995; Wagner 1995; Whistler 1970; Wilcox 1995). The insurance industry spends 52% of its capital budget on information technology (Harris and Katz 1991b). The annual budget increase for information technology for the health care industry, which includes the insurance industry, is expected to be 10.6% for each of the next three years (Morrissey 1995).

Evaluation Methods Used

All the literature discussing valuing information technology in the insurance industry used spending ratios as the quantitative analysis method. The studies also examined the information technology at the organizational level, not at the individual project level. With spending ratios, spending on information technology is compared to other internal values (e.g., total sales, labor costs, profits, etc.). Alternatively, spending ratios can be used to compare one company to another in the same industry or compare bottom lines before and after spending on information technology (Belcher and Watson 1993; Bender 1986; Gold 1993; Martin 1989; Strassman 1985; Thomas and Edwards 1993). Spending ratio analyses can be easily and quickly performed with minimal problems. However, they do not provide explanation of results, nor help when evaluating new projects. More importantly, they do not measure the

effectiveness of information technology usage. Additionally, many factors can influence ratios, especially "before and after" ratios. Spending ratios do not provide, or prove, any causality relationships between the use of an information technology project and the spending ratio.

Looking at specific literature, Bender (1986) proposed that the economic benefits of information technology might be best evaluated at the level of a company's entire expenditure for information processing rather than at the level of individual projects. He used the ratio of information processing expense to total general expense as his independent variable and the ratio of total general expense to total premium income to measure financial success as the dependent variable. He found that too little spent on information processing could have a negative financial impact while high spending on information technology did not guarantee a positive financial impact.

Three studies by Harris and Katz (1989; 1991a; 1991b) also examined spending ratios related to information technology in the insurance industry. The first study (1989) examined the usefulness of two spending ratios to classify insurance companies into various organizational performance categories. They used the ratios of: 1) information technology expense to premium income, and 2) information technology expense to total operating expense to develop a discriminant model. The classification accuracy of their model was 92% for a test sample and 76% for a secondary sample. They concluded that spending ratios can be used for classification purposes. Their second study (1991b) examined whether organizational performance was linked to information technology investment intensity. They found a relationship between the two variables. However, they did not determine whether information technology investment intensity was a cause or consequence of organizational performance. Their third study (1991a) examined the relationship between firm size and information technology investment intensity. They found that small firms spend a larger percentage

of their operating expenses on information technology than larger companies. Their interpretation was that small companies had to be more effective in using information technology to stay competitive with larger firms. They also stated that "how the information technology was used" is probably more important than the amount spent.

Conclusion

This section examined the insurance industry and the literature related to information technology evaluation. The insurance industry has changed over the past two decades. Companies are facing much greater competitive pressures because of the changing nature of the industry and the consumers. For these reasons, the insurance industry has expanded its use of information technology from its traditional use of transactional level systems to strategic systems designed to provide competitive advantages.

There have been relatively few research studies examining the benefits of information technology in the insurance industry. The studies that have been performed have examined the role of information technology at the organizational level rather than the project level. This type of research, while useful, does not assist the organization in evaluating competing information technology projects. Additionally, the research has used spending ratios to evaluate projects. Spending ratios evaluate projects after the fact and again do not assist in the evaluation of competing projects.

Model Integrating Real Options and Information Technology

This dissertation examined the existing and potential use of real options to assist in measuring the benefits associated with information technology in the insurance industry. The idea of real options is relatively new and the majority of the literature has been conceptual in nature. There has been very little research done on the application of real options from an industry perspective. There has been no research

done benchmarking the existing or potential use of real options in any industry or for any type of project.

To evaluate the existing or potential use of real options, a model needs to be developed that can be empirically tested. Thus, the purpose of this section to generate a model that describes how real options can be incorporated into a valuation model for information technology projects. This section will integrate the concepts of traditional cost-benefit analysis for information technology projects and real options. Part of the model developed in this section will be evaluated as part of the dissertation process. The methodology chapter will discuss what aspects of the model will be empirically tested.

The overall model is split down into three levels of hierarchy. The top level looks at how real options, in general, fit into the information technology valuation process. The next level down describes the variables that fit together to determine the total value of the real options to a single project. The bottom level describes the variables that determine the value of any particular real option.

Project Level

The purpose of information technology is to process data into information. The data fed into the information system consists of raw, unorganized facts. The data can come from multiple sources including internal data generated by company transactions and external data from outside sources such as market surveys and industry trade groups. The processing performed by the information system can include sorting, merging, calculating, retrieving and displaying. The information generated can assist decision makers in evaluating problems and add value to the goods and services provided by an organization.

Another way to view information technology is to look at the costs and benefits associated with any specific project. This view is the focus of this dissertation. Both

the costs and benefits associated with an information technology project can include tangible and intangible aspects.

The costs associated with an information technology project fall into a number of categories. King and Schrems (1978) broke the costs into four categories. The first category was procurement costs associated with the equipment such as the actual cost, installation costs, facilities modifications, and supervisory costs. The next category was start-up costs which includes the system software, personnel costs and disruption costs. The third category was project related costs such as application software costs, software modifications, training, and data collection. The last cost category is ongoing costs and includes system maintenance, utilities, personnel costs and equipment depreciation.

For an information technology project to be worthwhile, the benefit(s) provided must outweigh the costs. The benefits can also be placed into a number of categories (Chang and Lee 1992; Farbey, Land, and Targett 1993; Glazer 1993; King and Schrems 1978; Sethi, Hwang, and Pegels 1993). Some of the benefits provided are concrete such as a reduction in processing errors or reduction in the amount of labor to perform tasks. Other benefits are abstract such as "better data for decision making". The benefits are grouped into seven categories — cost reduction, error reduction, decreased time to perform tasks, improvements in effectiveness, flexibility, strategic advantages, and required task. The "required task" benefit typically corresponds to information technology projects described as "threshold" projects. Certain activities are performed by an organization because the activity is required to stay in or compete in business.

The overall impact of the benefits should be to increase the organizational performance. The impact on performance can be both direct and indirect. For example, some cost reductions may directly show up in the organization's performance. On the

other hand, reducing errors might increase customer satisfaction and result in increased market share and indirectly increase organizational performance. Figure 4 shows a model that ties the costs and benefits of an information technology project together.

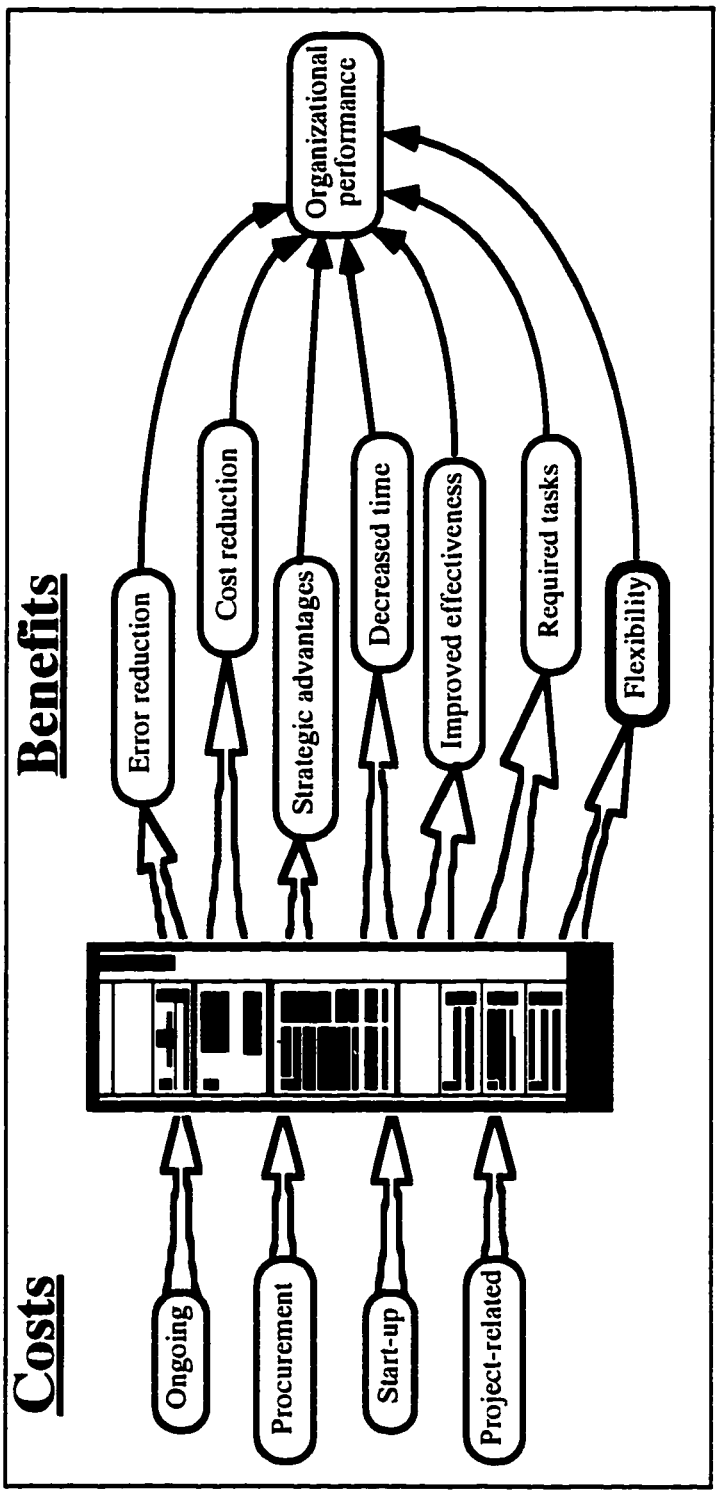


Figure 4: Costs and benefits of an information technology project

Of particular interest in Figure 4 is the benefit called "flexibility". Real options are a technique that can be used to value the flexibility. Information technology can provide flexibility in a number of ways. Companies can use information technology to "mine" new information from previously collected data. For example, banks that have credit cards can review the spending records of their cardholders and, using specialized software, determine which card holders appear to be interested in buying a house and forward mortgage information to those card holders. In a similar vein, tobacco companies can use data collected from smokers through surveys, merchandise purchases, etc. to generate "grass-roots" campaigns to influence legislation at the state or federal government level (Fields 1994).

The majority of the costs and benefits shown in Figure 4 are already accounted for in the traditional net present value analysis. The traditional net present value analysis can be extended to include the value of the flexibility under an adjusted present value (APV) framework. Therefore the value of a project under adjusted present value equals the value of the net present value analysis plus the value of the real options associated with a project (Brookfield 1995; Busby and Pitts 1995; Dixit and Pindyck 1994; Dixit and Pindyck 1995; Kamrad 1995; Myers 1977; Ross 1995; Sercu and Uppal 1994; Smith and Nau 1995; Trigeorgis 1988; Trigeorgis and Mason 1987). In equation form, this is equivalent to:

adjusted present value = traditional net present value + value of the real options

The flexibility associated with information technology can be considered from two aspects. First of all, the flexibility can be associated with the information technology itself. The flexibility to grow can indicate the hardware and software associated with the project can be expanded if there is a need. For example, additional

memory and hard disk space can be added to the hardware if the future conditions warrant. Alternately, the flexibility to grow can mean that the organization can grow because of the information technology project. For example, developing an information technology project that can mine new information from previously collected data allows the organization the flexibility to use that information to grow in ways that were not possible without the information technology project. In this dissertation, the distinction between the two types of flexibility was ignored.

Total Value of the Real Options

This section looks at the factors that determine how valuable the real options are to a specific project. Three factors included in this model are: the type of real options inherent in a project, the type of information technology project, and the potential interactions between the real options. The model is shown in Figure 5.

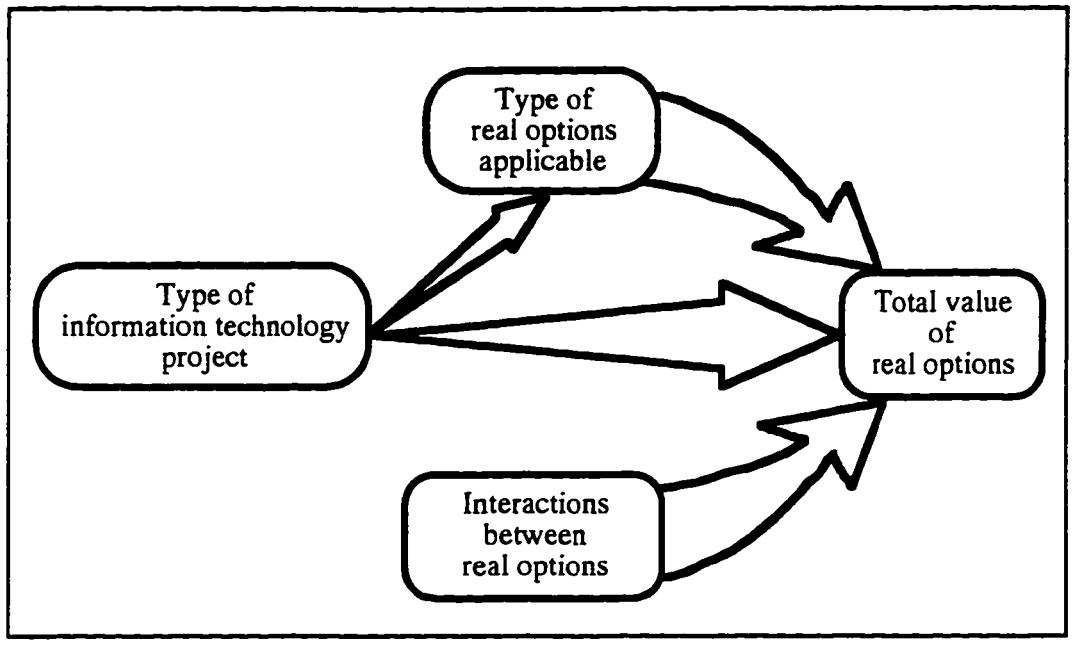


Figure 5: Factors that determine the value of the real options associated with a project

The first factor is whether all six types of the real options have the same value when evaluating an information technology project. The literature on real options links the different types of real options with different types of industries and projects. The majority of the literature deals with a single option and a single project. There appears to be minimal analysis to systematically determine which options are applicable to a project. Instead, a subjective judgment is made to determine which single real option should be evaluated for that project. That particular option may not be the one that had the greatest potential value to the organization. Additionally, it may not be the only real option inherent in the project.

For example, an organization is considering developing a new database system which can analyze the gathered data in new ways allowing additional products to be developed. This project provides the organization the option to grow. Furthermore, a

standardized database system is used. This allows the organization the option to switch among a number of differing vendors without having to restart the project. Thus this project provides at least two separate options.

The second factor is whether the type of the information technology project affects the usefulness of real options. The literature review described a taxonomy that split information technology projects into four categories — strategic, informational, transactional, and threshold. The literature review also discussed the fact that existing quantitative techniques are primarily suited for lower-order type information systems such as transactional systems. However, it is the higher-order (e.g., strategic) type systems that generally provide greater overall value to an organization. Unfortunately, these are the systems in which economic analysis is the hardest to perform since many of the benefits are intangible.

Therefore, it appears that the value of the real options inherent in a project should be related to the type of information technology project. The value of the real options should be greater in strategic projects when compared to threshold projects. In a threshold project, there is limited flexibility associated with the project. The project is performed because it is required to either stay in or compete in the business. On the other hand, many strategic projects are initiated without all the benefits fully quantified. The project is approved because of the options inherent in the project such as the project's ability to obtain or sustain competitive advantage.

Tied in with the type of information technology project, is whether the type of project impacts which real options are valuable. For example, the option to grow may have limited value in a threshold project while having a critical value in a strategic project.

The third factor is whether there are any synergy effects (plus or minus) when more than one real option is combined for an information technology project. Most of

the literature dealing with real options examines only a single option at a time. However, in many circumstances, more than one real option can be applicable to a specific project. That condition is covered under the first factor. However, it is possible that certain options interact with one another. In some cases, the interaction may provide value either greater than or less than the sum of the individual real options combined.

Components of a Real Option

The third level of the model looks at the components that determine the value of any specific real option. Real options may be valued similarly to financial options even though they can not be directly traded (Dixit and Pindyck 1994; Kasanen and Trigeorgis 1993; Mason and Merton 1985). The value of a stock (i.e., financial) option is determined by five variables: current value of stock; exercise price; time to expiration; stock value uncertainty; and riskless interest rate. An analogy can be made between the variables that determine the value of a stock call option and a real option as shown in Table 1 (Dasgutpa and Stiglitz 1980; Dixit and Pindyck 1994; Gehr Jr. 1981; Kester 1984; Trigeorgis 1988). The value of a real option is determined by the value of the individual variables as shown in Figure 6. Changes in the individual variables will affect the value of the real option.

Table 1: Comparison of variables on stock and real option

Stock Call Option	Real Option
Current value of stock	Gross present value of expected cash flows
Exercise price	Investment cost
Time to expiration	Time until opportunity disappears
Stock value uncertainty	Project uncertainty
Riskless interest rate	Riskless interest rate

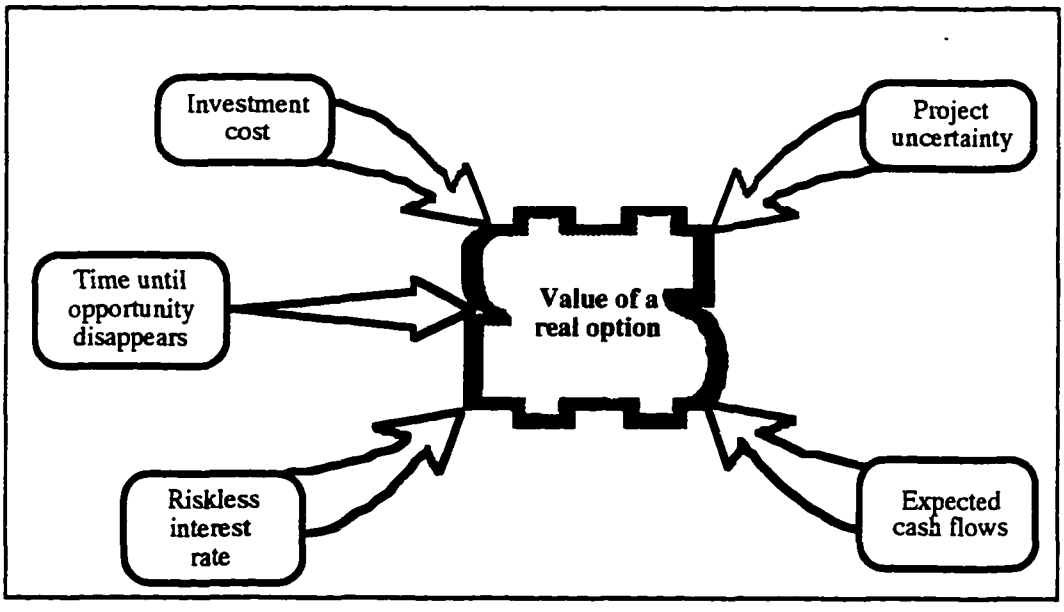


Figure 6: Factors that determine the value of a single real option

The cash flows are the amount of money that the project will bring in. As the expected cash flows increase, the real option becomes more valuable if the other variables are kept constant.

The investment cost is the amount of money that needs to be committed to provide the organization with the real option. Keeping the other variables fixed, increasing this amount will decrease the overall value of the real option.

Increasing the time a project can be deferred increases the real option's value. As the deferment time increases, the uncertainty associated with future events decreases since there is more time to gather information about future conditions. Additionally, the future conditions become more known since the "future becomes the present". If the future is unfavorable, the project is not pursued. If the future is favorable, the original project can be expanded to provide the maximum return.

The uncertainty associated with a project impacts the value of the real option. If two projects with identical traditional net present values can be deferred the same amount of time, the riskier of the projects will have a greater adjusted present value. A risky project usually provides the opportunity to generate high returns, but there is also a high probability of failure associated with the project. Since management has the flexibility to expand the project if it succeeds or abandon it if things do not go well, the associated riskiness is reduced. This aspect of uncertainty causes the results of a traditional net present value and adjusted present value to differ significantly. With a high degree of uncertainty, a traditional net present value analysis makes the project seem less attractive while an adjusted present value analysis makes a project seem more attractive (Brookfield 1995; Busby and Pitts 1995; Dixit and Pindyck 1994; Ross 1995; Sercu and Uppal 1994; Smith and Nau 1995).

Higher interest rates increase the value of the real options associated with a project. Normally, higher interest rates convert into higher discount rates that decrease

the value of a project. However, higher discount rates also mean a decreased present value of the future capital needed to exercise the real option. This counterbalancing effect helps to sustain the option's value as interest rates rise. This real option can give growth oriented projects an advantage in the capital budgeting process.

Conclusion

This section has presented a general model of how real options can be incorporated in the evaluation process of information technology projects. This model integrates variables from three conceptual levels. The model looks at how real options fit into the benefit side of projects. It also details some factors that help determine the value of the flexibility associated with a project. Finally, the model identifies what variables determine the value of an individual real option.

Notes:

[1] A later study by Brynjolfsson (1994) found that information technology projects do provide productivity improvements. He found that the return on investment for information technology was more than 50% per year as compared to 10% for other types of capital investments. While this is encouraging, the basic mismeasurement problem still exists and improved techniques are still needed to reduce the problem.

[2] Any number of introductory finance books (e.g., Brealey and Myers 1991; Copeland and Weston 1992) discuss the different methods to evaluate an investment. These books will also discuss why the net present value rule yields the most reliable analysis of the three techniques.

CHAPTER III

RESEARCH METHODOLOGY

This chapter describes the methodology used to investigate the model developed in the previous chapter. The approach consisted of sending a questionnaire to senior management in the insurance industry. This questionnaire investigated the executives' opinions concerning the actual and potential impact that real options have on valuing information technology projects. A review of the literature indicated that no previous work has been done in this area and there were no previous questionnaires available. Therefore, as part of this dissertation, a questionnaire was developed and evaluated.

This chapter is split into four sections. The first section lays out the specific research questions to be evaluated and the hypotheses that were used to test the model. The second section identifies the population and sample that was used to evaluate the research hypotheses. The third section provides an overview of the development of the questionnaire that was used to evaluate the research hypotheses. The last section lays out the analysis techniques that were used to analyze each research hypothesis.

Research Hypotheses

The previous chapter described a model of how real options can impact the information technology valuation process. It was not feasible to evaluate the entire model developed. Rather, only a portion of the overall model was evaluated. This section describes the specific research questions and hypotheses that were tested.

This dissertation focused on the variables related to the total value of the real options shown in Figure 5 on page 48. Specifically this dissertation examined the

impact that the type of information technology project, type of real options applicable, and the interaction effects had on the value of the real option. Additionally, the impact of real options on an organization's performance was evaluated. Figure 7 shows the research model evaluated as part of this dissertation.

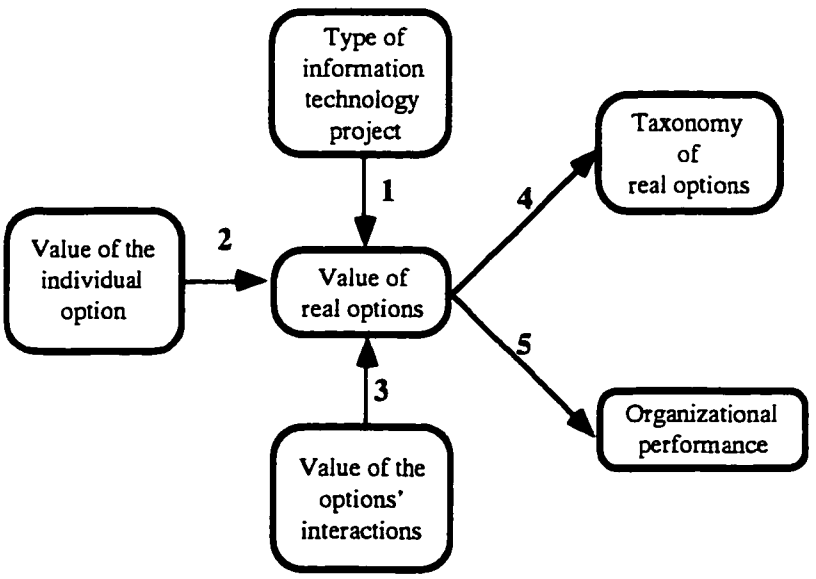


Figure 7: Research model that was evaluated

Work in the area of real options is still in the early stages. There has been no work to determine the relationships that may exist between different types of real options and different types of information technology projects. The work performed in this dissertation was a preliminary exploration examining the relationships between real options and information technology projects. The results provided a benchmark of existing usage in the insurance industry. The research also gathered information on the

work that must be done to convince industry that real options should be incorporated into their existing analysis framework.

This dissertation limited itself to five research variables. Of the five variables, four were based on the model presented in Figure 5 on page 48. The fifth variable examined the concept of organizational performance shown in Figure 4 on page 45.

The first variable examined was whether industry executives believed that the value of the embedded options is dependent on the type of the information technology project. This research question will help determine what type of information technology projects would benefit the most from quantitative analysis using option pricing theory. The null hypothesis, H_0, that was tested was: The value of real options is not related to the type of an information technology project. The research hypothesis, H_a, was: The value of real options is related to the type of information technology project.

The second variable examined was whether some of the six real options were more important than others when evaluating an information technology project. This portion of the research looked at the impact of each individual option on an information technology project. It also examined the impact each of the six real options had on the four types of information technology projects. This issue was not looking at any combination and interaction effects of real options. The null hypothesis, H_0, that was tested was: All of the real options are equally important. The alternate hypothesis, H_a, was: Some of the real options are more important than others.

The third variable examined was whether there were any synergy effects (plus or minus) when more than one real option was examined for information technology projects. This was an investigation as to whether certain of the six real options linked to provide benefits either greater or less than the sum of the individual options'

benefits. The null hypothesis, H_0, that was tested was: None of the real options have a synergistic effect when combined. The research hypothesis, H_a, was: One or more combinations of the real options have a synergistic effect.

The fourth variable examined was whether a classification scheme could be generated that linked together similar real option types and project types. It attempted to tie together the three variables identified from the previous three issues into a single model.

Quantitative modeling of the value of the real options is not a trivial task. The greater the number of project types and real options in the model, the greater the difficulty to build quantitative models. For example, looking at strategic projects only, it would be a major effort to build a quantitative model that included the value of all six real options. This research effort attempted to reduce the number of variables (i.e., types of real options or projects) that would need to be included in the quantitative modeling process. The null hypothesis, H_0, that was tested was: A classification scheme that is statistically valid can not be generated. The research hypothesis, H_a, was: A classification scheme that is statistically valid can be generated.

The fifth variable examined was whether including the value of the real options in the analysis process for an information technology project would improve the organization's overall performance.

This is the critical issue from an organization's perspective. While valuing real options should improve the information technology valuation process, this by itself may not justify the resources that are needed to perform the real options analysis. What makes real options, or any analysis technique, valuable to an organization is the ability to increase an organization's bottom-line performance.

This issue was trying to determine if there was a relationship between a company's present use of real options and its organizational performance. Including the value of real options in the analysis of information technology projects should improve the selection process among competing projects. Choosing projects that have a greater potential to benefit the organization should increase performance.

Analysis of this research question was examining whether the organizational performance of companies who were including the value of real options when evaluating information technology projects was greater than companies not presently including the value of real options in the information technology valuation process. This issue tried to determine if there was a relationship between companies who include the value of real options in information technology projects and their organizational performance. It did not attempt to prove causality. There are too many other variables that could affect the relationship. The null hypothesis, H_0, that was tested was: There is no relationship between the use of real options in the information technology valuation process and an organization's performance. The research hypothesis, H_a, was: There is a positive relationship between the use of real options in the information technology valuation process and an organization's performance.

Population and Sample

The insurance industry was chosen as the population to be examined for a number of reasons. Information and the related technology are critical in the service industry, including insurance. For many service industries, information and knowledge are their primary products. Since information and knowledge are intangible, it is harder to place a value on information technology that improves the product. The traditional measures of input and output are not designed to handle this

intangible value. Additionally, information technology comprises the largest part of the capital budget in the insurance industry (Harris and Katz 1991b; Morrissey 1995).

The insurance industry has been a leader in the use of information technology. It has been used for routine transaction processing, administrative support, new product development, product distribution, and marketing (Bartling 1995; Gagne 1994; Hammer 1990; Hoyt 1995; Ingrassia 1994; Jones 1994; LOMA 1988; Morrissey 1995; Nelson 1995; Schwartz 1995; Sippel 1989; Survey forecasts ... 1995; Van Gilder 1995; Wagner 1995; Whistler 1970; Wilcox 1995). Use of the insurance industry is also consistent with an earlier research effort of this author (Flatto 1992) which examined the ability of insurance companies to measure the costs and benefits associated with their information technology. One other reason for choosing the insurance industry was the existence of an insurance association that was willing to assist in the collection of data related to real options' valuation.

The Life Office Management Association (LOMA), which was created in 1924, is an association of life–health and property–casualty insurance companies[1]. LOMA supports member companies by providing services in a number of areas including customer service, employee development, financial management, human resources, insurance operations and technology. LOMA is also heavily involved in research. Areas currently being researched include demographics, financial management, management of technology, human resources, industry trends and concerns, information technology, and operational strategies.

In the area of information technology, LOMA provides conferences, seminars and workshops that address technical and non-technical issues of concern to the insurance industry. Additionally, LOMA conducts surveys of, and distributes the

results to, member companies that allow each company to compare their own hardware and software statistics to other member companies.

LOMA has a total membership of 775 companies. Of the 775 members, 186 are based outside the U.S. or Canada. Of the 589 members in the U.S. and Canada, 166 members are involved in activities not directly related to the sale of insurance. Many of these 166 companies are involved in consulting or providing support to insurance companies. Therefore, there are 423 member companies in the U.S. and Canada whose primary business is insurance. The 423 members of LOMA in the U.S. and Canada account for 94% of the total premium income and 96% of company assets of all insurance companies in the two countries.

The sample for this dissertation consisted of all companies in the U.S. and Canada who were members of LOMA and whose primary line of business was insurance. This provided a sample size of 423. From a practical perspective, the sample size was very close to the population size, at least in terms of premium income and company assets.

Choosing a large sample size provided a number of benefits. First, depending on the response rate, the concern with generalizing results from a sample to the population was minimized. It was also likely that a larger sample size would yield more usable responses than a smaller sample would have. This was important since increasing the sample size in statistical analysis increases the probability of being able to determine whether there are statistical differences in the data being evaluated.

Additionally, the topic under study (i.e., real options) was not a familiar subject to most people, even in the academic community. It was expected that the industry respondents would be even less familiar with the subject. Thus many of the potential respondents might not even complete the questionnaire since they were not

familiar with the subject under study. Therefore, making the sample size as large as possible would hopefully improve the total number of responses.

The specific individual inside the company to receive the questionnaire was the chief information officer or equivalent. The chief information officer and his or her personnel are responsible for justifying proposed information technology projects. Many information technology projects provide benefits that are difficult to quantify. A lack of quantifiable benefits puts a project at a disadvantage when it is being compared to projects where the benefits are clearly defined. Any new techniques available, such as real options, that can quantify benefits will improve the chief information officer's ability to get new projects approved. While other top management should also be favorably impacted by improving the ability to quantify the value of new projects, the chief information officer will be affected the most.

Questionnaire Development

This dissertation examined the existing and potential usefulness of real options to value information technology projects in the insurance industry. In this dissertation, the impact of real options was measured qualitatively by asking information technology executives their attitudes on the existing and potential usefulness of real options.

To gather the attitudinal information, a questionnaire was used. This dissertation used a cross-sectional study to evaluate the use of real options. The sample used was examined at a single point in time. A combination of mail and phone questionnaires were used. The initial data gathering was performed using a questionnaire mailed to the respondents. Because of the specific sample used, mailed questionnaires were the only feasible approach. An advantage of mailed questionnaires is that it provides the respondent sufficient time to consider their responses. Also mail

questionnaires tend to reduce biasing errors that result from personal attributes of interviewers. Disadvantages of mail questionnaires include the potential for a low response rate and no control over who fills out the questionnaire. Also, mail questionnaires can not go beyond the questions asked. There is no capability for delving beyond those questions on the questionnaire.

In conjunction with the mailed questionnaire, telephone interviews were also conducted with some of the executives. The mailed questionnaire asked the respondent if he or she would be willing to be contacted to discuss real options in more depth. Those people who indicated in the affirmative were the executives contacted for the telephone interview.

A review of the literature indicated that no previous work had been done in surveying the impact of real options in an industry setting. There were no existing questionnaires available to be used. The questionnaire needed to be developed from scratch. The development of a questionnaire became another objective of the dissertation.

Mail Questionnaire

In the design of the mail questionnaire, a number of trade-offs had to be made. The over-riding design criteria was the relative obscurity of the topic under study. The concept of real options has been around for a very long time, since the term real options just formalizes the flexibility that management has always had to alter decisions as future information becomes available. However, the use of option pricing theory to quantitatively value the worth of real options is relatively recent and knowledge concerning the subject is most likely limited to academics in a small specialty of finance. Therefore the questionnaire had to include sufficient explanations to explain real options.

Additional tradeoffs had to be made concerning the type of questions and the length of the questionnaire. Closed-ended questions are typically easier to answer since the respondent has a known and relatively small number of choices from which to choose. However, closed-ended questions have a limited ability to gather data beyond what is directly asked. Increasing the length of the questionnaire allows additional information to be gathered. Additional questions also provide more opportunities to evaluate the reliability of the questionnaire. Unfortunately, increasing the length of the questionnaire increases the time needed to complete it and thus usually decreases the response rate.

The mail questionnaire was split into four sections. The first section used a combination of closed-ended and open-ended questions to gather information concerning the respondents' familiarity with real options and their existing practices of evaluating information technology projects. The second section was evaluating the existing use of real options. The third and fourth sections were evaluating the potential use of real options. The last three sections used closed-ended questions that are typically easier to answer and analyze.

Section 1 had a series of closed-ended and open-ended questions to gather information in three areas. The first area examined the respondents' existing familiarity with real options and whether they are incorporating the value of the real options in their existing analysis process. The second area is whether their existing analysis techniques captures the costs and benefits associated with an information technology project. Finally, the respondent was asked whether he or she could be contacted by telephone to further discuss real options in more detail. Respondents who answered "yes" to this question were contacted by phone for further discussion.

Sections 2 and 3 used semantic differential scales to record the respondents' answer. The semantic differential scales had seven possible values that could be selected. The value of seven was chosen for several reasons. First, using an odd number provided for a clearly defined middle, or neutral, value. Second, seven possible values provided respondents sufficient range to differentiate their responses that would not have been possible if there were only three possible responses. On the other hand, seven possible responses was a small enough number of choices so that different values had different implications.

Section 2 evaluated the present use of real options in the respondent's company. The respondent was asked to indicate his or her agreement or disagreement with six statements asking whether he or she presently included the value associated with the six types of real options in the evaluation process. The results from this section were used to answer the fifth research question.

Section 3 was designed to evaluate the impact that each of the six real options had on each of the four types of information technology projects. The results from this section were used to evaluate the first, second, and fourth research questions. These questions were related to the potential of real options to assist in the information technology valuation process. They were not evaluating the respondent's existing usage of real options.

Section 4 was designed to evaluate the impact of interacting real options. The results were used to evaluate the third research question. Many projects have more than one real option applicable. This section was attempting to determine which real options fit together and which real options didn't. The design of this section was a compromise between not evaluating the impact of interacting options at all and evaluating the interactions between the fifteen possible combinations (six items taken

two at a time). It was unlikely that the respondent would be able to provide significant responses on all fifteen possibilities. It would also have increased the length of the questionnaire. Therefore, this section was asking the respondent to identify only those option pairs that were significant because of either positive or negative interaction effects. This section was evaluating the interaction effect between two real options. While there may be interactions between three or more real options, trying to test for such interactions would complicate the process dramatically and was left for further research. The results from this section were used to answer the third research question.

Validity, reliability, and response bias

When developing a mail questionnaire, a great deal of effort must be made to ensure that problems due to validity, reliability, and response bias are minimized. This section will discuss what steps were taken in the development and implementation of the mail questionnaire to minimize any problems.

The content validity of the mail questionnaire was determined by the subjective judgment of the people involved in the process. The mail questionnaire underwent review by three different groups before full scale use. The first group was the doctoral committee. The second group was members of LOMA involved with researching information technology in the insurance industry. Both groups understood the objectives of this dissertation and were familiar with questionnaire development.

After the questionnaire had been reviewed by both groups, a pilot study using the questionnaire was performed using a subset of LOMA's member companies. The pilot sample received the pilot questionnaire and the pilot survey cover letter. The respondents were asked to review the questionnaire to ensure that:

- All terms are clearly defined.
- All the questions and statements are clearly stated.
- The types of questions asked correspond to the purpose of the questionnaire as stated in the cover letter.

Additionally, the respondents were asked to complete the questionnaire to the best of their ability. These responses were reviewed and the questionnaire modified as required.

Appendix 2 reviews the pilot questionnaire developed along with the results of the pilot questionnaire. The appendix also discusses changes that were made in the final questionnaire based upon feedback from the pilot questionnaire.

Empirical validity compares the result of the questionnaire to a standard. This dissertation was the first to examine the use of real options in industry from a conceptual perspective. Therefore there were no standards against which the use of real options could be compared. The same problem exists for construct validity.

Reliability is often used as a surrogate measure for validity. The reliability of the questionnaire could be directly determined and expressed quantitatively. Cronbach's Alpha analysis was performed on the results of both sections 2 and 3. The purpose of Cronbach's Alpha is to test the reliability of the respondent data. It does so by testing the correlation of each of the questions with one another. Using this test, the impact each question has on the total reliability can be evaluated along with the impact that removing the question from the questionnaire will have on the reliability. The Cronbach's Alpha result should be at least .70 for the instrument to be considered reliable (Rummel 1970).

The final concern that development of this questionnaire addresses was potential problems with response bias. The questionnaire was handled on a strictly confidential basis with only aggregate data being released. Since responses were

confidential, this reduced the potential motivation to write down the expected answer rather than the actual answer. Furthermore, the questionnaire was being distributed in cooperation with an agency that respondents are familiar with — LOMA. LOMA is funded by the respondents' companies and the respondents use information supplied by LOMA for analysis and planning. Therefore, they are already comfortable with LOMA, and in the past, had an "enlightened self-interest" in ensuring the data they provided, and eventually received in another form, was correct.

Additionally, the cover letter attached to the questionnaire identified the purpose of this research and how this research would benefit the respondents. The cover letter also clearly identified LOMA's involvement and was signed by LOMA personnel. The procedure used to distribute the pilot and final questionnaire is detailed in Appendix 1.

Telephone Interview

One of the questions on the mail questionnaire asked the respondent if he or she would be willing to be contacted by telephone to discuss real options in more detail. For those respondents who answered "yes", a letter was sent to them indicating that they would be contacted. The letter, shown in Appendix 9, provided the respondents with the types of information to be gathered in the telephone discussion. This allowed the respondent to consider his or her answers.

The telephone interviews were performed after the questionnaires were returned. The general direction of the conversation was based upon review of the mail questionnaires. Therefore, a discussion of the telephone interview's purpose, along with the results of the interviews, will be covered in the research findings chapter.

Hypotheses Evaluation Approach

This section details the techniques that were used to analyze the data obtained from the questionnaire. The results from the analysis were used to answer each of the research questions posed previously. All data analysis was performed using SPSS version 6.1.1 for the Macintosh. A 95% confidence level was used for all statistical analysis to determine whether the null hypothesis was either rejected or could not be rejected.

Research Question 1

The first research question to be evaluated was whether there was a relationship between the importance of being able to quantitatively value real options and the type of information technology project. The null hypothesis, H_0, that was tested was: The value of real options is not related to the type of an information technology project. The research hypothesis, H_a, was: The value of real options is related to the type of information technology project. Data obtained from section 3 of the questionnaire was used to answer this question.

A two-way analysis of variance (ANOVA) model was used to analyze the data[2]. The two factors to be studied were the type of information technology project and the type of real option. The type of project had four levels (i.e., strategic, informational, transactional, and threshold). The type of real option had six levels (i.e., defer, staged investments, change scale, abandon, switch use, and grow). The model therefore had a total of twenty-four cells. This model was a "fixed-effect" design since the factors and levels being studied were the only ones in which there was an interest.

An analysis of variance of the data obtained from section 3 was performed. The null hypothesis would be rejected if two conditions were met. First, the mean scores for any two cells in the model had to be statistically different. Second, the two cells must have had different project types applicable to the cell. If either or both of the two conditions were not met, then the null hypothesis would not be rejected.

The second condition was included to prevent the null hypothesis from being rejected by a "false positive" reading. The purpose of this research question was to determine if there were differences between the importance of the four types of information technology projects. Without the second condition, the null hypothesis would be rejected if the scores were different for two types of real options within the same type of information technology project (e.g., differing scores for the option to defer versus the option to abandon for a strategic project). While the scores for the two cells would be statistically different, that would not demonstrate that the importance of one type of information technology project was statistically different than the importance of another type of project.

One method to eliminate the need for the second condition would be to collapse the table from twenty-four cells to four cells by averaging the importance scores together for the six types of real options for a single project type (i.e., average the scores for the six statements for a single project type). However, performing this action could affect the outcome of the analysis and mask the impact of real differences between the four project types. For example, assume that the scores for five of the six real option types were nearly identical for all four project types while the score for the sixth real option was statistically different for different project types. If the table was collapsed down to four cells, then the one dissimilar score would be averaged with the five similar scores for each project type. This averaging process might mask the

statistical differences between project types. To prevent this from occurring, the table was not collapsed and the second condition was included.

Research Question 2

The research question to be evaluated was whether each of the six types of real options were equally important. The null hypothesis, H_0, that was tested was: All of the real options are equally important. The alternate hypothesis, H_a, is: Some of the real options are more important than others. Data obtained from section 3 of the questionnaire was used to answer this question.

Identical to question 1, a two-way analysis of variance model was used to analyze the data obtained from section 3. The null hypothesis was rejected if two conditions were met. First, the mean scores for any two cells in the model had to be statistically different. Second, the two cells must have different real options applicable to the cell. If either or both of the two conditions were not met, then the null hypothesis could not be rejected. The second condition was included for the same logic as in the previous question to prevent statistical differences from being masked by averaging data together.

Research Question 3

The third issue to be examined was whether there were synergistic effects (plus or minus) when more than one real option was examined for information technology projects. The null hypothesis, H_0, that was tested was: None of the real options have a synergistic effect when combined. The research hypothesis, H_a, was: One or more combinations of the real options have a synergistic effect. Data obtained from section 4 of the questionnaire was used to answer this question.

This hypothesis could not be tested directly by statistical methods. Instead, a subjective approach was used to evaluate the hypothesis. The null hypothesis was rejected if ten percent or greater of the respondents indicated the same pair of real options for either a positive or negative interaction.

Research Question 4

Research on this issue examined whether a classification scheme could be generated that linked together similar real option types and project types. The null hypothesis, H_0, that was tested was: A classification scheme can not be generated. The research hypothesis, H_a, was: A classification scheme can be generated. Data obtained from sections 2, 3 and 4 of the questionnaire was used to answer this question.

The issue to be examined was whether the four types of information technology projects and the six types of real options could be collapsed into a smaller set. For example, was the potential of real options to assist in evaluating threshold, transactional and informational projects equivalent? If the answer was "yes", rather than having to build three quantitative models, one model that covers all three cases could be generated. Alternatively, were all six types of real options equally important? If the six types of real options could be collapsed into groups of differing importance then quantitative modeling could concentrate on the most important group first. Thus, the aim of this research question was to reduce the number of potential quantitative models and the number of variables in each model that would need to be developed.

Since there has been minimal work done to generate a classification scheme, exploratory analysis techniques were used to examine the data obtained from the questionnaire. A factor analysis was run on the data from the twenty-four cells in

section 3. The purpose of factor analysis is to reduce a large number of variables to a smaller set of factors that capture the underlying construct of the variables. The results of this analysis were then integrated with the analyses performed on other sections of the questionnaire.

There was no predefined method to generate the classification scheme. At each step in the process, human judgement was used to evaluate the analysis performed and determine the next step. For the purposes of evaluating the hypothesis, the null hypothesis would be rejected if two conditions were met. First, the classification scheme reduced the number of types of information technology projects to less than four or the number of real options to less than six. Second, the classification scheme had to be supported by the statistical analysis. If both conditions were not met, then the null hypothesis could not be rejected.

Research Question 5

The issue to be examined was whether including the value of the real options in the analysis process for an information technology project would improve the organization's overall performance. The null hypothesis, H_0, that was tested was: There is no relationship between the use of real options in the information technology valuation process and an organization's performance. The research hypothesis, H_a, was: There is a positive relationship between the use of real options in the information technology valuation process and an organization's performance. Data obtained from sections 1 and 2 of the questionnaire and A.M. Best's Insurance Reports was used to answer this question.

Three different measures for organizational performance were used. The first was the operating expense ratio. The operating expense ratio is the ratio of total

expenses to total premium income. This ratio captures a company's cost advantages or disadvantages that occur from current operations including the impact of information technology. It is a short term measure of a company's profitability. A lower ratio indicates that the company sets aside a greater portion of each dollar for investor and policyholder benefits. The use of this ratio was consistent with previous studies of the insurance industry (Harris and Katz 1989; Harris and Katz 1991a; Harris and Katz 1991b). This is also one of the primary ratios that A.M. Best Corporation uses to rate an insurance company's profitability (Best's Insurance Reports ... 1995a; Best's Insurance Reports ... 1995b; Technology and Ratings 1994).

The second performance measure was the company's return on equity which is a value commonly used to evaluate performance. The third measure was the company's Best rating. A. M. Best was incorporated in 1899 and was the first agency to evaluate the financial condition of insurance companies. Best's ratings of insurance companies is performed on a quarterly and annual basis. A. M. Best performs both a quantitative and qualitative analysis (Best's Insurance Reports ... 1995a; Best's Insurance Reports ... 1995b; Technology and Ratings 1994). For quantitative analysis, A. M. Best examines over one hundred and twenty financial tests and supporting data. In the qualitative analysis, Best looks at the organizations' spread of risk, reinsurance program, quality and diversification of assets, and management's experience among other factors. Best's rating is an amalgamation of all their analysis efforts.

Data from sections 1 and 2 of the questionnaire was used to quantify the company's existing use of real options. From section 1, data from questions 2a and 4b was included in the analysis. Question 2a asks in what percentage of projects did real options make the difference between approval and disapproval. Question 4b asks what

percentage of the projects are approved even with a negative net present value. Projects that are approved even with a negative net present value indicate that the project has the potential (i.e., real option) to benefit the organization even though existing quantitative analysis does not support this position. From section 2, the average score for each group of real options was calculated.

A multiple regression model was used to evaluate the hypothesis. The null hypothesis was rejected if there was a relationship between the independent and dependent variables with a 95% confidence level. The null hypothesis would not be rejected if there was a non-statistically significant relationship between the independent and dependent variables.

Evaluation of Data Analysis Approach

An evaluation of the data analysis approach in this section was performed. There were two goals in performing this evaluation. The first was to ensure that SPSS had the functionality to evaluate the data and provide the types of analyses required. The second, and more important, goal was to ensure that the methodology described could discriminate between rejecting or failing to reject the null hypothesis for each research question.

The first step in evaluating the methodology was to generate test data for each question or statement on the pilot questionnaire. The data was generated so that the null hypothesis would be rejected for all the research questions. The data was also generated so that the expected results would occur based upon the review of the literature.

The data was created using Microsoft Excel for the Macintosh. The desired mean score for each question or statement was identified and then Excel's "random"

function was used to provide variation around the mean score. The data from two hundred respondents was generated.

The data in Excel was then transferred to SPSS 6.1.1 for the Macintosh. Using SPSS, the different types of statistical analyses required were performed. These analyses included general descriptive data (i.e., mean and standard devation); analysis of variance, both ANOVA and MANOVA; cluster analysis; factor analysis, and multiple regression models.

In all the cases, the null hypothesis was rejected indicating that the methodology detailed above will allow the research questions to be evaluated. The analyses were repeated with different simulated data. In some circumstances, depending on the data, the null hypotheses were not rejected.

This evaluation showed that SPSS did have the required functionality to perform all of the analyses required. More importantly, the methodology detailed did provide the ability to discriminate between rejecting or failing to reject the null hypotheses depending on the data.

Notes:

[1] LOMA is based in Atlanta, Georgia.

[2] Even though the majority of data collected by the questionnaire is ordinal data, statistical analysis was performed using techniques for higher-order data (i.e., interval data). Work by Labovitz (1970) and Bollen and Barb (1981) has shown that with at least five categories in an ordinal scale, interval data analysis techniques are appropropriate.

CHAPTER IV
RESEARCH FINDINGS

The data obtained by the use of the mail questionnaire and telephone interviews is examined in this chapter. The results discussed in this chapter are objective in nature and no discussions of the data results are provided. This chapter will be split into eight sections. The first four sections will look at the results obtained from analyzing the data on the returned mail questionnaires. The next section will analyze the relationship, if any, between the results on the questionnaire and an organization's performance. The next section will detail the development of a framework that ties together different types of real options and information technology projects. The seventh section will review the results obtained from the telephone interviews. The last section will review the data analysis results in terms of the specific hypotheses evaluated in this dissertation.

A total of fifty-one questionnaires were returned. Of the fifty-one questionnaires, five were returned as part of the pilot study with the remaining forty-six returned in the general mailings. This corresponds to a 12.1% response rate (i.e., 51 out of 423). LOMA also received a small number of calls (approximately ten) concerning the questionnaire. The calls were evenly split into two categories. The first category of people indicated that he or she did not know enough about real options to feel comfortable answering the questionnaire. The second category indicated that real options appeared to have no value to them and completing the questionnaire would be a waste of time.

Of the fifty-one questionnaires returned, twenty-four of the respondents indicated that their names and company identification could be released to this author. Eleven of the twenty-four respondents indicated a willingness to be contacted by telephone. Of the twenty-seven who wished to remain anonymous from this author, two did not fill out any identifying information so they are completely anonymous.

Open-Ended Questions Results

This section examines the data obtained from the first section of the questionnaire. The first section used a combination of closed-ended and open-ended questions to gather information concerning the respondents' familiarity with real options and their existing practices of evaluating information technology projects.

This work is a benchmark study of industry's use and perception of real options. There was a concern that condensing and categorizing the responses to the open-ended questions might result in a loss of valuable information. Therefore, only minimal collapsing of respondents' comments was performed. This collapsing process was only used when multiple respondents used nearly identical wording. A discussion of the implications of this data is provided in the following chapter.

The following tables summarize the responses obtained in the first section of the questionnaire. The only question not summarized here was question 5. Question 5 asked the respondents if they could be contacted by phone for further follow-up. The responses to this question and the telephone follow-ups are covered later on.

Table 2: Ever heard of the term "real options"

Have you ever heard of the term real options before?		
No	Yes	Missing
Percent (Number)	Percent (Number)	Percent (Number)
86.3% (44)	11.8% (6)	2.0% (1)

What term do you use, if any?

- Cost-benefit analysis (four respondents)
- Creeping commitment
- Flexibility (four respondents)
- Project prioritization/resource management (two respondents)
- Phased projects; qualitative and quantitative benefits
- Opportunity costing (two respondents)
- Opportunity to change action without loss
- Structured analysis
- Fictitious dollars
- Making the best decision with then current information
- Reacting to change
- Timing options

Table 3: Real options impact on projects

Did the value of the real options, either qualitative or quantitative, ever make a difference between approval or disapproval of a project?		
No	Yes	Missing
Percent (Number)	Percent (Number)	Percent (Number)
35.3% (18)	58.8% (30)	5.9% (3)
If real options did make a difference, in what percentage of projects did they make a difference?		
Project Type	Mean	Standard Deviation
Threshold	16.3%	22.2%
Transactional	38.3%	32.3%
Informational	44.8%	36.1%
Strategic	57.0%	34.5%

Table 4: How are real options are being treated

How are you presently handling real options?				
No treatment	Qualitatively	Quantitatively	Both	Missing
% (Number)	% (Number)	% (Number)	% (Number)	% (Number)
21.6% (11)	29.4% (15)	9.8% (5)	29.4% (15)	9.8% (5)

If qualitatively, how do you treat the value?

- Budget adjusted accordingly.
- Competitive Analysis - It often adds weight to the "soft" benefits to be able to point out other companies in our industry who are moving in the same direction.
- Creating subjective values and using cash flow analysis, economic analysis, etc.
- Customer service impact.
- Gather intelligence from key decision makers and subjectively determine weight of that input relative to total decision process.
- Have primary users of system rank on scale 1-10 (1 low) impact on qualitative measure. High ranking can sway project to a "go" basis in determining resource allocation and project priority.
- In text as part of the narrative justification.
- Initial review of alternatives to insure any proposed alternative has desired flexibility.
- Justification is subjective sometimes. Dollar value is not the issue.
- Keep as qualitative and is added to support the quantitative benefits.
- Look at resources required for the project and the project's priority versus other projects. To the extent we can defer, stage, scale, grow - impacts decision on project's value.
- New Product Development - hypothetical projection of future sales vs. cost of implementation.
- Projects are re-estimated at each stage and approved/denied prior to starting next stage.
- Projects are small scale. Cost of projects is relatively small so value of real optons is not that important.
- Risk analysis incorporates internal and external factor and methods to control exposure.
- Seat of pants.
- Though Cost/Benefit is important, the emphasis is on developing *quality* products with customer satisfaction.
- Use to get a sense of dynamics of project. Judgement based on cash flows.
- Use weighting method.
- Varies by project but is based on intuition.
- We do not calculate a figure representing the value of the option. We just document the flexibility these options give us and the impact on risks.
- We do some qualitative work w/various options but the answer is closer to "neither". The value is purely subjective in a "soft" Cost Benefit Analysis.

Table 4 — Continued

• We don't. We just want to know in advance, the options we would have. • We try to anticipate whether the technologies will be needed to compete effectively in our market place. • We use qualitative values of business input and strategic fit to ensure that we have the qualitative side covered. • With words.
If quantitatively, how do you treat the value? • "Real Option to Abandon" would be covered partially in the cost benefit analysis using value of the equipment at the end of the project period. • Benefits and functions are re-stated as each stage of the project is completed. • Business case preparation. • Cost benefit analysis on larger projects. Return on investment. • Discounted cash flow. • Estimate cost of the new technologies or systems and the dollar payback we expect to realize. • I always project growth based upon input from business partners - include milestones for reassessment - strive for standards-based solutions vis-a-vis product-based. • Identify benefits, reducing all to tangible values and measure those vs. the cost to build and maintain over life of the product. • Internal operations impact. • Internal Rate of Return. • Most frequently, initiatives are staged or phased with a form of cost/benefit analysis done at the end of each stage. • Our cost revenue analysis usually determine resources and how we will generally solve the problem so we have a costed out approach. • Pretty much along the lines that you have outlined: Defer, Stage, Change scale, Abandon, Switch & Grow. We use them all where it make sense. • Seat of pants. • Structured analysis with alternate cost benefit analyses. • Traditional cost benefit approach evaluating benefits. • Try to convert quantitative definition to dollars. • Use of formal mathematical models has not been adopted. Would be beneficial to do so if they existed. • We have taken many of the concepts you describe into consideration in building our systems architecture but don't assign a value to options per se, although we do evaluate opportunity costs.

Table 5: Accept projects with negative net present value

Do you accept projects even when the quantifiable costs outweigh the quantifiable benefits (i.e., negative net present value)?		
No	Yes	Missing
Percent (Number)	Percent (Number)	Percent (Number)
23.5% (12)	74.5% (38)	2.0% (1)
	Mean	Standard Deviation
What percentage?	22.5%	18.2%

What are the reasons given?

- Strategic/competitive advantage. (11 responses)
- Competitor's actions. (6 responses)
- Required by state or federal regulations. (16 responses)
- Customer Service. (3 responses)
- Required to stay in business. (5 responses)
- "Window of Opportunity"; "Infrastructure".
- Company has to in order to maintain the field force.
- Have to do it to be able to do something else of greater value to organization.
- Productivity improvement.
- Upper management directive.
- Difficulty in quantifying benefits. Strong belief by executive management that true ROI exceeds our hurdles.
- Either difficult to quantify the benefits or the project is determined to be strategic.
- Inability to assess value of intangible benefits. In decision making, management uses experience and intuition to make the final decision on hard to quantify situations. Most often in strategic or threshold projects.
- Intangible benefits.
- Many projects don't require a strong dollar case if they fit a strategic direction.
- Market conditions. Soft benefits.
- May be threshold activity or part of a larger initiative.
- Product positioning, intangible benefits.
- Regulatory requirements.
- Senior management wants automation to reduce staff, even if current data processing costs outweigh savings.
- Typically done in the case of threshold projects, rationalized as the cost of doing business.
- Very, very seldom. Perception of quality service.
- Want to get into this technology because this is where to be.
- We want to be a leader in automation and that will sometimes over ride the lack of cost benefit.
- When we believe the nonquantifiable benefits justify the cost.

Table 6: Comments on real options

Any comments concerning real options?
• Concern is difficulty in applying concept effectively. Valuation issues. Training issues. • I agree that traditional accounting methods used to develop cost/benefit analysis should be changed. However, I prefer activity based accounting concepts at this point. This method appears to be simple, however. • I do not see the applicability of real option to switch. • I have attended some seminars which discuss this concept by other names. Quantifying the value of options is an interesting exercise, but we don't use it explicitly in our shop. Our "real option" discussions are implicit part of all business discussions. • I hope my reply is useful. I believe that we match to this behaviour model as a normal way of conducting business. I can see the value in bringing some formality to an intuitive process so it would help to strengthen my/our competence when using it. • I use as many of the options as I can to mitigate risk for the company - the more risk - the more I try to anticipate alternatives for defer, staged, abandon & switch. I also plan for success - which is growth & Standards (Switch). • I would say that we don't cover the benefits in the cost-benefit analysis. We seem to talk about the options as we talk with project sponsors about project scope and timing. Staged investment called Phased implementation. Change scale called scalable implementation. • In my opinion, too much time and effort is expended to define and analyze something like this. Whether or not mathematical models are used, the fact that dollars are attributed to something so difficult to measure is the direct result of assumptions and opinions of those doing the measuring. This will differ to a large degree just based on the individuals and personalities involved. Due to this high reliance on these "human" factors, any results must be inherently suspect. Manipulation of the numbers is a relatively easy chore. • It sounds interesting & useful. I'd like to learn more about the results of this research. • Many, many examples of real options in the insurance industry would have to be described clearly for the concept to be understood well enough to use for analysis. • Real Options could be of value if incorporated as part of the cost/benefit analysis and updated during the development process. • Some of it really doesn't sync. Ex. Staged investment - in any project you are always checking to see environment justifies continuation of the project. System Development Life Cycle does exactly this - justify step 1 before you proceed to step 2. "Real Option to Grow" - You would evaluate future potential growth in any project, discounting that value back to current costs. I don't see anything new here. • The concept looks useful, but not for us at this time.

Table 6 — Continued

Any comments concerning real options?
• The term real options is not currently in use at our company. The responses to this survey reflect practices in place which, to some extent, correspond to the real options definitions provided. • These are common questions frequently asked in discussing a new project. A more structured approach to these issues would be a valuable service. • These options would have to be easily calculated and maintained for the industry to use them. • This appears to be a structured view of what most companies do at one time or another on various initiatives • This is an academic waste of time. If the boss says do it, you do it. Heck with the cost. What would you do with the Real Value for Abandon? If you spent $500,000 on a project and then abandoned it, and the Real Value for Abandon was $100,000, does this mean you only lost $400,000? Bull! • This is a real issue, so you are on to something. I am intrigued by the idea. I wonder, however, if it places too much emphasis on the technical vs. business aspect of a project. • We feel that they are crucial to having a planned approach to getting the projects done when, how, and if they need to get done and to also be working on uses that provide the best "value" for the cost. • We have had so many theories espoused that everyone has grown weary of them. Whatever is used needs to be readily embraced by our business partners - otherwise it is a waste. And they seem to have a habit of only accepting those things which easily apply to their business, not a technology solution or slant. • What you have defined and are studying is only one of many technology risks of managing change during project activity: i.e., will things change and what are our options if this occurs. If you use this you should develop a matrix of both internal and external "risk" forces and determine if they are controlled or uncontrolled to the project scope and management.

Existing Use of Real Options Results

Section 2 of the questionnaire gathered information relating to the respondents' existing use of real options. The final questionnaire directly asked the respondents for their opinions on whether they are currently incorporating the value of the real options in their existing cost-benefit analysis process. The pilot questionnaire collected this same type of data using an indirect approach. The respondents were presented with twenty-four statements relating to existing practices in their organization. Each statement was designed to evaluate the respondent's existing use of the concepts that form the foundation of real options. An evaluation to determine whether the twenty-four statements mapped to the six types of real options as listed in Table 13 was not performed because of the small number of pilot questionnaires returned.

Since two different approaches were used to gather the data, only the data from the final questionnaire was used in this section. While this decreased the number of potential data points, it ensured that the respondents' answers were based upon the same conceptual framework. A review of the data was performed and found no obvious problems with the respondents' answers.

An analysis of variance was performed using the data to determine whether the six types of real options were equally important to the respondents. The analysis, shown in Table 7, indicated that not all of the real options were equally important. A Bonferroni analysis indicated that the score for the option for staged investment was statistically above the scores for the options to abandon and switch. Figure 8 is an error bar chart displaying the mean scores and standard deviations associated with each of the six types of real options. The box at the center of the vertical lines indicates the mean score. The horizontal lines at the top and bottom of the vertical lines bracket the 95% confidence interval.

Table 7: Analysis of variance of existing use of real options

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	5	61.7576	12.3515	3.7724	.0026
Within Groups	258	844.7273	3.2741		
Total	263	906.4848			

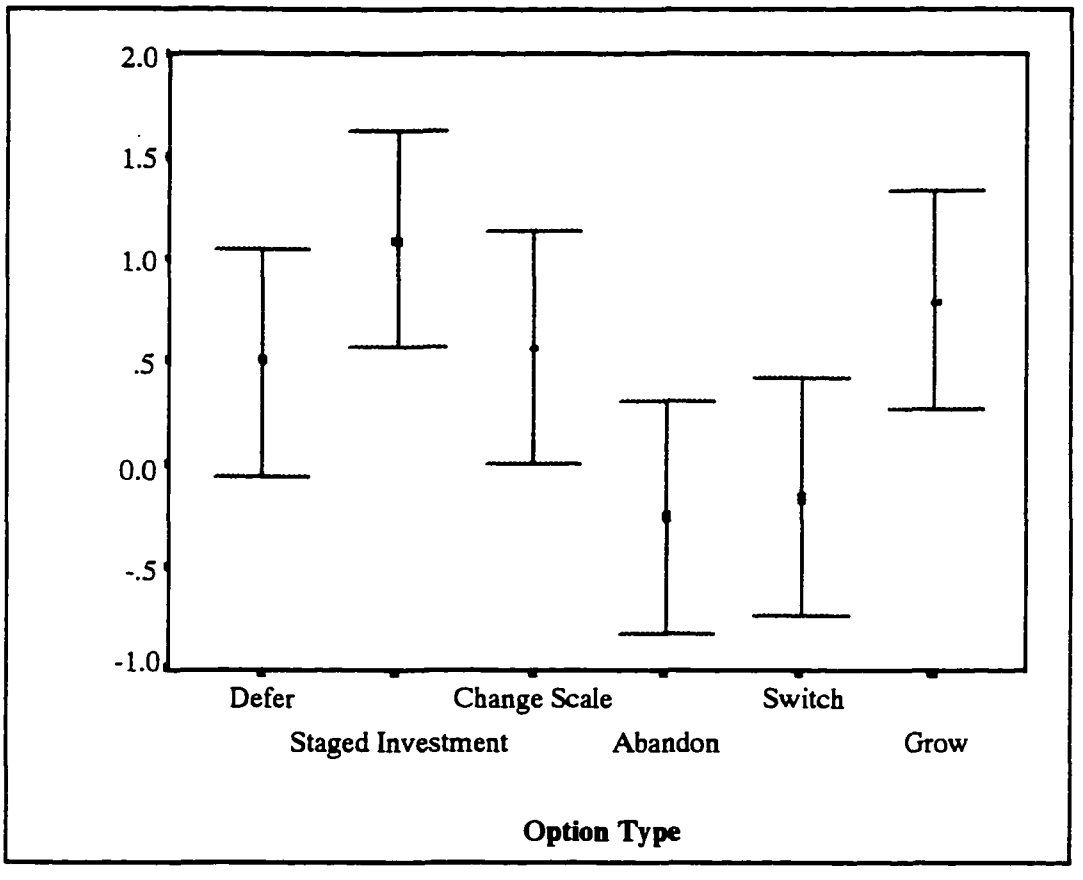


Figure 8: Existing use of real options

The reliability of the data in section 2 was evaluated using Cronbach's Alpha analysis. This analysis evaluates the internal consistency of a test. It is based on the average correlation of items on the test with the items standardized to a standard deviation of 1. This test assumes that all the items on the scale are positively correlated with each other since they are all measuring a common entity. In this case, the six statements in section 2 are evaluating the respondents' existing use of real options. The Cronbach's Alpha analysis yielded a value of 0.8924. A Cronbach's Alpha result of 0.70 or greater indicates that the test instrument is reliable (Rummel 1970).

Potential of Real Options Results

This section gathered the respondents' opinions on how valuable it would be to quantify the real options associated with information technology projects. The opinions were gathered for the six types of real options and the four types of information technology projects. The section was written so that the respondent provided his or her opinion on each of the four information technology project types for each of the six types of real options. Both the pilot questionnaire and the final questionnaire had the same arrangement so the data analysis in this section used the combined data.

Before analysis was performed, an evaluation was performed to determine if the respondents were carefully considering their responses. This was done by manually reviewing the respondents' answers to see if any unusual trends were found. In five of the questionnaires, the data appeared suspect. The respondents circled "-3" for all of the entries in the section. In the qualitative section, some of these respondents indicated that real options were "a waste of time" or "cost benefit analysis was useless". Leaving this data in the analysis would skew the overall analysis and might cause meaningful results from the other respondents to be missed. To prevent this from occurring, the analysis was run with both the complete set of data and an edited set of data. Except as noted, the overall results were the same. The analyses shown in the tables and figures in this section are based upon the edited data.

The first analysis performed was a two-way analysis of variance. Table 8 shows the results of the analysis. First, the analysis showed that the type of option and the type of project did not interact with one another. Therefore, the value of being able to quantify any individual real option is not dependent on the type of project, and vice-versa. Since the two variables did not interact, the variables may be examined separately. The analysis also showed that there were differences between different

types of real options and different types of projects. Figure 9 shows an error bar chart[1] that summarizes the section 3 data. The reliability of the data in section 3 was also evaluated using Cronbach's Alpha analysis. The Cronbach's Alpha analysis yielded a value of 0.9709.

Table 8: Analysis of variance of potential use of real options

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+ RESIDUAL	2347.69	1040	2.26		
OPTION	59.96	5	11.99	5.31	.000
PROJECT	414.52	3	138.17	61.21	.000
OPTION BY PROJECT	32.89	15	2.19	.97	.484
(Model)	509.43	23	22.15	9.81	.000
(Total)	2857.12	1063	2.69		

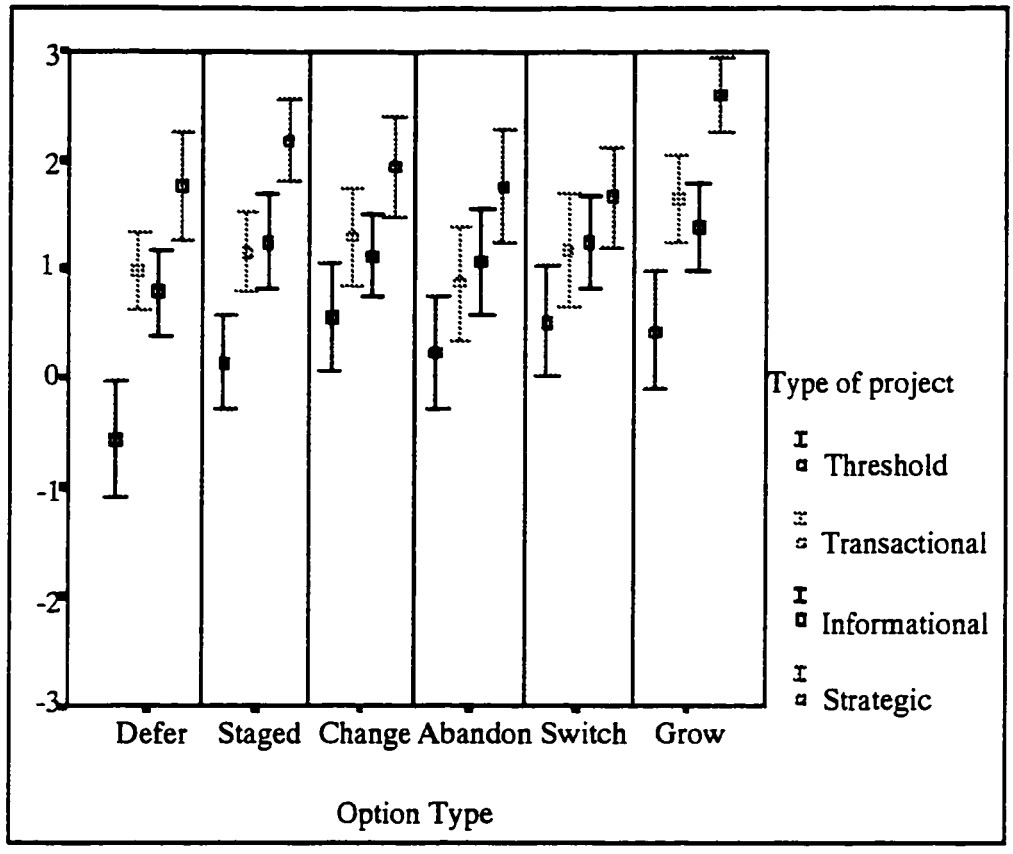


Figure 9: Potential value of real options

Since the type of option and the type of project did not interact, two Bonferroni analyses were performed to determine individual differences. Looking at the types of real options, the analysis found that the score for the option to grow was statistically greater than the scores for the option to defer and the option to abandon. When the same analysis was performed using all of the available data, the option to grow was statistically greater than the option to defer only. Figure 10 shows an error bar chart of the data for the different types of real options. Looking at the types of projects, the score for threshold projects was statistically lower than the score for the other three

project types. On the other hand, the score for strategic projects was statistically above the other three project types. Figure 11 shows the differences in project types.

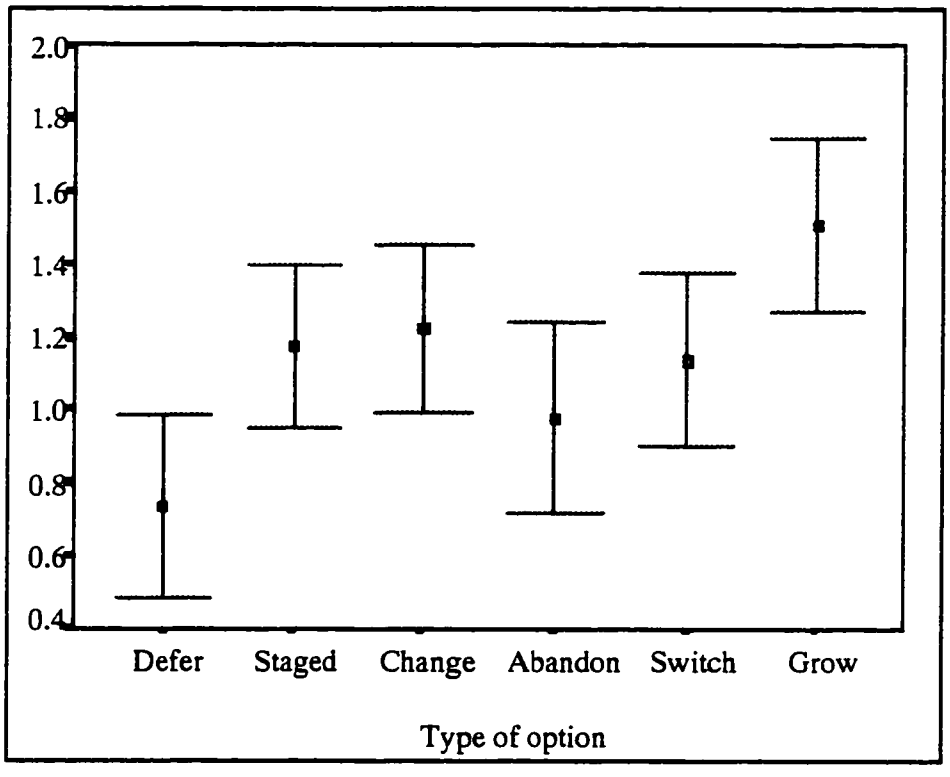


Figure 10: Potential value of the different types of real options

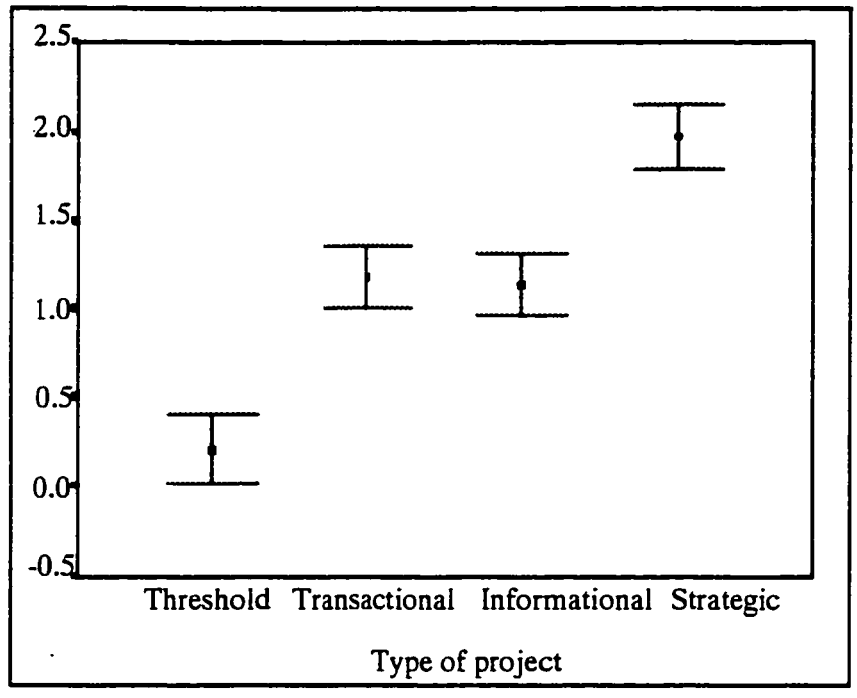


Figure 11: Potential value of real options on different types of information technology projects

As these results are examined, remember that the purpose of this dissertation is only to determine whether some types of real options and information technology projects may benefit from quantifying the flexibility associated with a project. The scores reported are only the opinions of the respondents, not that intrinsic value of a type of project or option. For example, the analysis indicated that the respondents feel that being able to quantify the flexibility associated with a strategic project would be more useful to them than valuing the flexibility associated with other types of projects. The analysis did not show, nor attempt to show, that the dollar value associated with the flexibility of a strategic project is greater than a threshold project.

Option Pair Synergy Results

This section looked at pairs of real options. Specifically, it attempted to determine whether there were any synergistic effects (plus or minus) when more than one real option was examined for information technology projects. This was an investigation as to whether certain of the six real options linked to provide benefits either greater or less than the sum of the individual options' benefits. Since the pilot and final questionnaire used the same format for this section, the data from both returns was combined.

Each respondent could indicate which options pairs either did or did not fit together. There were no set requirements for the number of pairs to provide. In some cases, a respondent did not provide any pairs while in one case, a respondent provided five pairs of options that he or she felt belonged together. There was a total of seventy-one responses for option pairs that fit together and twenty-five responses for option pairs that did not fit together. Table 9, Figure 12 and Figure 13 detail the results of this analysis. In Table 9, the percentages shown are based upon a total of fifty-one respondents. The criteria for rejecting or failing to reject the null hypothesis is based upon the percentage of respondents who choose specific option pairs, not the percentage based upon the total number of responses. The percentages will not total to 100% but rather 139.2% (i.e., 71/51) for the option pairs that fit together and 49.0% (i.e., 25/51) for the option pairs that did not fit together.

Table 9: Option pair synergy

Option Pair	Options	Fit together % (Number)	Not fit together % (Number)
1	Defer & Staged Investment	11.8% (6)	3.9% (2)
2	Defer & Change Scale	0% (0)	2.0% (1)
3	Defer & Abandon	19.6% (10)	2.0% (1)
4	Defer & Switch	2.0% (1)	3.9% (2)
5	Defer & Grow	5.9% (3)	9.8% (5)
6	Staged Investment & Change Scale	13.7% (7)	3.9% (2)
7	Staged Investment & Abandon	19.6% (10)	3.9% (2)
8	Staged Investment & Switch	13.7% (7)	2.0% (1)
9	Staged Investment & Grow	9.8% (5)	2.0% (1)
10	Change Scale & Abandon	0% (0)	2.0% (1)
11	Change Scale & Switch	3.9% (2)	2.0% (1)
12	Change Scale & Grow	29.4% (15)	0% (0)
13	Abandon & Switch	7.8% (4)	2.0% (1)
14	Abandon & Grow	0% (0)	9.8% (5)
15	Switch & Grow	2.0% (1)	0% (0)
—	Total	139.2% (71)	49.0% (25)

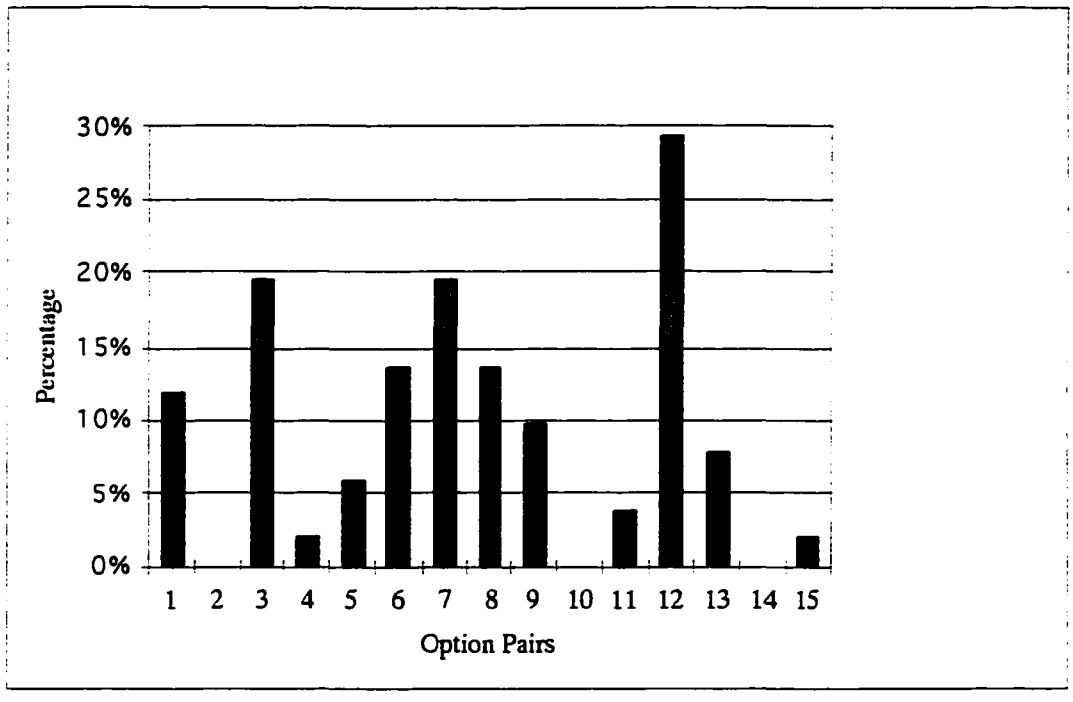


Figure 12: Option pairs that fit together

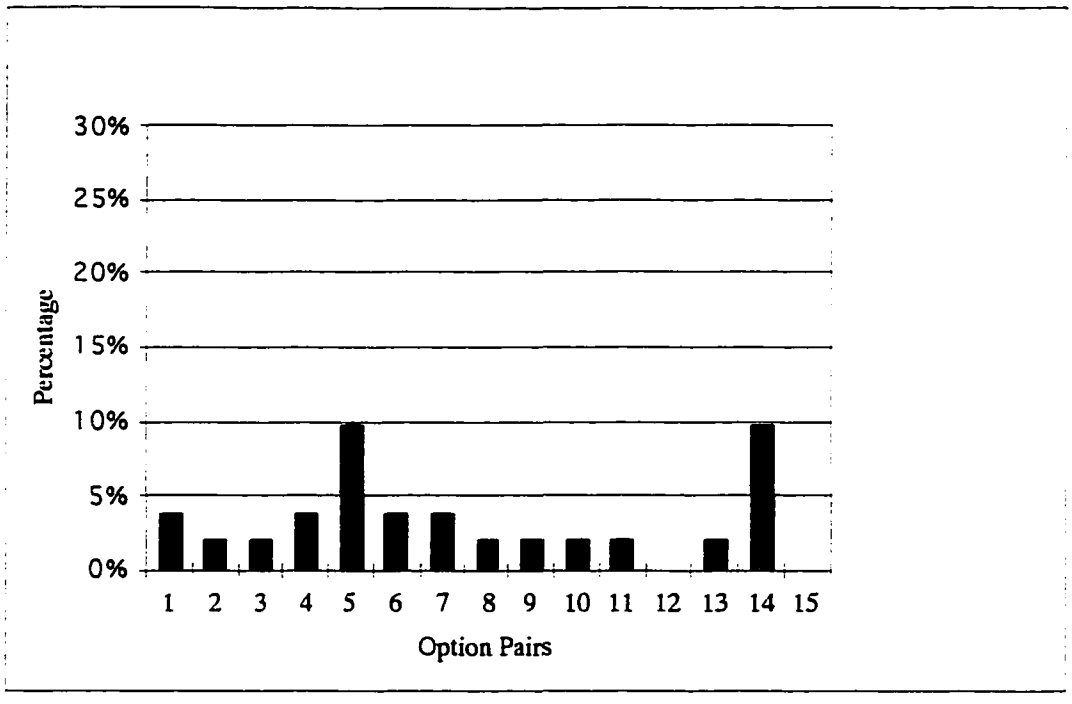


Figure 13: Option pairs that do not fit together

Company Performance Results

One of the research questions that this dissertation was examining was whether there was a relationship between the existing use of real options and an organization's performance. An organization's existing use of real options was measured as a function of responses to all six questions in section 2 of the questionnaire and to questions 2 and 4b from section 1. The organization's performance was measured using three different measures — operating expense ratio, return on equity, and Best's Rating.

Section 2 of the questionnaire asked the respondents to indicate whether they were presently including the value of the six types of real options in their existing cost-benefit analysis process. Question 2 in section 1 evaluated how often the value of real

options made the difference between approving or disapproving a project. Question 4 asked the respondents how often they accepted projects even with a negative net present value. Accepting a project with a negative net present value indicates that some other factors, possibly including the value of the real options, can counteract the negative value. In all these questions, the greater the value, the greater the use of the concepts underlying real options by the organization.

Of the fifty-one companies which responded, performance data was obtained for forty-two companies. For the nine missing companies, two did not provide any identifying information when they returned the questionnaire. The other seven companies were Canadian subsidiaries of U.S. firms. A.M. Best does not typically rate these subsidiaries even though they may operate independently of their U.S. parent. For each of the forty-one respondents, information was compiled relating to their operating expense ratio, return on equity, and Best's rating. One of the companies is under state supervision and does not have an associated operating expense ratio, return on equity value, or financial size. Figure 14 details the organizations' operating expense ratios; a smaller value is better. Figure 15 details the organizations' returns on equity; a larger value is better.

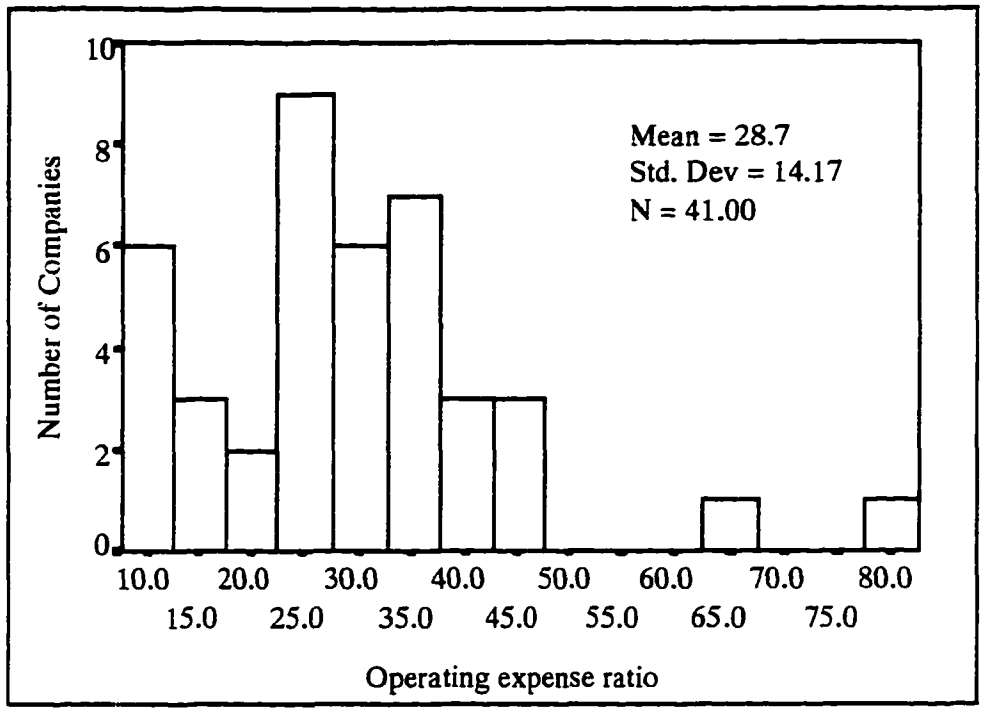


Figure 14: Operating expense histogram

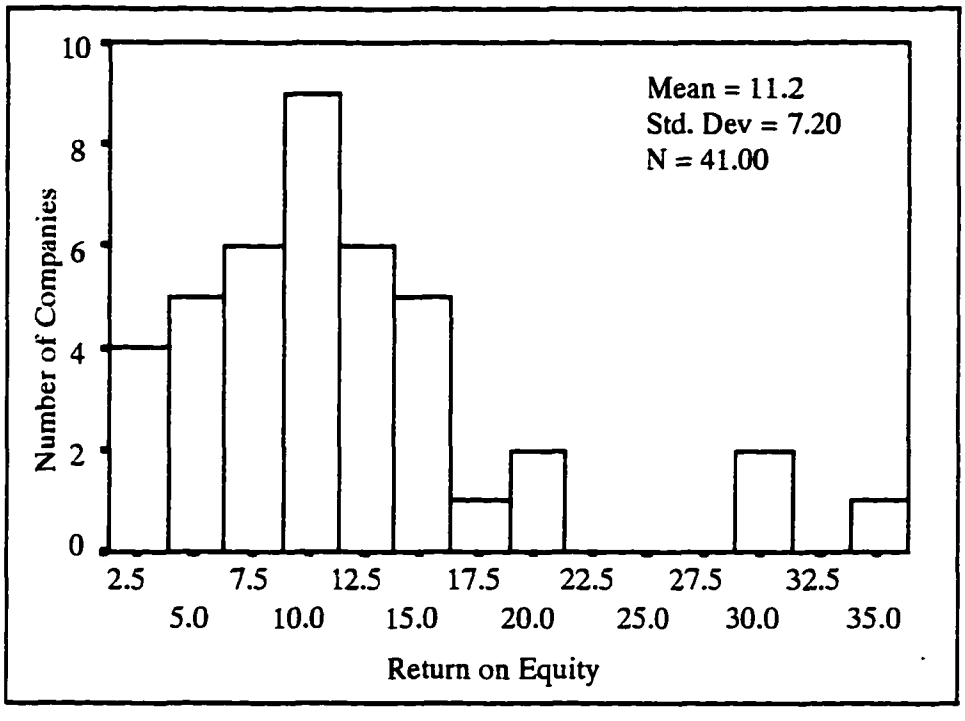


Figure 15: Return on equity histogram

Table 10 and Figure 16 show the breakdown of organizations by Best's rating. The table provides frequency and percentage data for both the respondents of the questionnaire and for all the companies that A. M. Best rates. Since LOMA's membership information was confidential, a breakdown of LOMA members' ratings in the tabular format of Table 10 was not possible. It is highly probable that LOMA's member companies are among the companies that A. M. Best rates and thus included in the table. A large percentage (approximately 48%) of companies are not rated by A. M. Best. These companies are primarily very small and do not need to complete annual statements which are filed with the states. Additionally, some companies are subsidiaries of larger companies and a rating is applied to the parent company only.

Table 10: Company's Best's rating

		Questionnaire's respondents		A. M. Best evaluated companies	
Rating	Category	Frequency	Percent	Frequency	Percent
A++	Superior	8	15.7	36	2.52
A+	Superior	17	33.3	114	7.98
A	Excellent	7	13.7	180	12.60
A-	Excellent	4	7.8	104	7.28
B++	Very Good	1	2.0	51	3.57
B+	Very Good	4	7.8	116	8.12
B	Adequate	0	0	73	5.11
B-	Adequate	0	0	17	1.19
C++	Fair	0	0	11	0.77
C+	Fair	0	0	7	0.49
C	Marginal	0	0	11	0.77
C-	Marginal	0	0	3	0.21
D	Very Vulnerable	0	0	2	0.14
E	Under State Supervision	1	2.0	13	0.91
F	In Liquidation	0	0	5	0.35
Missing		9	17.6	NA	NA
Other		NA	NA	685	47.96
Total		51	100.0	1,428	100.0

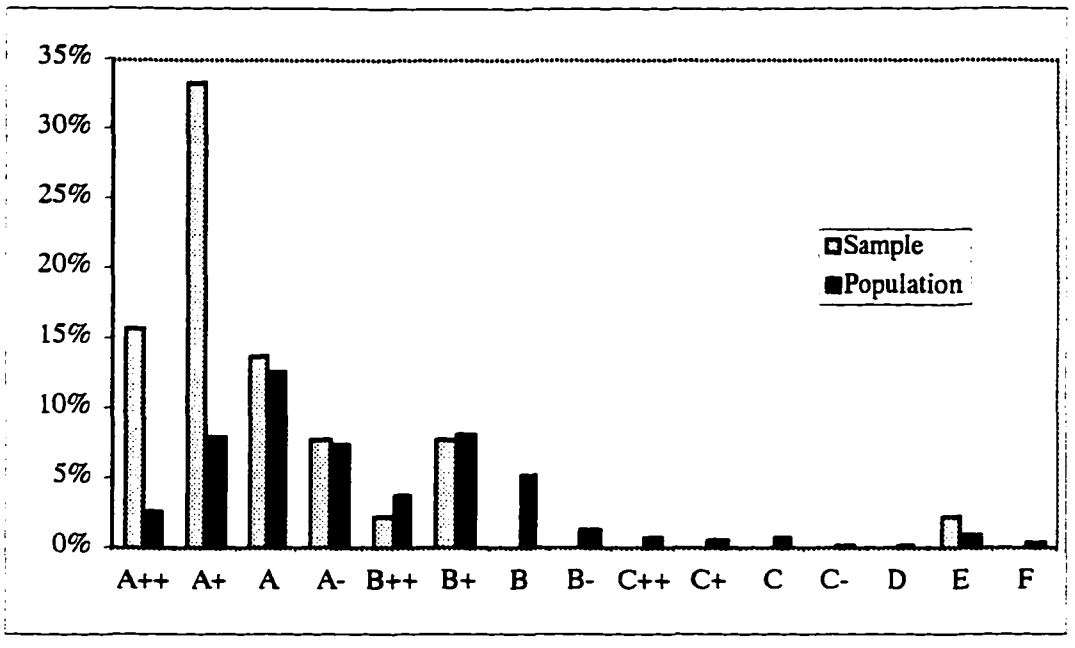


Figure 16: Population and sample Best's rating

Unfortunately there are a number of disadvantages associated with the different performance measures which limits their usefulness. These disadvantages can make direct comparison of performance information between organizations invalid.

The first factor which can affect an organization's numbers is the product mix of insurance that it handles. For example, an organization involved in dental insurance typically has a large number of comparatively low price claims. This will drive up the expenses associated with processing the claims compared to an organization that does not have much dental business. Some companies also provide administrative services for self-insured companies. In these cases, a company provides medical insurance to its employees directly. The company then hires an insurance company to handle all the paperwork associated with medical claims. In these cases, the insurance company has no liability in potential medical claims. Theoretically, the insurance company's return

on investment is nearly infinity since they are making money for very little investment. Therefore, insurance companies' mix of products and services can affect their performance ratios. Additionally, different types of insurance such as life, health, and property will have different regulations and requirements associated with surpluses and reserves which will impact the numbers.

The second factor is the type of insurance company. Some insurance companies are "mutual insurance" companies in which the company was formed to provide a service to individual members. These companies are not trying to make a profit but simply meet customer needs. A similar analogy can be made between credit unions and commercial banks.

The third factor is the location of the insurance company. Different states have differing regulations and requirements that the companies must meet. These differences can impact a company's numbers. There are even greater differences in requirements and regulations when comparing insurance companies in the U.S. and Canada. For example, required surpluses on hand can vary from state to state.

Both the operating expense ratio and return on equity measures are impacted by the three factors just discussed. This severely limited their usefulness when trying to compare an organization's existing use of real options with its performance. For these reasons, Best's rating was the most valid surrogate for organizational performance.

A correlation was run between the three performance measures used in this dissertation. Figure 17 is a matrix scatter diagram that combines the results of the correlations onto a single graph. The plot in the top middle of the figure shows the relationship between the operating expense ratio (y axis) versus Best's rating (x axis). The plot in the top right of the figure shows the relationship between the operating expense ratio (y axis) versus return on equity (x axis). The plot in the middle right of

the figure shows the relationship between Best's rating (y axis) versus return on equity (x axis). The numbers in the three plots are the correlation coefficients. The dotted line in each plot indicates what a perfect correlation would look like based on the financial theory. In terms of organizational performance, a lower operating expense ratio is better than a higher value, a lower Best's rating is better than a higher rating[2], and a higher return on equity is better than a lower value.

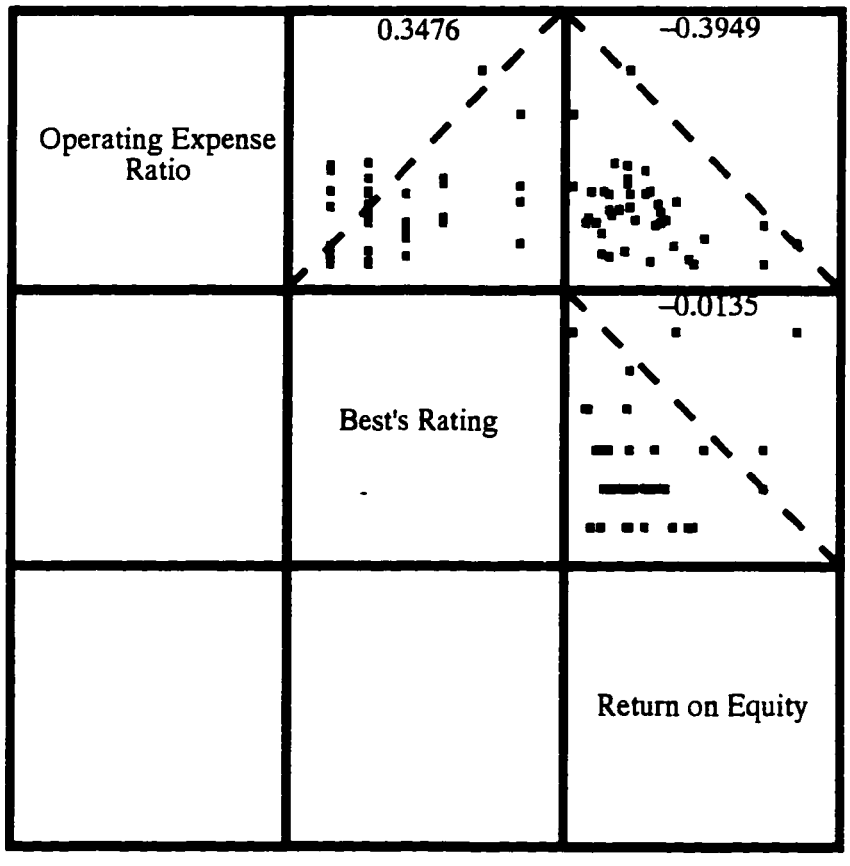


Figure 17: Correlation between organizational performance measures

As can be seen, there is a relatively low correlation between the three different performance measures. This limits the ability to evaluate a correlation between the existing use of real options and an organizations' performance. No valid relationships between an organization's use of real options and performance were found.

In addition, the financial size for each of the companies who responded to the questionnaire was gathered. The financial size of a company is based upon the reported policyholders' surplus plus conditional reserve funds in dollar terms. Those who did respond are generally larger companies[3]. Additionally, there appears to be a positive relationship between a company's size and its Best rating. A correlation of 0.6251 was found. Table 11 and Figure 18 provide a comparison of the size of those companies who filled out the questionnaire and those in the population.

Table 11: Company size

Financial Size (in $000)		Questionnaire's Respondents		A. M. Best evaluated companies	
Label	Class	Frequency	Percent	Frequency	Percent
Up to 1,000	I	1	2.0	190	11.8
1,000 to 2,000	II	0	0.0	160	10.0
2,000 to 5,000	III	0	0.0	232	14.5
5,000 to 10,000	IV	1	2.0	242	15.1
10,000 to 25,000	V	4	7.8	226	14.1
25,000 to 50,000	VI	2	3.9	148	9.2
50,000 to 100,000	VII	1	2.0	131	8.2
100,000 to 250,000	VIII	10	19.6	125	7.8
250,000 to 500,000	IX	12	23.5	68	4.2
500,000 to 750,000	X	2	3.9	22	1.4
750,000 to 1,000,000	XI	1	2.0	21	1.3
1,000,000 to 1,250,000	XII	1	2.0	11	0.7
1,250,000 to 1,500,000	XIII	1	2.0	5	0.3

Table 11 — Continued

Financial Size (in $000)		Questionnaire's Respondents		A. M. Best evaluated companies	
Label	Class	Frequency	Percent	Frequency	Percent
1,500,000 to 2,000,000	XIV	1	2.0	10	0.6
2,000,000 or more	XV	4	7.8	13	0.8
Missing		10	19.6	NA	NA
		-------	-------		
	Total	51	100.0	1,604	100.0

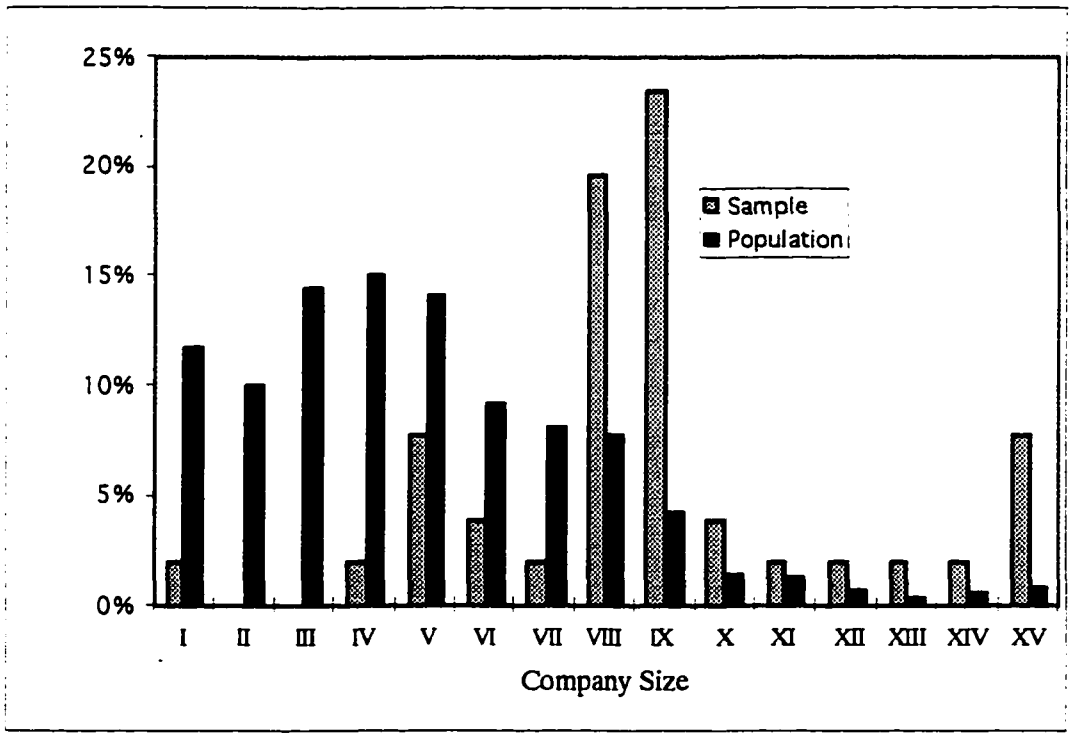


Figure 18: Comparison of population and sample company size

Taxonomy Results

This section examines whether the different types of real options and different types of information technology projects can be combined into some form of general framework. The issue examined was whether a classification scheme could be generated that linked together similar real option types and project types. It attempted to tie together three variables — option type, project type, synergy effects — into a single model.

Factor and cluster analyses were performed on the data from section 3 of the questionnaire. Similar results were found from the two analysis techniques which was not unexpected since the techniques are closely related.

Section 3 provided data for twenty-four cells: the six types of real options by the four types of information technology projects. The factor analysis combined the data into five separate factors. Table 12 shows the results from the factor analysis. The cluster analysis provided no additional data.

Table 12: Factor analysis of project types and real option types

Factor	Factor Score	Type of real option	Type of project
1	.80338	Abandon	Informational
1	.78177	Abandon	Strategic
1	.75903	Abandon	Transactional
1	.64368	Change Scale	Strategic
1	.62654	Change Scale	Informational
1	.61036	Staged Investment	Informational
2	.86889	Switch	Threshold
2	.75993	Grow	Threshold
2	.71400	Switch	Transactional
2	.64757	Change Scale	Threshold
2	.60164	Grow	Transactional
2	.58303	Abandon	Threshold
2	.55737	Grow	Informational
3	.82812	Defer	Strategic
3	.69197	Defer	Informational
3	.69160	Switch	Strategic
3	.64031	Grow	Strategic
3	.62129	Switch	Informational
3	.62027	Staged Investment	Strategic

Table 12 — Continued

Factor	Factor Score	Type of real option	Type of project
4	.80710	Defer	Transactional
4	.79562	Staged Investment	Transactional
4	.63559	Change Scale	Transactional
5	.88185	Defer	Threshold
5	.63222	Staged Investment	Threshold

A review of the results from the factor analysis indicated that while the analysis was able to yield five factors, the composition of the factors did not appear to be meaningful. No patterns were found in the results. The results were not consistent with the two-way analysis of variance performed on the section 3 data. Nor were the results consistent with the results obtained from section 4 of the questionnaire.

Therefore, no general framework can be constructed. Based upon these results, none of the types of real options and types of information technology projects can be combined together.

Telephone Interviews

The questionnaire provided a location where the respondent could indicate whether he or she was willing to be contacted to discuss real options in more detail. A total of eleven respondents indicated a willingness to discuss real options further. A letter was sent to each of these eleven respondents and is shown in Appendix 9.

The objective of this interview was to gather information related to what further research should be performed to assist in the application of real options to evaluating information technology projects. Nine of the respondents were contacted with the other two unavailable after multiple attempts to contact them. In eight cases, the respondents stated that they indicated their willingness to discuss real options in more detail mainly out of politeness rather than because they had additional comments to make. They felt that they did not know enough about real options or how they would fit into evaluating information technology projects to provide any additional information.

There was one meaningful discussion with one of the respondents. In this discussion, the respondent stated that his company accepted information technology projects for one of four specific reasons. First, the project has to provide a true dollar cost reduction. Second, the project has to give a service advantage unique enough and large enough that it is significant in the market. Third, the project has to enable the company to participate in a new or expanded portion of its existing market. A fourth reason was that the project was required in order to meet regulatory requirements. Projects in this fourth category were automatically done with little cost-benefit analysis.

The respondent felt that real options could provide value but the application of real options would have to be simple. The respondent receives information regarding a number of analysis techniques proposed by consultants willing to "assist" the respondent's company with analyzing information technology projects. In most of the cases, the techniques are too complicated and unwieldy to be useful.

The respondent also mentioned that he/she was originally involved in the insurance operations side of the business, not the information systems side. After complaining to the chief executive officer that the information systems department was not supporting him/her, he/she was notified a few days later that a solution had been

found. He/she was put in charge of the information systems department. This gave the respondent a different perspective than most chief information officers. The end result of the discussion was an agreement to keep in touch and the respondent indicated that he/she would be willing to look at further work on real options and evaluate the usefulness of this work from an industry perspective.

Hypotheses Results

The previous sections of this chapter reviewed the results of the data analysis of the questionnaire. This section will take these results and put them in terms of the specific hypotheses posed in this dissertation.

The first issue examined was whether industry executives believed that the value of the embedded options is dependent on the type of the information technology project. The null hypothesis, H_0, that was tested was: The value of real options is not related to the type of an information technology project. The research hypothesis, H_a, was: The value of real options is related to the type of information technology project.

Analysis of the results indicated that there were statistical differences between different types of information technology projects. The null hypothesis was rejected. The value of being able to measure the flexibility associated with a threshold project was statistically less than the other three types of projects. Additionally, the value of being able to measure the flexibility associated with a strategic project was statistically greater than the other three types of projects.

The second issue examined was whether some of the six real options were more important than others when evaluating an information technology project. The null hypothesis, H_0, that was tested was: All of the real options are equally important.

The alternate hypothesis, H_a, was: Some of the real options are more important than others.

Analysis of the results indicated that there were statistical differences between different types of real options. The null hypothesis was rejected. The analysis found that the score for the option to grow was statistically greater than the scores for the option to defer and the option to abandon.

The third issue examined was whether there were any synergy effects (plus or minus) when more than one real option was examined for information technology projects. The null hypothesis, H_0, that was tested was: None of the real options have a synergistic effect when combined. The research hypothesis, H_a, was: One or more combinations of the real options have a synergistic effect. The null hypothesis would be rejected if ten percent or greater of the respondents indicate the same pair of real options for either a positive or negative interaction.

Analysis of the results indicated that certain of the option pairs that fit together did exceed the ten percent hurdle. The null hypothesis was rejected. Looking at option pairs that fit together, the pairs "defer and staged investment", "defer and abandon", "staged investment and change scale", "staged investment and abandon", "staged investment and switch", and "change scale and grow" exceeded ten percent. None of the options pairs that did not fit together exceeded the ten percent hurdle.

The fourth issue examined was whether a classification scheme could be generated that linked together similar real option types and project types. The null hypothesis, H_0, that was tested was: A classification scheme that is statistically valid can not be generated. The research hypothesis, H_a, was: A classification scheme that is statistically valid can be generated.

A meaningful classification scheme was not generated. The null hypothesis could not be rejected.

The fifth issue examined was whether including the value of the real options in the analysis process for an information technology project would improve the organization's overall performance. The null hypothesis, H_0, that was tested was: There is no relationship between the use of real options in the information technology valuation process and an organization's performance. The research hypothesis, H_a, was: There is a positive relationship between the use of real options in the information technology valuation process and an organization's performance.

No statistically significant relationships were found between an organization's existing use of real options and its organizational performance. The null hypothesis could not be rejected.

Notes:

[1] The x-axis of the error bar chart shows the six types of real options or four types of information technology projects. The y-axis shows the score associated. The theoretical score runs from -3 to +3 with -3 indicating that a respondent saw no value in quantifying the dollar value of a particular type of real option while a +3 indicates that a particular option would be extremely valuable if it could be quantified. Inside the chart, the box at the center of the vertical lines indicates the mean score. The horizontal lines at the top and bottom of the vertical lines bracket the 95% confidence interval.

[2] The fact that a lower Best's rating is better than a higher rating is arbitrary and related to how Best's rating was coded. A Best's rating of A++ (best possible rating) was coded with the value "1", a rating of A+ (second highest rating) as a "2" and so on.

[3] As mentioned previously, since LOMA members are anonymous, no comparisons can be made between the respondents and the other LOMA member companies who did not respond. Therefore, all the companies tracked by A. M. Best were used as a surrogate for the LOMA member companies.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

The previous chapter reviewed the results obtained from the mail questionnaires and telephone interviews. In the previous chapter, only objective results were discussed. The purpose of this chapter is to discuss the results obtained. The results will be discussed in terms of their significance and implications for further research.

The results obtained need to be reviewed in terms of the objectives of this dissertation. The objectives of this dissertation were:

- Perform a benchmark study of the existing use of real options to evaluate information technology in the insurance industry.
- Evaluate the potential of real options to assist in valuing information technology.
- Evaluate the different factors that determine how valuable real options are to information technology projects.
- Design and test a survey instrument that can be used to gather the data required to evaluate the other objectives.

This chapter is broken into five sections. The first section examines and evaluates the survey instrument which was developed from scratch to gather the needed information.The next section looks at the results from the questionnaire and telephone interviews. The third section ties together the results and presents an overall description of the existing use of real options. The fourth section provides recommendations for further research. The last section is the conclusion which discusses the results in terms of the original objectives.

Questionnaire Evaluation

One of the objectives of this dissertation was to develop a questionnaire that could be used to gather information related to an organization's existing and potential use of real options. A questionnaire was developed from scratch and used to gather information related to the use of real options. This section evaluates the questionnaire and provides guidance on what types of changes can be made to improve the questionnaire for further research efforts.

Overall the questionnaire worked well in gathering the required information. The questionnaire was straight-forward in the data gathering approach. The respondents were directly asked their opinions concerning the potential and existing value of being able to determine a dollar value associated with real options.

Not only was the questionnaire able to gather the needed data but the data gathered could be easily analyzed. With the exception of the few open-ended questions in the first section, all the data gathered was numeric. Most importantly, the data gathered could be used to answer the research questions posed in this dissertation. The data analysis methodology stated in the dissertation proposal did not have to be modified "after the fact" to answer the research questions.

While the questionnaire accomplished its required tasks, certain changes in the questionnaire may increase its effectiveness. The changes recommended should not be construed to indicate that the questionnaire was faulty. As stated above, the questionnaire did work and it is the first questionnaire developed to gather information related to industry's use of real options.

The major change recommended is to modify the questions used to gather the information related to the existing use of real options. The questions in the final

questionnaire directly asked the respondents' opinions on their existing and potential use of real options. The questions themselves assumed that the respondents understood the concept of real options, and could therefore provide meaningful answers. In the case of real options, this assumption is not valid. In most cases, respondents had not heard of real options[1]. Therefore the cover letter and directions on the questionnaire had to provide sufficient explanations to make the questions understandable.

One of the tradeoffs in questionnaire design is the tradeoff between length and response rate. Generally, the longer the questionnaire, the lower the response rate. In the questionnaire on real options, increasing the explanations would increase the overall length of the questionnaire. It would also make the questionnaire appear more bewildering since the respondents would be confronted with long explanations that they needed to read and comprehend in order to answer the questionnaire. This would likely have decreased the response rate.

To overcome the problem just discussed, it is recommended that the questionnaire gather the needed information using a more indirect method. Specifically, the questionnaire should ask the respondents their opinions on a number of statements whose contents encompass the concepts that underlie real options. This is the approach that was originally used in the pilot questionnaire to evaluate a respondent's existing use of real options.

The advantage of this approach is that detailed explanations concerning real options are not required. The respondent does not need to be familiar with the specific terms associated with real options in order to complete the questionnaire. Therefore, the respondents are more likely to complete the questionnaire.

The biggest disadvantage associated with this approach is the difficulty in mapping the statements to the different types of real options. For example, the first statement from the pilot questionnaire is "When implementing a project, there are a number of formal review sessions where the project may be continued or cancelled." The initial mapping of this statement was to the real option for staged investment. However, it is possible that a respondent may interpret this statement as providing the ability to defer making a decision until more information is gathered. Another respondent may interpret this statement as providing the ability to change the scale of the project as future conditions warrant.

It was for this reason that the approach of the final questionnaire was changed to a more direct approach. However, with some additional fine tuning of the statements, the approach in the pilot questionnaire may provide a higher response rate. More importantly, respondents are more likely to provide more accurate responses since there are no terms with which they are unfamiliar.

Results from the Questionnaire

This section discusses the results obtained from the mail questionnaire and telephone interviews. Each area from the questionnaire and telephone interview is examined and discussed independently. When reading this section, it should be remembered that the results are based on a twelve percent response rate. Possible reasons for, and the implications of, the low response rate are covered in a later section.

Project Types

The analyses indicated that the value associated with the real options was dependent on the type of information technology project. Real options have the

potential to impact strategic projects the most and threshold projects the least. This is supported by the results from two different sections of the questionnaire. First, the analysis is supported by question 2 of section 1 of the questionnaire, shown in Table 3 on page 79. This question asked whether real options ever made the difference between approval or disapproval of a project. The respondents indicated the real options made the least difference in threshold projects and the greatest difference in strategic projects. The analysis of variance for the section 3 data, shown in Figure 11 on page 92, also provided the same results.

These results are consistent with the previous literature in the area of valuing information technology. Strategic projects typically provide an organization the best opportunity to gain a competitive advantage (Bharadwaj, Varadarajan, and Fahy 1993; Brown, Gatian, and Hicks 1995; Ives and Learmonth 1984; Johnson and Vitale 1988; Kanter 1987; Keen 1992; Kettinger et al. 1994; Parker and Benson 1989; Parker, Benson, and Trainor 1988; Rackoff, Wisemann, and Ullrich 1985; Turner and Lucas 1985; Wisemann 1985; Wisemann and MacMillan 1984). Strategic projects typically also have the largest risk associated with them. This risk can be both internal and external. For example, internal risks can include technology concerns with actually getting the project working or integrating the project into the organization. External risks can include changes in the business environment invalidating the usefulness of the project such as competitors' projects that are similar.

Real options measure the ability to reduce the risk associated with the projects. Since strategic projects have the greatest risk associated, real options provide the greatest value in conjunction with strategic projects. Additionally, many of the benefits afforded by strategic projects are intangible such as providing growth opportunities for

the organization. Real options have the potential to measure the value of these opportunities. Since the majority of these opportunities are linked to strategic projects, it makes sense that strategic projects would benefit the most from including the value of the real options in the analysis process.

The data analysis found that threshold projects would benefit the least from including the value of the real options in the analysis process. This is consistent with expectations (Parker and Benson 1989; Parker, Benson, and Trainor 1988; Turner and Lucas 1985; Weill and Olson 1989). Threshold projects are projects that must be performed in order to stay in business or maintain competitiveness. In these cases, detailed cost and benefit analyses are not required. This is also consistent with the results of the telephone interview which indicated that threshold systems had minimal analysis required.

Real Option Types

The data analyses found differing results of the most important type of real option when comparing the respondents' existing use of real options and their potential use of real options. The respondents feel that the option for staged investment is the real option they presently use the most, shown in Figure 8 on page 87, while the option to grow is the real option with the greatest potential to be valuable, shown in Figure 10 on page 91.

The dual results are not surprising. Many information technology projects are developed using the systems development life cycle. In this process, information systems are developed in a series of phases. These phases include: project definition, feasibility study, requirements analysis, general high level design, detailed design, implementation, and operations and maintenance (McKeown and Leitch 1993). In this

process, the next phase is not started until the existing phase is completed. Agreement between personnel from both the information system department and the user department is required before starting the next phase. Formal meetings and structured walk throughs are used to ensure that the requirements in each phase are met.

Projects designed using the systems development life cycle already have the real option for staged investment embedded in the design process. In each phase, a decision is made on whether to perform the next phase or whether the project should be modified or cancelled. Therefore, the respondents are already making use of the real option for staged investment, which is reflected in the data analysis results.

The respondents indicated that being able to value the real option to grow has the greatest potential to be useful for them. This is also consistent with the literature review. The literature split information technology projects into four categories — threshold, transactional, informational, and strategic. The literature indicated that strategic projects provided the greatest value to the organization. The results of this dissertation supports the same conclusion. What makes strategic projects the most important type of project is their ability to provide a competitive advantage to the organization (Bharadwaj, Varadarajan, and Fahy 1993; Brown, Gatian, and Hicks 1995; Ives and Learmonth 1984; Johnson and Vitale 1988; Kanter 1987; Keen 1992; Kettinger et al. 1994; Parker and Benson 1989; Parker, Benson, and Trainor 1988; Rackoff, Wisemann, and Ullrich 1985; Turner and Lucas 1985; Wisemann 1985; Wisemann and MacMillan 1984). The competitive advantage may yield an increase in market share or increased revenue. Thus the information technology project provides an opportunity for the organization to grow. Being able to value the option to grow that is associated with a strategic project would be very beneficial.

Organizational Performance

This dissertation attempted to determine if there was a relationship between the existing use of real options and an organization's performance. The existence of a positive relationship would help justify the resources that would be required to perform the real options analysis.

No relationships were found between the existing use of real options and an organization's performance. One possible explanation is the lack of a single measure of organizational performance. The low correlation between various performance measures, shown in Figure 17 on page 103, raises a warning flag when a single measure of organizational performance is used as a surrogate for total organizational performance. For example, Harris and Katz use the operating expense ratio in two of their articles (1989; 1991b) as the surrogate for organizational performance. The 1995 edition of A. M. Best's insurance reports for life and health states that the operating expense ratio is only one of seventy-one financial tests to evaluate the profitability of an insurance company (Best's Insurance Reports ... 1995a, p. xvii). The low correlation between organizational performance surrogates does not invalidate Harris and Katz's efforts, however, it does raise a flag that additional work may be required.

Further research should be performed in the insurance industry on determining good surrogates to capture an organization's performance. As part of this research, a clear definition of organizational performance needs to be declared since performance is relative based upon the framework of the researcher. One researcher may define organizational performance as short term profitability, while another researcher may define it as market share, while a third may look at stakeholder satisfaction.

Open-Ended Questions

The first question, shown in Table 2 on page 78, asked whether the respondents had ever heard of the term "real option"? The majority (86.3%) had not. This response was expected. The term "real options" is fairly new and rooted mostly in the academic literature. The number of people who had heard of the term (6 out of 51) is larger than expected[2]. It is possible that some of the six respondents confused the term with the more common term associated with stock options. The respondents may also have heard of the term in a different context than the one presented in the questionnaire. It is also possible that they may actually be familiar with the term. Further work in this field may help answer some of these questions.

The second question, shown in Table 3 on page 79, asked whether the value of the real options ever made a difference between approval and disapproval of a project. The majority (58.8%) indicated that real options did make a difference. This result indicates that the insurance industry is already making use of real options in one form or another. Additional work on real options, especially in the area of formalizing the process by which they are incorporated in the analysis process, appears to be beneficial.

When looking at the type of projects that real options benefit, the value of the real option varies directly with the type of project. Real options benefit strategic projects the most and threshold projects the least. This is consistent with the results previously discussed from the analysis of section 3 data. It is also consistent with the expectations of this research effort. Since strategic projects typically embody many real options, strategic projects would benefit the most when the impact of the options are included in the cost benefit analysis (Bacon 1992; Brookfield 1995; Busby and Pitts 1995; Hayes

and Garvin 1982; Kogut and Kulatilaka 1994b; Ross 1995; Smith and Nau 1995; Trigeorgis 1993b).

The third question, shown in Table 4 on page 79, examined the method, if any, that the respondents were using to incorporate the value of the real options in their analysis process. The majority of the respondents (68.6%) used either qualitative, quantitative or both methods. Therefore, improving the techniques, either quantitative or qualitative, that organizations use to incorporate the value of the options would be beneficial to the majority of the companies.

The approaches used to qualitatively include the value of the options varied depending on the organization. A similar variety of techniques are also used to incorporate the value quantitatively. Closer examination of the quantitative techniques indicates that most of the approaches are some form of discounted cash flow techniques. It appears that none of the companies use mathematical models specifically designed to determine the value of the real options associated.

The fourth question, shown in Table 5 on page 82, examines whether companies accept projects even with a negative net present value. Three-quarters (74.5%) accept projects even with a negative net present value. This result is similar to the result of another survey which found that 76% of the companies accept projects that fail quantitative analysis (Freeman and Hobbes 1991). This result means that there are benefits that are not included in the existing analysis process. In some cases, the benefits are related to staying in business because a project, typically a threshold project, is required by state or federal regulations or to provide the same services as a competitor. However, in a number of cases, strategic reasons compensate for a negative net present value. Real options have the potential to assist in these cases by

quantifying some of the intangibles and helping to provide a more accurate net present value analysis.

The last question, shown in Table 6 on page 83, asked the respondents for any other comments that they would like to make concerning real options. The responses varied all over the place. Some respondents indicated that they felt that real options could be used if a better structure was developed to incorporate real options in the analysis process. Other respondents felt that real options were a waste of time and that projects needed minimal formal analysis. These comments match discussion in the literature concerning analysis of information technology. Some articles feel that no formal analysis is needed for projects beyond the desire to implement them while other articles feel detailed analysis is required for all projects (Bonczek, Holsapple, and Whinston 1980; Dyle 1995; Heenan 1976; Lembersky and Chi 1984; McLean and Riesing 1977; Waldman 1992).

Telephone Interview

In addition to the mailed questionnaire, telephone interviews were also conducted with those respondents willing to discuss real options. Out of the nine people contacted, only one was willing to discuss real options in any detail. The reason for this was not lack of interest by the respondents, but rather their lack of knowledge concerning real options. The only knowledge that the respondents had concerning real options was the knowledge they picked up from the questionnaire and cover letter. The respondents did not have enough knowledge concerning real options to add anything useful, from their perspective, to the conversation.

There was a similar lack of knowledge in the case with the one respondent who was willing to talk about real options. While the respondent was willing to discuss real

options, the only contact the respondent had with real options was because of this research.

Existing Use of Real Options and Implications

The previous section discussed the questionnaire results regarding the use of real options to value information technology in the insurance industry. This section ties together the results and provides a benchmark of the existing use of real options to value information technology in the insurance industry. This section also examines the implications of the present situation.

Summarizing the results of the existing use of real options[3]:

- The majority of respondents had not heard of the term "real options".
- In approximately 60% of the cases, the value of the real options inherent in a project made a difference between approval and disapproval.
- Real options made a difference in only 16% of threshold projects while making a difference in 57% of the strategic projects. The relative importance of real options to strategic and threshold projects was also supported by two different analyses.
- Approximately 70% of the respondents are incorporating the value of the real options in their existing analysis.
- It appears that no companies are using formal models designed to value the real options. In the majority of cases, the value of the real options is being incorporated qualitatively.
- A majority of the companies (75%) accept projects even when the quantitative analysis does not support this action.
- The real option for staged investment is the real option most frequently being incorporated.

The benchmark results are based on only on the companies who responded to the questionnaire. The majority of companies, 372 out of 423, did not respond to the questionnaire even with multiple follow-up letters, postcards and a duplicate mailing.

There are a number of possible reasons why the questionnaire was not completed and returned[4]. Among the most likely reasons that potential respondents did not complete the questionnaire are:

- Did not feel that they knew enough about real options to complete the questionnaire.
- Felt that the concept of real options, or the larger topic of valuing information technology, was a waste of time.
- Busy with many other tasks at work and completing the questionnaire was not a high enough priority to spend time on.

It is felt that these three reasons encompass the majority of respondents who did not complete the questionnaire. Even for those people who did respond, comments were made that fit under the three statements listed above. In many cases, it may have been a combination of these reasons.

In summary, it appears that the majority of companies are not incorporating the value of the real options when they evaluate information technology projects. Most likely, the companies are not including the value of the real options in their analysis process for projects other than information technology projects.

The implications of these facts are that many companies are underestimating the potential value of information technology projects which may cause valuable projects to be rejected when they should be accepted. From the larger perspective, companies are using inadequate techniques to evaluate investment decisions which may lead to sub-optimal decision making.

In terms of information technology projects, 95% of the companies indicated that discounted cash flow analysis was either very important or somewhat important in getting a project accepted (Gillin 1994a). However, failure to include the value of the real options in the analysis process will result in monetary estimates that undervalue the

actual value of the investment (Bacon 1992; Brealey and Myers 1991; Brennan 1995; Brookfield 1995; Busby and Pitts 1995; Hayes and Abernathy 1980; Hayes and Garvin 1982; Kogut and Kulatilaka 1994b; Ross 1995; Sercu and Uppal 1994; Smith and Nau 1995; Trigeorgis 1993b; Weaver et al. 1989).

Ross (1995, p. 96) states: "I have become convinced that it is time to revisit the usefulness of NPV and to reconsider just how much stock we want to place in it." Ross (1995, p. 101) further goes on to say: "For most investments, the usefulness of the NPV rule is severely limited. ... If modern finance is to have a practical and salutary impact on investment-decision making, it is now obligated to treat all major investment decisions as option pricing problems." Therefore, even though the application of option pricing theory to real projects is relatively new, companies need to understand the concepts and learn how to incorporate this value in their existing analysis techniques.

Further Research

The research performed as part of this dissertation included the first benchmark study concerning the existing and potential use of real options in any industry and for any type of project. This section will provide some suggested areas for further research that are closely linked with the research effort performed as part of this dissertation. Some of the areas parallel the efforts of this dissertation while other suggestions are follow-on research based upon the results of this research.

Parallel Research

This research examined the existing and potential use of real options to value information technology in the insurance industry. An obvious area for parallel research is to examine the use of real options in other industries and for other uses.

This research examined the use of real options in valuing information technology in the insurance industry only. Examining other industry's use of real options to value information technology might prove interesting. It is very possible that similar results to this research effort would be found. Regardless of the type of industry, the same four level hierarchy of projects (i.e., threshold, transactional, informational, and strategic) are still applicable. Different industries have the same general needs to be supplied by information technology even though specific projects may differ. Therefore, it would not be surprising to find similar results to the ones in this dissertation.

A more beneficial area might be examining the application of real options to projects other than information technology projects. Real options are applicable to many types of projects. Depending on the type of project, valuing the flexibility may be more or less useful. Certain types of projects with a high uncertainty associated with them would benefit much more from real options analysis than projects with mostly known outcomes. The literature review discusses application of real options to many types of projects such as oil exploration (McDonald and Siegel 1986; Paddock, Siegel, and Smith 1988; Pickles and Smith 1993), flexible manufacturing (Arbel and Seidmann 1984; Kogut and Kulatilaka 1994b; Kulatilaka 1988; Pant and Ruff 1995), or pharmaceuticals (Kogut and Kulatilaka 1994b; Nichols 1994; Solt 1993; Trigeorgis 1988). The existing and potential use of real options for different types of projects may vary considerably.

Another potential research topic includes evaluating whether the benchmark results are dependent on the specific recipient of the questionnaire. For example, this research effort targeted the chief information officer as the person to respond to the

questionnaire. The results may have been different if the questionnaires had been sent to the chief financial officer. The chief financial officer may have been more comfortable with the concepts of real options due to his or her involvement with financial options. On the other hand, he or she probably would not have been as familiar with the potential impact of real options on different types of information technology projects.

One last topic related directly to this research would be to evaluate any potential differences caused by internal versus external flexibility. This research made no distinction between the internal and external flexibility associated with information technology projects. Consider the option to defer. Internal flexibility is associated with the project itself. The project itself may be deferred until further information about its technical feasibility is gathered. For example, a company may defer building an application tied in to Windows 95 until Windows 95 has gained widespread use in the marketplace. External flexibility is how a project may tie in to other projects. Building the information technology project may allow other projects within the organization to be deferred. For example, actually building a new marketing information system may allow the company the ability to defer entering a new market until further information is available. If the information is favorable, the new market can be entered immediately since the information system has already been built.

Follow-On Research

This section provides some recommendations for follow-on research based upon the results of this dissertation. This research has found that very few companies are aware of the concept of real options and even fewer have any formal process to include the value of the real options in their existing analysis process.

In order to raise the awareness of real options and their value in the analysis process, more "marketing" must be done, regardless of the types of projects or industry. Without this effort, applications of real options will likely be limited to academic interest and specialized applications in certain companies.

Looking at the body of work on real options, the conceptual models are too theoretical for the majority of people in industry who perform the cost benefit analysis. Most of these people are not willing to delve into the theory of real options and try to determine how they might be applied. Nor would these people be convinced of the usefulness of real options from the quantitative models that have been developed. The existing models, even relatively simple models, are complicated. Compounding the problem with the mathematical models is a belief by industry that the models' numbers can be manipulated to provide the "desired" result[5].

Real options have actually been applied in industry settings in only four published cases. In the four cases, two of the models were developed primarily for academic use (Paddock, Siegel, and Smith 1988; Quigg 1993). In the other two cases, the models were developed for very specialized activities that had a direct impact on the organizations' line of business (Kemna 1993; Nichols 1994).

Arguments can be made about how adding the value of real options associated with a project to the existing analysis process will provide a more technically correct approach. This is a similar argument to the statement that net present value analysis is more technically valid than internal rate of return (see for example Brealey and Myers 1991; Copeland and Weston 1992).

These type of arguments are not going to sway most people in industry who perform the cost benefit analysis. Previous studies have shown that internal rate of

return and payback are more popular than net present value analysis (Cooper and Petry 1994; Cooper, Cornick, and Redman 1992; Evans and Forbes 1993; Freeman and Hobbes 1991). This is in contradiction to what is expected based on the technical merits of the differing analysis techniques.

Therefore, it is recommended that further research in the area of real options be focused on demonstrating to industry how real options can fit into their evaluation models and improve them. Rather than developing mathematical models, effort should be allocated to improving existing qualitative models. There are a number of existing models that break down both the steps involved with building an information system (e.g., Laudon and Laudon 1996; McKeown and Leitch 1993) and performing cost benefit analysis of the systems (e.g., Farbey, Land, and Targett 1993; Parker, Benson, and Trainor 1988).

The research that needs to be done is integrating real options into these existing models. At each step in the model, the appropriate types of real options should be added to the model. The expanded model should detail not only the types of real options applicable, but more importantly how these real options can reduce the risks associated with the projects' development.

For example, one of the typical decisions involved in information technology projects is the "make or buy decision". In this decision, the organization has to determine whether they want or need to write the software themselves or buy a software package. There are real options embedded in the tradeoff analysis. If the organization chooses to buy the software, they may be able to defer the decision on what specific software to buy since buying software is much quicker than writing it. They also have the ability to switch between competing software products. On the other

hand, writing the software might provide a competitive advantage if nobody else has the same capabilities. Therefore, the option to grow may be embedded in the decision to write the software.

The existing model used to detail this decision process and the cost benefit analysis associated should be modified to incorporate these real options. Tied in with these additions should be an evaluation of how much the real options are worth. In the initial models, the benefit provided by the real options should be treated qualitatively. For example, the option to defer provides a value of 7 on a scale of 1 to 10.

The existing models that are modified should be consistent with the system development models and cost benefit models commonly used in industry. This will help ensure that the modified models have the opportunity to be accepted by industry. Any models developed should be validated by industry. Failure to do this will likely result in the models not being accepted by industry.

Models developed should concentrate on strategic projects with special attention given to areas in the model which can provide the option to grow. These statements are based upon the research performed in this dissertation which found that strategic projects would benefit the most from incorporating the value of the real options, and that the respondents' felt that incorporating the option to grow would provide the greatest potential.

These suggestions for further research are consistent with the seven step process that Kemna (1993) discusses. Kemna's steps include convincing management that traditional methods do not incorporate the flexibility that real options can measure and determining the options inherent in a project.

Respondent's feedback on further research

As indicated in the cover letters which forwarded the questionnaire, all the respondents would receive a report that summarized the results of the research. Appendix 11 shows the cover letter for the report[6]. The cover letter discussed the follow-on research and asked the respondents if they felt that performing this research would make them more likely to include the value of the real options in their analysis process.

A stamped, self-addressed postcard, shown in Appendix 12, was included with the cover letter and executive report. Fourteen postcards were returned. Eight of the respondents indicated that the further research would make a difference and six indicated that further research would have no effect. Four of the postcards included comments:

- Indicating "YES" — My understanding of real options, although still very limited, has increased by participating in the survey. Of particular value were the examples of real options given in the survey results.
- Indicating "YES" — Intuition tells me this is good. Practically speaking, I can't see how to implement or use the academic ideas. Perhaps the examples will help.
- Indicating "NO" — Probably due to ignorance. Also, cost benefit analysis here is extremely rare.
- Indicating "YES" — Please include me in further correspondence and/or studies. I am interested in establishing "value-added" dimensions to my information systems division. (Name and address provided. Title listed as "Information System Financial Controller".)

Additional follow-up associated with this dissertation includes an article being written for *Resource — The Magazine for Life Insurance Management. Resource* is published by LOMA and distributed to management, supervisory, professional, and

technical personnel in LOMA member companies. The article will discuss real options along with the results of this dissertation. The article will also indicate that the executive summary is available upon request and provide contact information where additional information can be obtained[7]. The article will request additional feedback from industry personnel concerning the application of option pricing theory to real projects.

Conclusion

This dissertation examined the information technology valuation process. It focused on the problem of the mismeasurement of benefits provided by information technology. Specifically it examined the existing and potential use of real options to value information technology projects in the insurance industry. This was the first research study to examine industry's existing use of real options and their attitudes towards the potential benefits provided by real options in any industry and for any type of real project. This dissertation had four objectives. The completion of these objectives added to the growing body of knowledge on real options.

The first objective was to perform a benchmark study and determine the existing use of real options to value information technology in the insurance industry. This research has found that very few companies are aware of the concept of real options and even fewer have any formal process to include the value of the real options in their existing analysis process.

The second objective was to evaluate the potential of real options to assist in valuing information technology. Based upon the responses to the questionnaire and the non-response rate, more "marketing" of real options must be accomplished before companies will expand their existing analysis tools to include real options.

The third objective was to evaluate different factors that can affect the value of the real options. The research found that including the value of the real options would benefit strategic projects the most and threshold projects the least. Additionally, incorporating the value of the option to grow in the analysis tools would provide the greatest benefit.

The final objective was to develop a survey instrument that can be used to gather data related to an organization's existing and potential use of real options. The questionnaire developed from scratch as part of this research was able to gather the needed information. The information gathered could be directly analyzed to answer the research questions posed in this dissertation. Evaluation of the responses indicated a high degree of reliability associated with the test instrument. Some recommendations to modify the questionnaire to improve the response rate were developed based on the research effort.

In conclusion, this dissertation added to the growing knowledge concerning the application of option pricing theory to real projects. A benchmark study was performed indicating that little work has been done in applying real options to actual industry situations. More effort and education is needed to transfer real options from the academic arena to industry use. This effort is vital since existing analysis tools such as net present value underestimate the value of projects. As Ross (1995, p. 101) states: "For most investments, the usefulness of the NPV rule is severely limited. ... If modern finance is to have a practical and salutary impact on investment-decision making, it is now obligated to treat all major investment decisions as option pricing problems."

Notes:

[1] Of the 51 responses, 44 had not heard of the term previously.

[2] A very informal poll of the finance professors where this author was working found that none of the three professors had heard of the term "real option".

[3] Previous sections of this chapter have discussed the specific results obtained from the questionnaire and cross referenced the results to specific figures and tables in the results chapter. In order to avoid redundancy, this section will not repeat this same cross reference process.

[4] Originally a mini-questionnaire, shown in Appendix 10, was to be sent to those companies who had not responded to the questionnaire after the second complete mailing. Unfortunately, due to unexpected circumstances it was never mailed.

[5] Some of the comments on the open-ended questions in section 1 of the questionnaire indicate respondent's concerns about the ability to manipulate the data to obtain the results desired.

[6] The actual report sent is not included in this dissertation since it simply summarized the information already contained in this dissertation. The report was 18 pages long.

[7] The article will be approximately 4000 words. My mailing address and electronic mail address will be included in the article. Interested parties are encouraged to contact me for additional information or discussion.

APPENDICES

Included in the appendices are copies of the cover letters, questionnaires, and follow-up letters used in this dissertation. In order to meet the requirements of the dissertation format, margins and page breaks were changed as needed to fit the documents into the required space. No other changes were made.

APPENDIX 1
PROCEDURE

This appendix details the process that was used to distribute, retrieve and analyze the questionnaire. The process of mailing out the questionnaire and keeping track of the respondents was handled by LOMA. The generation and data analysis of the questionnaire was handled by this author.

The first step after the pilot questionnaire and cover letter, shown in Appendix 4 and Appendix 3 respectively, were written was to have both of them reviewed by the doctoral committee. Additionally, the questionnaire was reviewed by personnel at LOMA to ensure that all terms and definitions used are clearly stated and there is a common consensus on their meaning.

The next step was to send out a cover letter and questionnaire to a subset of the sample as a pilot survey. This pilot survey was to ensure that the respondents would understand the directions provided and that the terms are not ambiguous. It was also to ensure that the questionnaire was properly designed to provide the needed information for analysis. A cover letter specific for the pilot survey was attached to the questionnaire.

The sample for the pilot survey was chosen using a convenience sample. Personnel from LOMA were meeting with groups of approximately twenty chief information officers on a periodic basis to discuss issues unrelated to this dissertation. One group was personally requested by the LOMA representative to complete the pilot study and return it to LOMA.

The procedure to be used for the pilot sample and full survey were identical. Before explaining the actual procedure, the ground rules under which this questionnaire was being performed must be clearly stated. To protect the identity of LOMA's member companies, both confidentiality and anonymity were maintained. From this author's perspective, company information was completely anonymous unless the member companies explicitly chose otherwise. LOMA acted as the intermediary and maintained a list of companies to whom the questionnaire had been distributed and which companies had returned their questionnaire. On the front page of the questionnaire there was a place where the respondent provided their name and company information. The questionnaire also provided a place to indicate whether this information could be shared with this author. All information gathered by questionnaire was to be kept in strict confidence. Questionnaires sent out had LOMA's address as the return address and completed questionnaires were returned to LOMA.

For each respondent, a cover letter, questionnaire and postage-paid return envelope was placed in a mailing envelope. LOMA then placed mailing labels on each envelope. The mailing label identified not only the company name, but also the name of the chief information officer so that the package was routed to a specific individual. As questionnaires were returned to LOMA, LOMA kept track of which companies had completed the questionnaire.

The pilot questionnaire was distributed and returned. Appendix 2 discusses the pilot questionnaire, the results obtained, and changes made to the final questionnaire. After the changes were made to the questionnaire, the updated questionnaire was distributed to LOMA member companies. Approximately three weeks later a follow-up postcard, shown in Appendix 7 was sent to those companies who had not responded. Approximately three weeks after the postcard, another questionnaire and cover letter

was sent to those companies who had not yet responded. The questionnaire remained the same, however, the cover letter was rewritten to incorporate suggestions based upon the questionnaires already received and some comments made to LOMA personnel by potential respondents. At this point, LOMA personnel received feedback from member companies indicating that no further follow-up was desired. Those respondents interested in the topic had already returned the questionnaire and further follow-up would simply antagonize LOMA member companies.

For those companies who did not wish their identity made known to this author, LOMA personnel added information related to the company. The source for this data was the latest edition of A. M. Best Insurance Reports. This information included the company's size, Best's overall financial rating, operating expense ratio, and return on equity. For those companies who did not request anonymity, company information was added by this author.

For those companies who indicated on the questionnaire that they were willing to discuss real options in greater detail, further action was taken. A letter (shown in Appendix 9) was sent to each of the individuals indicating that they would be contacted and indicating the type of information to be gathered.

APPENDIX 2

PILOT QUESTIONNAIRE DEVELOPMENT AND ANALYSIS

This appendix discusses the pilot questionnaire that was originally mailed out prior to the distribution of the final questionnaire. This section covers the differences between the pilot questionnaire and the final questionnaire. It also provides the results of the statistical analysis performed on the data provided by the pilot questionnaire.

Questionnaire Differences

The pilot questionnaire was arranged slightly differently than the final questionnaire. In the pilot questionnaire, the open-ended questions were placed in the last section. The closed-ended questions comprised the first three sections of the pilot questionnaire. The closed-ended questions also provided the respondent with eleven possible choices on the semantic differential scale.

The biggest difference between the pilot questionnaire and tne final questionnaire was the method used to evaluate the respondents' existing use of real options. In the pilot questionnaire, the respondents were presented with twenty-four statements relating to existing practices in their organization. Each statement was designed to evaluate the respondent's existing use of the concepts that form the foundation of real options. For example, statement 4 was designed to evaluate the respondent's use of standards-based equipment. If an organization does use standards-based equipment, it is easier to switch from one software or hardware package to another without losing all the existing work. This "real option to switch" has value. If the respondent agrees with the statement, they are signifying their existing use of real options, at least qualitatively, even though they may not be familiar with the terms.

Table 13 identifies the link between the twenty-four statements and the six real options. The actual order of the statements in section 1 was determined by a random number generator.

Table 13: Relationship between statements in section 1 of the pilot questionnaire and specific real option

Defer	Staged Investment	Change Scale	Abandon	Switch	Grow
2	1	8	5	4	3
9	10	15	7	11	6
16	19	18	12	17	13
22	23	20	14	21	24

Data Results

The questionnaire was distributed to twenty chief information officers whose companies are members of LOMA. These individuals were meeting with personnel from LOMA for other purposes and were requested to complete the pilot questionnaire. Therefore, the sampling method used was a convenience sample. Five pilot questionnaires were returned, a 25% response rate.

The majority of comments by the respondents on the pilot questionnaire were related to the use of real options in their respective companies. There was only a single comment by one of the respondents that was related to the questionnaire construction.

Section 1

The purpose for section 1 was to evaluate the companies' existing use of real options. Descriptive data from the first section of the pilot questionnaire is shown in Table 14. With such a small sample size, high standard deviations are not unexpected. The only comment related to questionnaire design was in this section. That comment was that the wording in statement 2 was confusing. As can be seen in Appendix 4, the wording for statement 2 makes it a "double negative" statement (the respondent's words).

The respondent's comment was accurate. In the pilot questionnaire, the wording of statements 2, 6, 13, 17, 22, and 24 was reversed from the other eighteen statements. In these six statements, a response of *strongly disagree* would indicate a high use of the concepts of real options. This was done as a check for response bias. However, this seemed to add another source of error to the questionnaire. As Table 14 indicates, the standard deviations for those six statements were higher than average. There is no reason to assume that the respondents will bias their answers.

Table 14: Existing value of real options based upon the pilot questionnaire

Variable[1]	Mean	Std Dev
S1_01	3.60	1.52
S1_02	-1.40	3.21
S1_03	2.60	1.14
S1_04	4.00	.00
S1_05	-2.00	1.41
S1_06	1.00	2.94
S1_07	1.20	1.79
S1_08	1.40	1.67
S1_09	1.00	2.00
S1_10	2.60	3.13
S1_11	.00	2.83
S1_12	2.80	3.83
S1_13	.40	4.10
S1_14	-1.80	1.64
S1_15	3.40	.55
S1_16	.40	3.13
S1_17	1.40	2.30
S1_18	1.40	1.52
S1_19	1.60	2.30

Table 14 — Continued

Variable	Mean	Std Dev
S1_20	.00	2.45
S1_21	1.40	2.49
S1_22	1.40	2.30
S1_23	1.80	1.79
S1_24	.40	2.88

To evaluate the reliability of this section, a Cronbach's Alpha test was performed. The Cronbach's Alpha score was 0.8458. For a scale to be considered reliable, the score must be greater than 0.70. A factor analysis of the responses in this section was not performed because of the small sample size.

Section 2

The purpose for this section is to evaluate the impact that being able to quantify the value of each of the six types of real option would have on the four types information technology project would have. Descriptive data from this section is shown in Table 15. The standard deviations in this section appear to be lower than the previous section. This may be due to the clearer nature of the statements in this section. The Cronbach's Alpha score for this section was 0.9469.

Table 15: Potential value of real options based upon the pilot questionnaire

Variable	Mean	Std Dev
S2_1A	-1.80	1.64
S2_1B	.60	1.14
S2_1C	1.20	1.48
S2_1D	3.40	1.14
S2_2A	-.20	1.64
S2_2B	1.60	1.67
S2_2C	1.80	2.17
S2_2D	3.80	.84
S2_3A	1.20	1.92
S2_3B	2.40	1.14
S2_3C	1.20	1.48
S2_3D	3.20	1.30
S2_4A	1.00	1.22
S2_4B	1.60	.89
S2_4C	2.00	1.58
S2_4D	3.60	.55
S2_5A	2.60	2.51
S2_5B	3.60	1.14
S2_5C	2.80	1.92
S2_5D	3.40	1.34

Table 15 — Continued

Variable	Mean	Std Dev
S2_6A	1.80	2.59
S2_6B	3.40	1.34
S2_6C	2.60	1.67
S2_6D	4.20	.84

An analysis of variance was run for the data in this section and is shown in Table 16. For "OPTION" and "PROJECT", the "F" and "Sig of F" values indicate that there are statistically significant differences between both the six types of real options and the four types of information technology projects. The score associated with being able to quantify the value of the real options is not the same for each of the six types in the respondents' opinions. A similar statement can be made concerning the four types of information technology projects. The "OPTION BY PROJECT" term looks at the interaction between the two main effects. The "F" and "Sig of F" indicates that there is no reason to assume that the two factors interact with one another. The type of project does not impact the type of real option and vice versa.

Table 16: Analysis of variance of potential use of real options based upon the pilot questionnaire

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	177.75	72	2.47		
OPTION	54.84	5	10.97	4.44	.001
PROJECT	107.11	3	35.70	14.46	.000
OPTION BY PROJECT	30.95	15	2.06	.84	.636
(Model)	192.91	23	8.39	3.40	.000
(Total)	370.66	95	3.90		

Typically, further analysis would be performed on this data to determine which of the six options are statistically different from one another and which of the four projects are different. Because of the small sample size obtained with the pilot questionnaire, the information would have little validity. Figure 19 shows an error bar chart of the section 2 data.

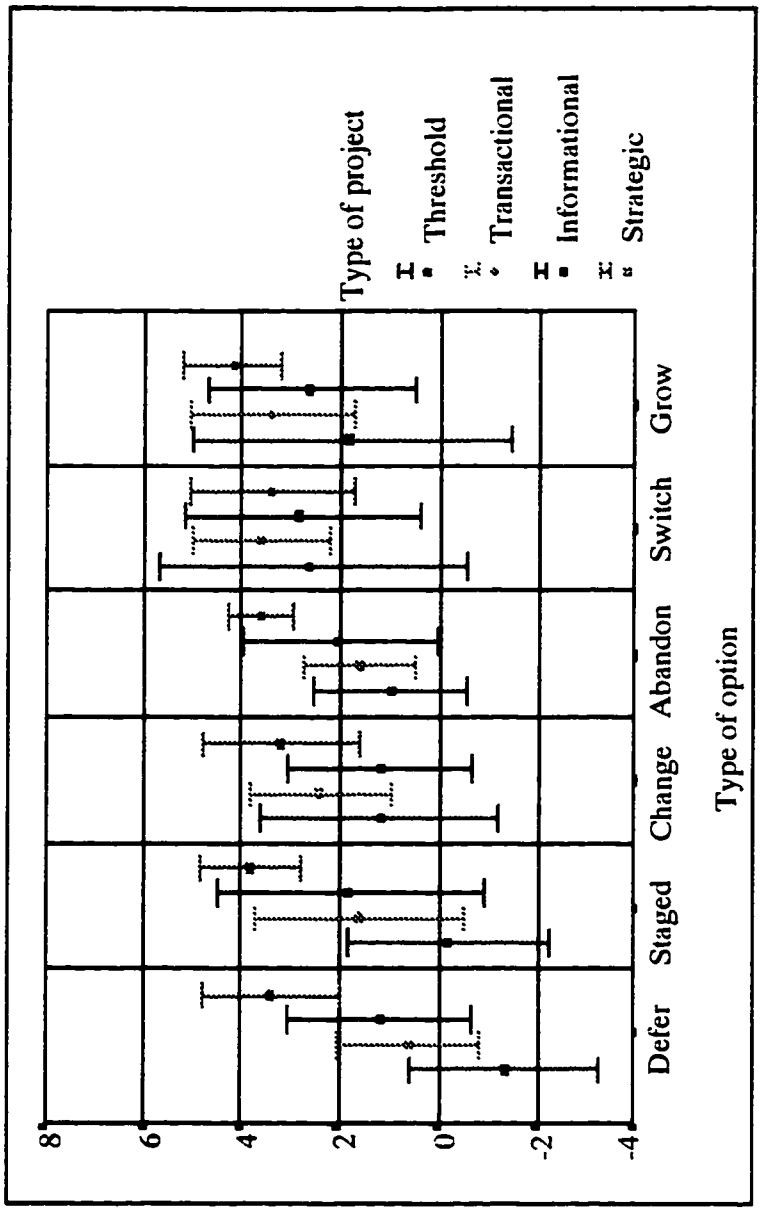


Figure 19: Potential value of real options based upon the pilot questionnaire

Section 3

This section of the pilot questionnaire examines whether there are synergistic effects between certain types of real options. The results from the pilot questionnaire are shown in Figure 20 and Figure 21[2]. One interesting result from the pilot questionnaire was that out of the five respondents, four of them picked the same option pair — the option to change scale and the option to grow — as a pair that fit together[3]. Looking at the option pairs that don't fit together, only one option pair — the option to defer and the option to grow — was selected by two respondents[4].

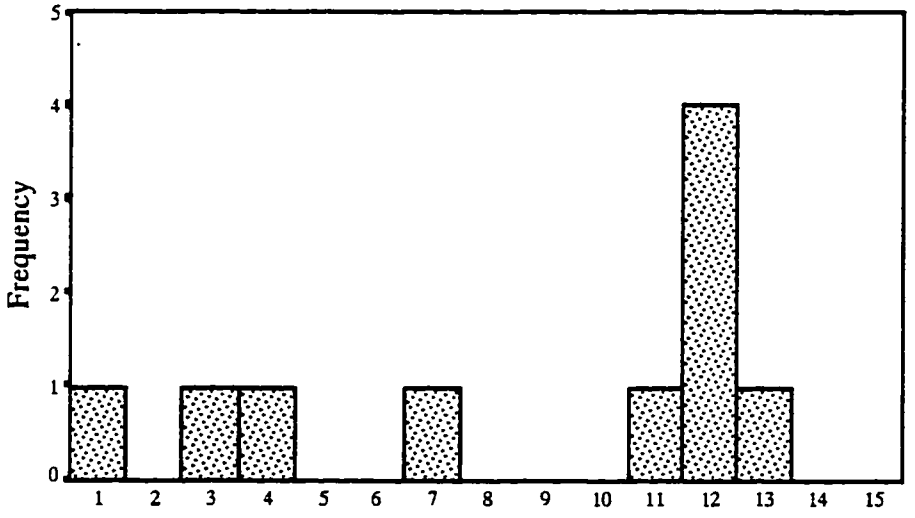


Figure 20: Histogram of option pairs that fit together based upon the pilot questionnaire

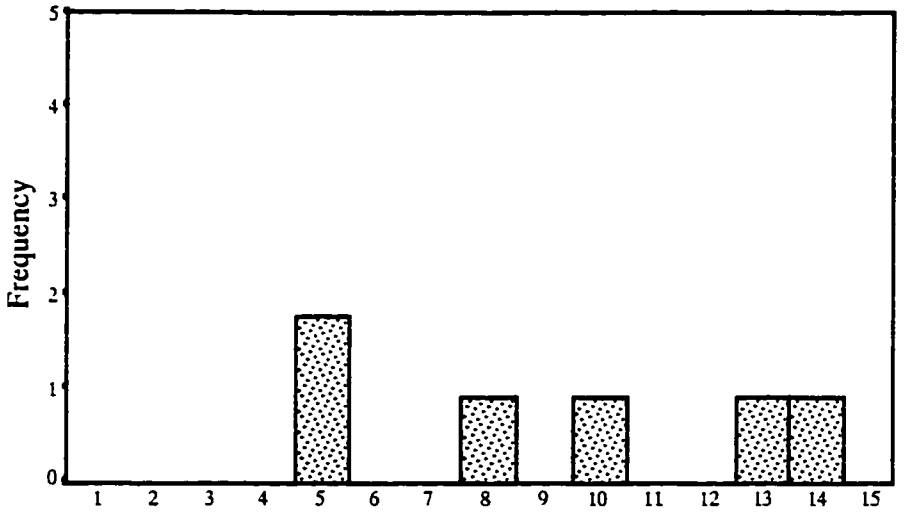


Figure 21: Histogram of option pairs that do not fit together based upon the pilot questionnaire

Section 4

The last section of the questionnaire consists of a number of open-ended and closed-ended questions to capture information in some general areas. Many of the questions in this section are Yes/No type questions. These questions were coded as "0" for No and "1" for Yes. Question 2 was coded so that "0" was Neither, "1" was Quantitatively, and "2" was Qualitatively. The results from this section are shown in Table 17.

Some observations can be made from these results. First, none of the respondents have heard of the term "real option" before. This was not unexpected. Second, real options made a difference in approving or disapproving a project for three out of the four respondents who answered this question. For those three respondents, real options made a difference in over 50% of the projects. These two figures were higher than expected. Even though the results are very preliminary, they indicate that

the ability to quantify the value of the real options would be very useful to the respondents. The last item of interest was that all five respondents were willing to include their name and company information on the pilot questionnaire.

Table 17: Descriptive data of the open-ended questions from the pilot questionnaire

Variable	Mean	Std Dev
S4_1	.00	.00
S4_2	1.67	.58
S4_3	.75	.50
S4_3A	58.33	33.29
S4_4	.80	.45
S4_4B_1	33.75	19.74
S4_4B_2	16.25	6.29
S4_4B_3	45.00	34.64
S4_4B_4	47.50	41.33
S4_5	.20	.45
JPF_SEE	1.00	.00
OE Ratio	.26	.09

Some of the comments in the open-ended questions were: Strategic objectives override negative net present value calculations; developing quality systems was the most important objective; state and federal regulation overrides a negative net present

value; product positioning and intangible benefits override a negative net present value; and competitive analysis is used to justify information technology spending.

Changes to the Questionnaire

Based upon the results of the pilot questionnaire, additional research, and further discussions with people familiar with questionnaire development, changes to the pilot questionnaire were made. The purpose for these changes were two-fold. First, to improve the data provided and second, to increase the response rate.

First, the open-ended questions were moved to the first section of the final questionnaire. This was done since the questions in the section could be easily answered and related to material that the respondents were already familiar with.

Two questions were added to the open-ended questions. The first question asks what term the respondents use to describe what the questionnaire calls "real options". The term "real options" comes from the literature.

The other question asks if the respondents would be willing to be contacted to discuss the use of real options in more detail. The major limitation of questionnaires, especially closed-ended questionnaires, is that they can not probe beyond the questions provided. If some respondents would be willing to be contacted, this limitation would be overcome.

The section asking the respondents about their existing use of real options was rewritten to make it more straightforward. In the final questionnaire, the respondents are directly asked their opinions for each of the six real option types. As the data analysis of the pilot questionnaire demonstrated, trying to determine their existing use through indirect methods provided results that may not have any meaning. Additionally, changing the format of this section decreased the overall length of the questionnaire which typically increases the response rate.

Finally, the eleven point semantic differential scale used in sections 2 & 3 was changed to a seven point scale. The literature indicates that if the scale has too many choices, the respondents may be confused on the interpretation of each value on the scale.

Notes:

[1] See section 1 of the pilot questionnaire shown in Appendix 4 for the actual questions.

[2] The identification of the options pairs is provided in Table 9 on page 94.

[3] This result from the pilot questionnaire was consistent with the final results. This option pair has the highest number of responses overall.

[4] This result was also consistent with the final results.

APPENDIX 3

PILOT QUESTIONNAIRE COVER LETTER

DATE: March 31, 1995 (On LOMA Letterhead)

TO: Members of Property and Casualty Systems Committee

As you know, measuring the benefits of an information technology project, especially the intangible benefits, is a difficult and error-prone process. Recently, an approach has been developed that has the ability to quantify some of the intangible values. This approach is called "real options" and is similar in concept to valuing stock options. Real options can assist you in the analysis of projects and allow you to better determine a dollar value for a project's worth. Jerry Flatto, a doctoral student at the University of New Haven is working with these real options.

To develop quantitative models that can assist you in valuing information technology projects, information about your needs is required. Your information will determine what types of information technology projects and real options should be included in the quantitative modeling. Limiting the types of projects and real options included in the modeling effort will decrease the time required to develop these models. More importantly, it allows the models to concentrate more heavily on those factors that you consider critical when evaluating information technology projects.

To solicit the required information, a questionnaire is attached. You may be assured of complete confidentiality. No individual results will ever be released. If you would like to receive a report but do not wish to share your identity with the graduate student please so indicate in a letter to me or on the survey form. The questionnaire has an identification number to facilitate tracking of responses. The identification number will allow some company data from A.M. Best's Insurance reports to be added to the questionnaire after it is returned.

As we discussed, you are part of a pilot study to ensure that the attached questionnaire will gather the required information to allow quantitative modeling to be performed. As you complete the questionnaire, please also indicate directly on the questionnaire if any of the terms used are not clearly defined, if any of the questions or statements are not clearly understood, or any other comments you feel appropriate. Your comments will be used to modify the questionnaire. The modified questionnaire will then be distributed to all insurance companies in the U.S. and Canada who are members of LOMA.

The results of this research will be summarized and you will receive a copy of the results along with a discussion of the next steps to be taken in developing quantitative models in the fall. Your participation in continuing efforts to develop quantitative models is welcome but not required.

Could you please complete the enclosed questionnaire by April 10, 1995. If you have any questions or comments concerning the questionnaire, please feel free to contact the graduate student, Jerry Flatto, at (910) 282-4852. Thank you for your cooperation.

Sincerely,
/s/ **Ann Purr**

APPENDIX 4

PILOT QUESTIONNAIRE

Use of Real Options in the Insurance Industry

Section 1

Instructions

Section 1 is being used to evaluate the applicability of statements that may be related to the current use of real options at your company. Look at each statement as it applies to **strategic** information technology projects (i.e., projects that change an organization's product or the way that the organization competes in the marketplace) only.

Using the scale below, indicate your agreement or disagreement with each of the statements listed below.

STRONGLY DISAGREE NEUTRAL STRONGLY AGREE

-5 ——4 ——-3 —— -2 —— -1 —— 0 —— 1 —— 2 —— 3 —— 4 —— 5

1. When implementing a project, there are a number of formal review sessions where the project may be continued or canceled. _____

2. I am not willing to pay a premium to lease software and/or hardware that would provide me more time before I need to make a decision. _____

3. I am willing to invest in projects even though all the benefits may not be known until the project is implemented. _____

4. Where possible, standards-based hardware and/or software is used. _____

5. Any salvage costs if the project is abandoned are included in the initial cost benefit analysis. _____

6. In the cost benefit analysis process, the strategic implications of a project can't compensate for a negative net present value. _____

7. I am willing to spend a premium to buy hardware and/or software that can be used for other purposes than originally planned. _____

8. I am willing to spend a premium (either cost or labor) on hardware and/or software to ensure that they can be expanded to meet currently unknown future needs. ____

9. I am willing to spend money that would provide me with more time before I need to make a decision on implementing a project. ____

10. Large projects are typically broken down into a series of independent, but linked, smaller projects. ____

11. The fact that there is only a single source for either the hardware and/or software is included as a liability in the cost benefit analysis. ____

12. When possible, I lease rather than buy hardware and/or software which makes it easier to abandon a project if the need arises. ____

13. I am not interested in taking a risk on the latest technology, but would rather wait until it has been accepted in the marketplace. ____

14. In the implementation plan, alternate uses for hardware, software and personnel are detailed in the event that the project is abandoned for any reason. ____

15. When a project is planned, the system chosen is capable of being expanded as future needs change. ____

16. When possible, hardware and/or software is leased to provide me greater flexibility on the time I have available to make a decision. ____

17. I am not willing to spend a premium to purchase standards-based hardware and/or software. ____

18. As part of the cost benefit analysis, the ability to expand the system is included in the analysis as a benefit. ____

19. I am willing to pay a premium (either labor or cost) that gives me the ability to split a project into a series of linked expenditures that makes it easier to cancel the project if the need arises. ____

20. I am willing to spend additional time to implement a system that is more sophisticated than presently required. ____

21. The fact that standards-based hardware and/or software is used is included as a benefit in the cost benefit analysis. ____

22. I typically make a decision as soon as possible on a project even if there is more time available before I need to make a decision. ____

23. I am willing to allocate additional time to provide me with the ability to split a project into a series of linked expenditures that makes it easier to cancel the project if the need arises. ____

24. I am not willing to invest in projects with high technological risks even though they may provide competitive advantage. ____

Section 2

Instructions

The section 1 examines your present use of the concepts that underlie real options. Section 2 is evaluating the potential that real options have to assist you in valuing information technology projects.

Section 2 is looking at four types of information technology projects (described below) and six types of real options. The six statements describe the six types of real options. Section 2 is trying to answer two questions:

- From your perspective, is the ability to quantify the dollar value of each of the six types of real options equally important?
- From your perspective, is the ability to quantify the dollar value of any individual real option equally important for the four project types?

The four types of information technology projects are:

- **Strategic** — Those that change an organization's product or the way that the organization competes in the marketplace. These projects are typically concerned with long-term objectives.
- **Informational** — Those that provide information for the general management of the organization and have medium-length objectives.
- **Transactional** — Those that support management in their day to day operations.
- **Threshold** — Those that are required to simply compete in the marketplace. In most cases, threshold projects are implemented in response to competitors' actions or governmental requirements.

You already can implement the ideas discussed in each statement below. Most likely, you incorporate the concepts below in your cost benefit analysis as intangible benefits. These statements are evaluating how valuable it would be for you to be able to convert these intangibles into a tangible (i.e., dollar) figure.

Therefore, for each of the statements below, identify how strongly you either agree or disagree that being able to include a quantitative (i.e., dollar) estimate in your cost benefit analysis process would be valuable for you.

STRONGLY DISAGREE NEUTRAL STRONGLY AGREE

-5 ——— -4 ——— -3 ——— -2 ——— -1 ——— 0 ——— 1 ——— 2 ——— 3 ——— 4 ——— 5

1. Real Option to Defer — Determine the value of being able to postpone making a decision on whether to implement an information technology project as long as possible so that future conditions become clearer. For example, delay implementing a system to support a new product until further information is available concerning the success or failure of the product.

   Threshold project _____ Transactional Project _____

   Informational Project _____ Strategic project _____

2. Real Option for Staged Investment — Determine the value of being able to fund an information technology project as a series of expenditures that makes it easier to cancel the project if future conditions become unfavorable. For example, provide sufficient funding to design a system, then review the project before providing funds to build the system.

   Threshold project _____ Transactional Project _____

   Informational Project _____ Strategic project _____

3. Real Option to Change Scale — Determine the value of being able to develop an information technology project that can be easily expanded if the need arises. For example, spend additional money to purchase a minicomputer that has the capacity to handle more users in the future than you presently require.

   Threshold project _____ Transactional Project _____

   Informational Project _____ Strategic project _____

4. Real Option to Abandon — Determine the value of being able to divert the hardware, software and personnel to other uses if a project is canceled. For example, abandon a project using personal computers and transfer the computers to another project.

   Threshold project _____ Transactional Project _____

   Informational Project _____ Strategic project _____

5. Real Option to Switch — Determine the value of being able to easily switch from one product to another without being forced to start the project over. For example, developing a new customer database using a software package that uses SQL to access the database. If problems with the software arise, you can switch to another software package that also uses SQL, so that you do not need to redevelop the database from scratch.

   Threshold project _____ Transactional Project _____

   Informational Project _____ Strategic project _____

6. Real Option to Grow — Determine the value an information technology project has on the potential for future growth of the company. For example, a new marketing system may be developed, not to support an existing product, but rather to allow a new insurance product to be developed.

Threshold project	_____	Transactional Project	_____
Informational Project	_____	Strategic project	_____

Section 3

Instructions

Section 3 is examining whether some of the real options link together so that the sum of the values is either greater than or less than the value of the individual options added together. In other words, when looking at the value of the six real options does two plus two always equal four or are there some circumstances where the total is five or three?

From your perspective, are there any pairs of real options that logically belong together and should be valued together (i.e., if real option A is included in the analysis, then real option B should be included)? Alternatively, are there any pairs of real options that do not make sense to value together and should not be included together in a model (i.e., if real option A is included in the analysis, then real option B should not be included)?

Listed below are the six types of real options described in the previous section. In the space provided below, identify any pairs of options that either fit together or do not fit together. Provided below is space to identify three pairs for both categories. You do **not** need to fill in the three spaces under each category and you may fill in more if need be. Identify how ever many pairs you feel appropriate. If there are no pairs that you feel appropriate under either or both categories, leave the space blank.

1. Option to Defer 2. Option for Staged Investment 3. Option to Change Scale
4. Option to Abandon 5. Option to Switch 6. Option to Grow

Option pairs that fit together	Option pairs that do not fit together
1. _____ & _____	1. _____ & _____
2. _____ & _____	2. _____ & _____
3. _____ & _____	3. _____ & _____

Section 4

1. Have you heard the term **real option** before? YES NO

   a. If yes, where did you hear the term? _____

   _____

   _____

2. Circle the word or words that represent(s) how you are presently handling **real options**?

   QUANTITATIVELY QUALITATIVELY NEITHER

   a. If quantitatively, what is the approach you use? _____

   _____

   _____

   _____

   b. If qualitatively, what is the approach you use? _____

   _____

   _____

   _____

3. Did the value of the **real options**, either quantitative or qualitative, ever make the difference between approval or disapproval of a project?

   YES NO

   a. If yes, in approximately what percentage of projects? _____ %

4. Do you accept projects even when the quantifiable costs outweigh the quantifiable benefits (i.e., a negative net present value)?

   YES NO

   a. If yes, what are the reasons typically given? _____

   _____

   _____

   _____

b. Approximately what percentage of the projects are approved even with a negative net present value?

Threshold Projects _____ %

Transactional Projects _____ %

Informational Projects _____ %

Strategic Projects _____ %

5. Are there any actions that you take other than those listed in this questionnaire to incorporate the value of **real options** in your information technology valuation process?

YES NO

a. If yes, what actions? _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

6. If there are any comments you have concerning the use of **real options** in the information technology valuation process, please feel free to make them below.

APPENDIX 5

QUESTIONNAIRE COVER LETTER

June 20, 1995 (On LOMA Letterhead)

TO: LOMA Member Company Information Technology Officers

We are working with a graduate student and we need your help to make his research complete. Please fill in the enclosed questionnaire. It should only take about 15 minutes of your time. Now let me tell you about the study.

As you know, measuring the benefits of an information technology project, especially the intangible benefits, is a difficult and error-prone process. Recently, an approach has been developed that has the ability to quantify some of the intangible values. This approach is called "real options" and is similar in concept to valuing stock options. Real options can assist you in the analysis of projects and allow you to better determine a dollar value for a project's worth. Jerry Flatto, a doctoral student at the University of New Haven, is working with these real options trying to apply them to information technology projects.

To develop quantitative models that can assist you in valuing information technology projects, information about your needs is required. Your information will determine what types of information technology projects and real options should be included in the quantitative modeling. Limiting the types of projects and real options included in the modeling effort will decrease the time required to develop these models. More importantly, it allows the models to concentrate more heavily on those factors that you consider critical when evaluating information technology projects.

To solicit the required information, a questionnaire is attached. You may be assured of complete confidentiality. No individual results will ever be released. If you would like to receive a report but do not wish to share your identity with the graduate student please so indicate in a letter to me or on the survey form.

The results of this research will be summarized and you will receive a copy of the results along with a discussion of the next steps to be taken in developing quantitative models in the fall. Your participation in continuing efforts to develop quantitative models is welcome but not required.

Could you please complete the enclosed questionnaire by July 14, 1995. If you have any questions or comments concerning the questionnaire, please feel free to contact Jerry Flatto, at (910) 282-4852. Thank you for your cooperation.

Sincerely,

/s/ Ann Purr

APPENDIX 6

QUESTIONNAIRE

Use of Real Options in the Insurance Industry

Real options are being used to quantify, in dollars, the intangible benefits provided by management's flexibility to change decisions as further information is gathered. Real options are just starting to be used in certain industries such as pharmaceuticals and oil exploration.

A couple of things to keep in mind as you complete this questionnaire:

- The questionnaire is primarily soliciting your *opinions*, rather than looking for hard data.
- Please feel free to identify what actions or steps you would like to see taken to ensure real options will provide you with value-added benefits. If you need additional space, place attach a sheet of paper to this questionnaire.
- Remember that the answers you provide will help ensure that real options simply don't become another fad.

Definitions

- A **real option** is simply the flexibility that you have to alter a decision as further information becomes available. A **real option** allows you to put a value on your ability to change a project's direction in the future as you receive additional information about future conditions.

Six categories of **real options** are: -

- **Defer** — The flexibility of being able to postpone making a decision on whether to implement an information technology project as long as possible so that further information can be gathered.
- **Staged Investment** — The flexibility of being able to fund an information technology project as a series of expenditures that makes it easier to cancel the project if future conditions become unfavorable.
- **Change Scale** — The flexibility of being able to develop an information technology project that can be easily expanded if the need arises.
- **Abandon** — The flexibility of being able to divert the hardware, software and personnel to other uses if a project is canceled.
- **Switch** — The flexibility of being able to easily switch from one product to another without being forced to start the project over.
- **Grow** — The flexibility that an information technology project provides for the potential for future growth of the company.

Four types of information technology projects are:

- **Strategic** — Those that change an organization's product or the way that the organization competes in the marketplace. These projects are typically concerned with long-term objectives.
- **Informational** — Those that provide information for the general management of the organization and have medium-length objectives.
- **Transactional** — Those that support management in their day to day operations.
- **Threshold** — Those that are required to simply compete in the marketplace. In most cases, threshold projects are implemented in response to competitors' actions or governmental requirements.

Methods to incorporate the value of the real options in your analysis process are:

- **Quantitatively** — The value of the real options is included in the analysis with a dollar figure associated. This dollar figure has been computed using some type of mathematical model.
- **Qualitatively** — The value of the real options is included in the analysis without a dollar figure associated or with a dollar figure that has been determined by subjective techniques without a formal mathematical model being used.

In the space below, please provide your name, company name, and address.

Name: _____

Company: _____

Mailing address: _____

_____

City: _____ State/Province: _____ ZIP: _____

May your name and company information be released to Jerry Flatto?

YES_____ NO_____

If you answer **NO**, this page will be removed at LOMA before forwarding this questionnaire back to Jerry Flatto. In any case, all data obtained from this questionnaire will be kept strictly confidential and individual company data will not be released.

---

1. Have you heard the term **real option** before? YES _____ NO _____

   a. If no, please identify the term that you use, if any, to describe the concepts discussed in this questionnaire. _____

2. Did the value of the **real options**, either **quantitative** or **qualitative**, ever make the difference between approval or disapproval of a project?

   YES _____ NO _____

   a. If yes, in approximately what percentage of projects?

   Threshold Projects _____ %

   Transactional Projects _____ %

   Informational Projects _____ %

   Strategic Projects _____ %

3. Circle the word or words that represent(s) how you are presently handling **real options**.

   QUALITATIVELY QUANTITATIVELY NEITHER BOTH

   a. If qualitatively, how do you incorporate the value _____

   _____

   _____

   b. If quantitatively, what is the approach you use? _____

   _____

   _____

4. Do you accept projects even when the quantifiable costs outweigh the quantifiable benefits (i.e., a negative net present value)?

   YES _____ NO _____

   a. If yes, what are the reasons typically given? _____

   _____

   b. If yes, in approximately what percentage of projects? _____ %

5. Would you be willing to be contacted to discuss the use of **real options** in more detail?

   YES _____ NO _____

   a. If yes, what is your phone number? _____

6. If you have any comments concerning the use of **real options,** please feel free to make them below. *These comments can include what work you feel is necessary to make real options a useful analysis tool for you.*

Existing use of real options

The statements below are examining your present use of real options, either **quantitatively** or **qualitatively.** For each statement, please circle the answer corresponding to your agreement or disagreement. *If you use another term than the ones provided below to describe a category of flexibility, please write in the term by the appropriate line*

STRONGLY DISAGREE — NEUTRAL — STRONGLY AGREE

-3 ——— -2 ——— -1 ——— 0 ——— 1 ——— 2 ——— 3

I am presently including the real option to **defer** in my cost-benefit analysis process.

-3 ——— -2 ——— -1 ——— 0 ——— 1 ——— 2 ——— 3

I am presently including the real option for **staged investment** in my cost-benefit analysis process.

-3 ——— -2 ——— -1 ——— 0 ——— 1 ——— 2 ——— 3

I am presently including the real option to **change scale** in my cost-benefit analysis process.

-3 ——— -2 ——— -1 ——— 0 ——— 1 ——— 2 ——— 3

I am presently including the real option to **abandon** in my cost-benefit analysis process.

-3——— -2——— -1 ——— 0 ——— 1 ——— 2 ——— 3

I am presently including the real option to **switch** in my cost-benefit analysis process.

-3——— -2——— -1 ——— 0 ——— 1 ——— 2 ——— 3

I am presently including the real option to **grow** in my cost-benefit analysis process.

-3——— -2——— -1 ——— 0 ——— 1 ——— 2 ——— 3

Potential use of real options

The statements below are examining the **potential** usefulness that being able to **quantitatively** value the real options associated with an information technology project would have for you. This section is trying to determine: 1. Is the ability to quantify the dollar value of each of the six types of real options equally important? and 2. Is the ability to quantify the dollar value of any individual real option equally important for the four project types?

For each pair of real option and information technology project, indicate how strongly you either agree that being able to include a **quantitative** (i.e., dollar) value associated with the combination would be useful to you.

1. Real Option to **Defer**

Threshold project

-3—— -2— -1 — 0— 1 — 2 —— 3

Transactional Project

-3—— -2— -1 — 0— 1 — 2 —— 3

Informational Project

-3—— -2— -1 — 0— 1 — 2 —— 3

Strategic project

-3—— -2— -1 — 0— 1 — 2 —— 3

2. Real Option for **Staged Investment**

Threshold project

-3—— -2— -1 — 0— 1 — 2 —— 3

Transactional Project

-3—— -2— -1 — 0— 1 — 2 —— 3

Informational Project

-3—— -2— -1 — 0— 1 — 2 —— 3

Strategic project

-3—— -2— -1 — 0— 1 — 2 —— 3

3. Real Option to **Change Scale**

Threshold project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Transactional Project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Informational Project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Strategic project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

4. Real Option to **Abandon**

Threshold project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Transactional Project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Informational Project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Strategic project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

5. Real Option to **Switch**

Threshold project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Transactional Project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Informational Project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Strategic project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

6. Real Option to **Grow**

Threshold project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Transactional Project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Informational Project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Strategic project

-3—— -2— -1 — 0—— 1 —— 2 —— 3

Interactions between real options

This section is examining whether some of the real options link together so that the sum of the values is either greater than or less than the value of the individual options added together. In other words, when looking at the value of two of the six real options combined together, does two plus two always equal four or are there some circumstances where the total is five or three?

From your perspective, are there any pairs of real options that logically belong together and should be valued together (i.e., if real option A is included in the analysis, then real option B should be included)? Alternatively, are there any pairs of real options that

do not make sense to value together and should not be included together in a model (i.e., if real option A is included in the analysis, then real option B should not be included)?

If there are any pairs, please indicate this below. You do not need to fill in all three spaces. If there are no pairs that you feel are appropriate, leave the space blank.

1. Option to Defer 2. Option for Staged Investment 3. Option to Change Scale
4. Option to Abandon 5. Option to Switch 6. Option to Grow

Option pairs that fit together	Option pairs that do not fit together
a. _____ & _____	d. _____ & _____
b. _____ & _____	e. _____ & _____
c. _____ & _____	f. _____ & _____

APPENDIX 7

FIRST REMINDER POSTCARD

We need your help!

Recently LOMA mailed you a survey on the *"Use of real options in the insurance industry"*. We have not yet received your response. We would appreciate it if you could fill out the survey and return it to LOMA as soon as possible. If you have any questions or need a replacement survey, please contact LOMA at (404) 984-3733 or Jerry Flatto at (910) 282-4852. Remember, you need not have heard of the term "real option" to answer this survey. Rather, this survey seeks to determine if you are using the concepts underlying real options and if real options would potentially be useful to you.

Thank you for your assistance.

Ann M. Purr, FLMI, CSP, ACS
Assistant Vice President
Information Management Products and Services
Life Office Management Association

LOMA

APPENDIX 8

FOLLOW-UP LETTER

August 4, 1995 (On LOMA Letterhead)

Dear Information Processing Executive:

You may be receiving this questionnaire for the first time. There appears to be a problem with our previous mailing.

The questionnaire is about a financial analysis technique that may allow us to better quantify the intangible benefits associated with an information technology project.

Please complete the questionnaire and return it to LOMA in the envelope provided by August 25, 1995. It should take you fifteen minutes to complete the survey. Most questions ask for your opinions and do not require hard data.

The questionnaire tries to determine the impact of "real options" on your ability to value information technology projects. The first page provides definitions for each of the six types of real options.

Most likely, you have not heard of this term "real options," although I am sure you are familiar with the concepts it includes. Real options are, simply stated, terms we use to describe the flexibility we have to alter decisions as new information becomes available. Then we attach a dollar value to that flexibility to determine its value to our operation.

There are a number of analysis techniques that "academics" have insisted are vital to us. This questionnaire solicits input so that real options do not become a fad with no value-added benefit. As you complete the survey, feel free to identify additional steps that would ensure that real options ultimately have value. Should we spend more time expanding the concepts of real options, or just limit our analysis to a single information technology project?

You may be assured of complete confidentiality. No individual results will be released. The work is being done by Jerry Flatto, a doctoral student at the University of New Haven. The results will be summarized and you will receive a copy, along with a discussion of possible next steps. There is no obligation to pursue any of these next steps.

I look forward to your response by August 25, 1995. Questions on the content in the survey are best directed to Jerry Flatto at (910) 282-4852. If I can be of any further assistance, please give me a call.

Sincerely,

/s/ Ann M. Purr

AMP/js

APPENDIX 9

PHONE INTERVIEW LETTER

3607 Friendly Acres Drive
Greensboro, NC 27410-2960
(910) 282-4852
E-mail - flattoj@aurora.ncat.edu

Sept. 28, 1995

«Salutation» «First_Name» «Last_Name»
«Company»
«Work_Street_1»
«Work_Street_2»
«Work_City», «Work_State» «Work_Zip_Code»

Dear «Salutation» «Last_Name»:

You recently completed a survey concerning the use of real options. I would like to thank you for taking the time to complete the survey and your willingness to discuss real options with me in more detail. I will be contacting you by phone in the next week or two.

The purpose for this letter is to explain what information I am looking to gather from you over the phone concerning real options. This will give you a chance to think about the questions I pose below. I will try to take only a few minutes on the phone since I know your time is very valuable. Of course, I would be happy to discuss any other comments or questions that you might have.

The information I would like to solicit from you concerns how to ensure that real options will provide value and not become another "academic fad". Specifically the type of information I am looking for includes:

- What type of work would you like to see done on real options to prove that they have value in your analysis process? Possible answers could include any or all of the following:
  - How other industries are presently using real options.
  - How the real options will impact valuing the projects.
  - How the value of real options can be qualitatively or quantitatively included in the cost-benefit analysis process.
- How would you use real options in evaluating an information technology project?

- Do you see any value for real options to evaluate projects other than information technology projects? If so, what type of projects?

The May-June 1995 issue of *Harvard Business Review* had an article discussing real options. I would happy to send you a copy of this article or other articles I have if you have any interest. As the survey indicated, you will also receive a summary of my results when I am completed, hopefully in another few months.

If you would like to contact me prior to my contacting you, my address, phone number, and electronic mail address are listed at the top of this letter.

Thank you again for your time and cooperation.

Sincerely,

Jerry Flatto

APPENDIX 10

MINI-QUESTIONNAIRE

Questionnaire on Real Options

We have not yet received your response to the questionnaire concerning the use of real options in the insurance industry. This is the final request you will receive. Your answers are important and can help determine the type of work that must be done with real options to make them useful.

If you are unable or unwilling to complete the real options questionnaire sent previously, please take 1 or 2 minutes and answer the questions below. No name or company identification is required. LOMA will remove your mailing label before forwarding this page to Jerry Flatto.

You can choose more than one answer in the questions below. If you do so, please indicate some sort of priority (e.g., 1 - most important, 2 - second most important, etc.) to your answers.

Why haven't you returned the questionnaire?

_____Never received it.

_____Too busy with other work.

_____Don't feel I know enough about real options to complete it.

_____Don't believe that real options have any value in assessing information technology projects.

_____Don't believe that information technology projects require quantitative justification.

_____Feel that existing information technology analysis techniques are adequate and more techniques aren't needed.

_____Other _____

What further work would you like to see done with real options to demonstrate that they do have potential for assisting in valuing information technology projects?

_____Descriptions from other industries on how real options are being used.

_____Descriptions and examples of how real options are inherent in information technology projects and how the real options will impact valuing the projects.

_____Work on how the value of real options can be qualitatively included in the cost benefit analysis process for information technology projects.

_____Work on how the value of real options can be quantitatively included in the cost benefit analysis process for information technology projects.

_____Other _____

_____

_____

If you have any comments concerning real options and/or valuing information technology projects indicate them below.

_____

_____

_____

_____

_____

_____

_____

APPENDIX 11

EXECUTIVE REPORT COVER LETTER

January 24, 1996

Dear insurance company executive:

I wanted to thank you for the time and effort you spent completing the questionnaire on *real options* that you were previously sent. The cover letter attached to the questionnaire stated that you would receive a report summarizing the results of the research effort. This report is enclosed with this letter.

The report provides an overview of the research effort, including the research model that was tested. It also includes analyses and interpretation of the data obtained from the questionnaire. Finally, the report includes recommendations for further research.

The report recommends that the next step in the research should be the expansion of existing information system models and associated cost benefit analysis models to incorporate the impact of real options. These modified models would show the impact that including the flexibility provided by the real options would have in reducing the riskiness associated with a project.

Included with this package is a self-addressed, stamped postcard with a single question on it. I would greatly appreciate it if you would answer the question and return the postcard. The response is completely anonymous and no identifying information is requested. The question asks: "Would you be more likely to use real options if you were provided with a number of examples demonstrating how real options can be included in your existing development and cost benefit analysis models?"

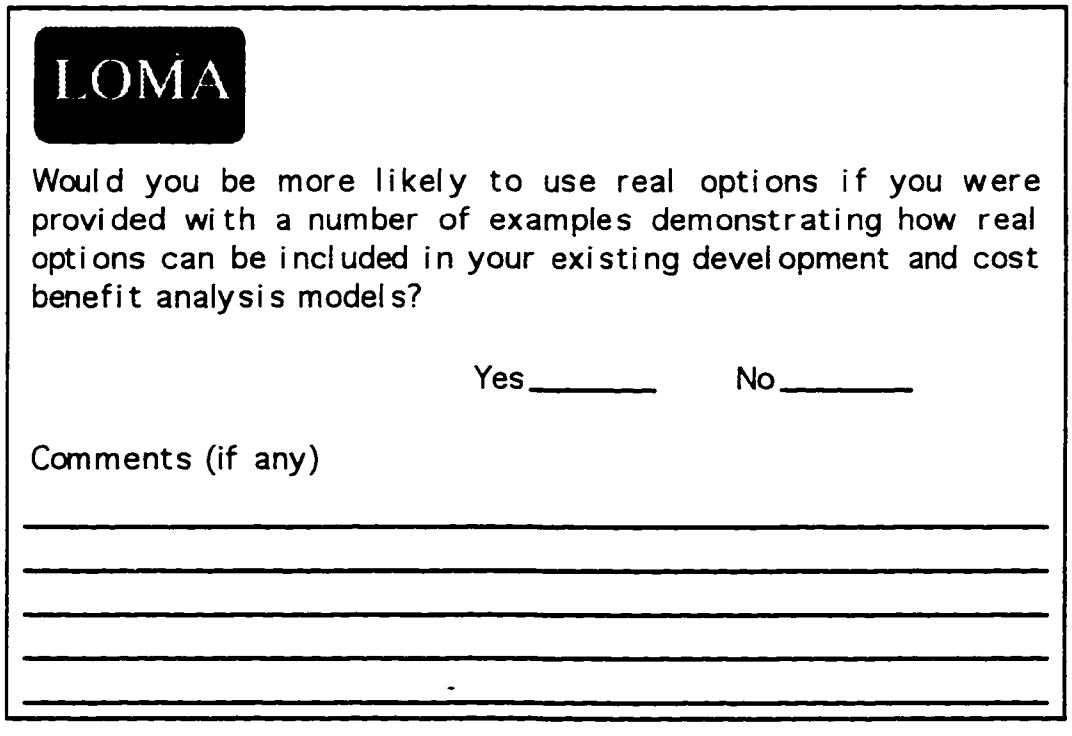
Again, I would like to thank you for your time and effort in this research. The attached report includes contact information for the author, Jerry Flatto, who would be happy to discuss his research with you.

Sincerely,

Ann Purr

APPENDIX 12

FEEDBACK REQUEST POSTCARD



REFERENCES

A survey of insurance companies: A question of balance. 1990. *Economist* (Oct. 27).

Abrahams, S. B., A. D. Flowerdew, and J. U. Smith. 1978. Correspondence on SOSOping or sophistical obfuscation of self-interest and prejudice. *Journal of the Operational Research Society* 29 (2):173-178.

Accola, W. L. 1994. Assessing risk and uncertainty in new technology investments. *Accounting Horizons* 8 (3):19-35.

Accola, W. L., S. P. Agrawal, and C. W. Holsapple. 1995. Adaptive decision support systems for evaluating risk and uncertainty in capital investment decisions: Opportunities for future research. *Managerial Finance* 21 (3):1-16.

Ackoff, R. L. 1981. *Creating the corporate future: Plan or be planned for.* New York City, NY: John Wiley & Sons.

Agarwal, R., M. R. Tanniru, and M. Dacruz. 1992. Knowledge-based support for combining qualitative and quantitative judgments in resource allocation decisions. *Journal of Management Information Systems* 9 (1):165-184.

Agmon, T. 1991. Capital budgeting and the utilization of full information: Performance evaluation and the exercise of real options. *Managerial Finance* 17 (2):42-50.

Andreou, S. A. 1990. A capital budgeting model for product-mix flexibility. *Journal of Manufacturing and Operations Management* 3:5-23.

Antle, R., and G. Eppen. 1985. Capital rationing and organizational slack in capital budgeting. *Management Science* 31 (February):163-174.

Antle, R., and J. Fellingham. 1990. Capital rationing and organizational slack in a two period model. *Journal of Accounting Research* 28 (Spring):1-24.

Arbel, A., and A. Seidmann. 1984. Performance evaluation of flexible manufacturing systems. *IEEE Transactions on Systems, Man, and Cybernetics* 14 (July-August):606-617.

Arrow, K. J. 1962. The economic implications of learning by doing. *Review of Economic Studies* 29 (6):155-173.

Ashton, D. J., and D. R. Atkins. 1978. Interactions in corporate financing and investment decisions — implications for capital budgeting: A further comment. *Journal of Finance* 33 (5):1447-1453.

Bacon, C. J. 1992. The use of decision criteria in selecting information systems/technology investments. *MIS Quarterly* 16 (3):335-353.

Badiru, A. B. 1990. A management guide to automation cost justification. *Industrial Engineer* 22 (2):27-30.

Baily, M. N., and A. Chakrabarti. 1988. *Innovation and the productivity crisis.* Washington, D.C.: Brookings Institute.

Baily, M. N., and R. J. Gordon. 1988. The productivity slowdown, measurement issues, and the explosion of computer power. In *Brookings Papers on Economic Activity*, edited by W. C. Brainard and G. L. Perry. Washington, D.C: The Brookings Institute.

Baker, G. A. 1993. Success factors affecting computer-based information system performance in agribusiness. *Agribusiness* 9 (4):309-316.

Baksh, S. N. 1986. The effectiveness of capital budgeting procedures for dealing with risk. PhD., University of Michigan.

Bar-Yosef, S. 1977. Interactions of corporate finance and investment decisions — implications for capital budgeting: Comment. *Journal of Finance* 32 (1):211-220.

Bartling, A. C. 1995. Trends in managed care. *Healthcare Executive* 10 (2):6-11.

Barua, A., C. H. Kriebel, and Mukhopadhyay. 1995. Information technologies and business value: An analytic and empirical investigation. *Information Systems Research* 6 (1):3-23.

Belcher, L. W., and H. J. Watson. 1993. Assessing the value of Conoco's EIS. *MIS Quarterly* 17 (3):239-253.

Bender, D. H. 1986. Financial impact of information processing. *Journal of Management Information Systems* 3 (2):22-32.

Benjamin, R. I. 1982. Information technology in the 1990's: A long range planning scenario. *MIS Quarterly* 6 (2):18-19.

Best's insurance reports — Life-Health. 1995a. Oldwick, NJ: A.M. Best.

Best's insurance reports — Property-Casualty. 1995b. Oldwick, NJ: A.M. Best.

Bharadwaj, S. G., P. R. Varadarajan, and J. Fahy. 1993. Sustainable competitive advantage in service industries: A conceptual model and research propositions. *Journal of Marketing* 57 (4):83-99.

Black, F., and M. Scholes. 1973. The pricing of options and corporate liabilities. *Jounral of Political Economy* 81 (3):637-659.

Boczany, W. J. 1983. Justifying office automation. *Journal of Systems Management* 34 (7):15-19.

Bollen, K. A., and K. H. Barb. 1981. Pearson's R and coarsely categorized measures. *American Sociological Review* 46 (April):232-239.

Bonczek, R. H., C. W. Holsapple, and A. B. Whinston. 1980. Future directions for developing Decision Support Systems. *Decision Sciences* 11 (2):337-356.

Boynton, A. C., and R. W. Zmud. 1984. An assessment of critical success factors. *Sloan Management Review* 25 (4):17-27.

Brealey, R., and S. Myers. 1991. *Principles of corporate finance*. Fourth ed. New York City, NY: McGraw-Hill Publishing Company.

Brennan, M., and E. Schwartz. 1985. Evaluating natural resource investments. *Jounral of Business* 58 (2):135-157.

Brennan, M. J. 1995. Corporate finance over the past 25 years. *Financial Management* 24 (2):9-22.

Bresnahan, T. F. 1986. Measuring the spillovers from technical advance: Mainframe computers in financial services. *American Economic Review* 76 (4):742-755.

Broadbent, M., and H. Lofgren. 1993. Information delivery: Identifying priorities, performance, and value. *Information Processing & Management* 29 (6):683-701.

Brookfield, D. 1995. Risk and capital budgeting: Avoiding the pitfalls in using NPV when risk arises. *Management Decision* 33 (8):56-59.

Brown, R. M., A. W. Gatian, and J. O. Hicks, Jr. 1995. Strategic information systems and financial performance. *Journal of Management Information Systems: JMIS* 11 (4):215-248.

Brynjolfsson, E. 1993. The productivity paradox of information technology. *Communications of the ACM* 36 (12):67-77.

Brynjolfsson, E. 1994. Paradox lost? *Cio* 7 (14):26-28.

Brynjolfsson, E., and L. Hitt. 1993. New evidence on the returns to information systems. Cambridge, MA: MIT Sloan School.

Burger, K. 1995. Preventing IS irrelevance. *Insurance & Technology* 20 (9):48.

Busby, J. S., and C. G. C. Pitts. 1995. Investment and unpredictability: Why yardsticks mislead us. *Management Accounting London* 73 (8):38-40.

Byers, C. R., and D. Blume. 1994. Tying critical success factors to systems development. *Information & Management* 26 (1):51-61.

Campbell, G. 1987. MIS faces restructuring, CIPs told. *Computing Canada* 13 (21):1, 8-9.

Canada, J. R., and W. G. Sullivan. 1989. *Economic and multiattribute evaluation of advanced manufacturing systems*. Englewood Cliffs, NJ: Prentice Hall.

Carey, D. 1993. Back to school - I.T. visits M.I.T. *I.T. Magazine* 25 (9):12-16.

Carlson, W. M., and B. C. McNurlin. 1992. Do you measure up? *Computerworld* 26 (49):95-98.

Carr, P. 1988. The valuation of sequential exchange opportunities. *Journal of Finance* 43 (5):1235-1256.

Carter, M. P. 1985. The valuing of management information. Part I: Bayesian approach. *Journal of Information Science* 10 (1):1-9.

Cash Jr., J. I., and B. Konsynski. 1985. IS redraws competitive boundaries. *Harvard Business Review* 63 (2):134-142.

Chang, C., and C. Lee. 1992. Information acquisition as a business strategy. *Southern Economic Journal* 58 (3):750-761.

Childs, P. D. 1995. Capital budgeting for interrelated projects in a real options framework. PhD, University of Wisconsin - Madison.

Cliff, V. 1990. Is IT value for money? *ReActions* 8:44-46.

Cooke, D. P., and E. B. Parrish. 1992. Justifying technology: Not measuring up. *CIO* 5 (14):84-85.

Cooper, D., and G. Petry. 1994. Corporate performance and adherence to shareholder wealth-maximizing principles. *Financial Management* 23 (1):71-78.

Cooper, W. D., M. F. Cornick, and A. Redman. 1992. Capital budgeting: A 1990 study of Fortune 500 company practices. *Journal of Applied Business Research* 8 (3):20-23.

Copeland, T., and J. F. Weston. 1992. *Financial theory and corporate policy*. Fourth ed. Reading, Ma.: Addison-Wesley.

Cox, J. C., and M. Rubinstein. 1985. *Options market*. Englewood Cliffs, NJ: Prentice-Hall.

Cristie, B. 1981. *Face to file communications: A psychological approach to information systems*. New York City, NY: John Wiley & Sons.

Daniele, E. 1995. Ready, willing, & able. *Insurance & Technology* 20 (5):26-33.

Dasgutpa, P., and J. Stiglitz. 1980. Uncertainty, industrial structure and the speed of R&D. *Bell Journal of Economics* 11 (3):1-28.

Davenport, T. H. 1989. The case of the soft software proposal. *Harvard Business Review* 67 (3):12-24.

Davis, G. B. 1976. *Management information systems.* New York City, NY: McGraw-Hill.

Denison, E. F. 1989. *Estimates of productivity change by industry: An evaluation and an alternative.* Washington, DC: The Brookings Institute.

Dertouzos, M., R. Lester, and R. Solow. 1989. *Made in America: Regaining the Productive Edge.* Cambridge, MA: MIT Press.

Dirks, P. 1994. MIS investments for operations management^ Relevant costs and revenues. *International Journal of Production Economics* 35 (1-3):137-148.

DiRomualdo, A. P. 1990. Toward asset-based IT. *CIO* 4 (3):18-19.

Dixit, A. K., and R. S. Pindyck. 1994. *Investment under uncertainty.* Princeton, NJ: Princeton University Press.

Dixit, A. K., and R. S. Pindyck. 1995. The options approach to capital investment. *Harvard Business Review* 73 (3):105-115.

Drucker, P. F. 1995. The information executives truly need. *Harvard Business Review* 73 (1):54-62.

Due, R. T. 1989. Determining economic feasibility: Four cost/benefit analysis methods. *Journal of Information Systems Management* 6 (4):14-19.

Due, R. T. 1994. The productivity paradox revisited. *Information Systems Management* 11 (1):74-76.

Dyle, W. F. 1995. Your bloody ROIT. *Cio* 8 (21):100, 198.

Eby, M., and P. Kufahl. 1995. Managing computer-based technologies. *Transmission & Distribution* 47 (7):30-38.

Epstein, B. J., and W. R. King. 1982. An experimental study of the value of information. *Omega* 10 (3):249-258.

Evans, D. A., and S. M. Forbes. 1993. Decision making and display methods: The case of prescription and practice in capital budgeting. *Engineering Economist* 39 (1):87-92.

Fama, E. F., and A. Laffer. 1971. Information and capital markets. *Journal of Business* 44 (3):289-298.

Farbey, B., F. Land, and D. Targett. 1993. *How to assess your IT investment.* Oxford, UK: Butterworth Heinemann.

Farinella, M. A. 1995a. A familiar refrain: Rates squeeze L/H profits. *BestWeek Life/Health Supplement*, April 10.

Farinella, M. A. 1995b. Slumping demand, weak distribution depress Life/Health premiums. *BestWeek Life/Health Supplement*, June 19.

Farrell, C. 1995. 1995 industry outlook. *Business Week* (3406):54-57+.

Feltham, G. A. 1968. The value of information. *The Accounting Review* 43 (4):684-696.

Fields, D. 1994. Database marketing. *Business Week*, Sept. 5, 56-61.

Fisher, A. 1995. Information economics: A new paradigm for information management and technology decision-making. *Government Accountants Journal* 44 (2):30-34.

Fitzgerald, M. D. 1987. *Financial options.* London, England: Euromoney Publications Limited.

Flatto, J. P. 1992. *Can the costs and benefits of information systems be quantified? A survey of insurance companies.* West Haven: University of New Haven.

Fortin, D. 1993. True costs must be determined. *Computing Canada* 19 (11):28.

Framel, J. E. 1993. Information value management. *Journal of Systems Management* 44 (12):16-21+.

Freeman, M., and G. Hobbes. 1991. Capital budgeting: Theory versus practice. *Australian Accountant* 61 (8):36-41.

Freeman, R. E. 1984. *Strategic management: A stakeholder approach.* Boston, MA: Pittman.

Fung, A. K. 1995. Entry and exit decisions with competition under uncertainty (real options, capital budgeting). PhD, University of Wisconsin - Madison.

Gagne, P. 1994. Improving service through technology. *Canadian Insurance* 99 (1):18-19.

Gehr Jr., A. 1981. Risk adjusted capital budgeting using arbitrage. *Financial Management* 10 (4):14-19.

Ghandforoush, P. 1982. Model for mini-computer selection. *Journal of Systems Management* 33 (6):11-13.

Gillin, P. 1994a. Premier 100: Feelin' groovy. *Computerworld* (Sept.19):38-39.

Gillin, P. 1994b. Premier 100: Pressure to produce. *Computerworld* (Sept. 19):10-12.

Glazer, R. 1991. Marketing in an information intensive environment: Strategic implications of knowledge as an asset. *Journal of Marketing* 55 (October):1-19.

Glazer, R. 1993. Measuring the value of information: The information-intensive organization. *IBM Systems Journal* 32 (1):99-110.

Gold, C. L. 1993. Divide and conquer. *Chief Information Officer Journal* 6 (2):33-35.

Green, W. R. 1980. Value added criterion for decision support system development. *Journal of Systems Management* 31 (5):15-19.

Gregory, A. J., and M. C. Jackson. 1992. Evaluation methodologies: A system for use. *Journal of the Operational Research Society* 43 (1):19-28.

Greis, P., and R. Materna. 1993. Value lesson for B-school. *Software Magazine* 13 (4):132, 131.

Grenadier, S. R. 1992. Real estate and other long-term development projects. Ph.d., Harvard University.

Hamilton, J. O. 1995. Medicine's new weapon: Data. *Business Week*, March 27, 184-188.

Hammer, M. 1990. Reengineering work: Don't automate, obliterate. *Harvard Business Review* 68 (4):104-112.

Harper Jr., R. M., N. G. Apostolou, and B. P. Hartman. 1992. The analytic hierarchy process: An empirical examination of aggregation and hierarchical structuring. *Behavioral Research in Accounting* 59 (October):5225-5250.

Harris, S. E., and J. L. Katz. 1989. Differentiating organizational performance using information technology managerial control ratios in the insurance industry. *Office: Technology and People* 5 (4):275-297.

Harris, S. E., and J. L. Katz. 1991a. Firm size and the information technology investment intensity of life insurers. *MIS Quarterly* 5 (3):333- 352.

Harris, S. E., and J. L. Katz. 1991b. Organizational performance and information technology investment intensity in the insurance industry. *Organizational Science* 2 (3):263-295.

Hayes, R., and W. Abernathy. 1980. Managing our way to economic decline. *Harvard Business Review* 58 (4):66-77.

Hayes, R., and D. Garvin. 1982. Managing as if tomorrow mattered. *Harvard Business Review* 60 (3):71-79.

Heenan, D. A. 1976. Quantitative techniques for today's decision makers. *Harvard Business Review* 54 (3):32.

Hertz, D. B. 1990. Risk analysis in capital investment. In *Strategic Planning: Models and Analytical Techniques*, edited by G. R. Dyson. New York City, NY: John Wiley and Sons.

Hilton, R. W. 1979. The determinants of cost information value: An illustrative analysis. *Journal of Accounting Research* 17 (2):411-435.

Hilton, R. W. 1981. The determinants of information value: Synthesizing some general results. *Management Science* 27 (1):57-64.

Hirshleifer, J. 1973. Where are we in the theory of information. *American Economic Review* 63 (2):31-39.

Hogarth, R. 1980. *Judgment and choice: The psychology of decision.* New York City, NY: Wiley.

Hogue, J. T., and H. J. Watson. 1983. Management's role in the approval and administration of decision support systems. *MIS Quarterly* 7 (2):15-26.

Horngren, C. T., and G. I. Sundem. 1991. *Introduction to management accounting.* Fourth ed. Englewood Cliffs, NJ: Prentice-Hall.

Howell, R. A., et al. 1987. *Management Accounting in the New Manufacturing Environment.* Montvale, NJ: National Association of Accountants.

Hoyt, R. J. 1995. Using information technology to reach objectives. *National Underwriter (Life/Health/Financial Services)* 99 (50):12.

Ingersoll, J., and S. Ross. 1992. Waiting to invest: Investment and uncertainty. *Journal of Business* 65 (1):1-29.

Ingrassia, P. V. 1994. Harnessing technology to remain competitive. *Best's Review [Prop/Casualty]* 95 (1):84-85.

Ives, B., and G. Learmonth. 1984. The information system as a competitive weapon. *Communications of the ACM* 27 (12):1193-1201.

Johnson, H., and M. Vitale. 1988. Creating competitive advantage with interorganizational information systems. *MIS Quarterly* 12 (2):153-165.

Jones, D. C. 1994. North American companies see service as key tech role. *National Underwriter [Life/Health/Financial Services]* 98 (44):14.

Kamrad, B. 1995. A lattice claims model for capital budgeting. *IEEE Transactions on Engineering Management* 42 (2):140-149.

Kanter, J. 1987. Progress in Tracking the Elusive ROI of New Systems. *Directors & Boards* 11 (4):38-40.

Kanter, J., and J. Miserendino. 1987. Systems architectures link business goals and IS strategies. *Data Management* 25 (11):17-22, 25.

Kaplan, R. 1986. Must CIM be justified by faith alone. *Harvard Business Review* 64 (2):87-95.

Kasanen, E., and L. Trigeorgis. 1993. A market utility approach to investment valuation. *European Journal of Operational Research* 74 (2):294-309.

Kathan, D. W. 1995. Application of option pricing concepts to regulated utility investment decision making. PhD., University of Pennsylvania.

Keen, P. G. W. 1981. Value analysis: Justifying decision support systems. *MIS Quarterly* 5 (1):1-15.

Keen, P. G. W. 1991. Wa$te not, want not. *Computerworld* 25 (8):77-79.

Keen, P. G. W. 1992. Positioning the IS future. *Modern Office Technology* 37 (9):12, 14.

Keen, P. G. W., and M. Scott-Morton. 1978. *Decision support systems: An organizational perspective*. Reading, MA.: Addison-Wesley.

Kehoe, D., D. Little, and A. Lyons. 1993. Strategic planning for information systems enhancement. *Integrated Manufacturing Systems* 4 (2):29-36.

Kemna, A. 1993. Case studies on real options. *Financial Management* 22 (3):259-270.

Kenny, R. L., and H. Raifa. 1976. *Decisions with multiple objectives: Preferences and value tradeoffs*. New York City, NY: John Wiley and Sons.

Kensinger, J. 1987. Adding the value of active management into capital budgeting equation. *Midland Corporate Finance Journal* (Spring):31-42.

Kester, W. C. 1984. Today's options for tomorrow's growth. *Harvard Business Review* 62 (2):153-160.

Kettinger, W. J., et al. 1994. Strategic information systems revisited: A study in sustainability and performance. *MIS Quarterly* 18 (1):31-58.

King, J. L., and E. L. Schrems. 1978. Cost benefit analysis in information systems development and operation. *Computing Surveys* 10 (1):19-35.

Kleijnen, J. P. 1984. Quantifying the benefits of information systems. *European Journal of Operational Research* 15 (1):38-45.

Kogut, B. 1991. Joint ventures and the option to expand and acquire. *Management Science* 37 (1):19-33.

Kogut, B., and N. Kulatilaka. 1994a. Operating flexibility, global manufacturing, and the option value of a multinational network. *Management Science* 40 (1):123-139.

Kogut, B., and N. Kulatilaka. 1994b. Options thinking and platform investments: Investing in opportunity. *California Management Review* 36 (2):52-71.

Krohe, J., Jr. 1993. The productivity pit. *Across the Board* 30 (8):16-21.

Kulatilaka, N. 1988. Valuing the flexibility of flexible manufacturing systems. *IEEE Transactions on Engineering Management* 35 (4):250-257.

Kulatilaka, N. 1993. The value of flexibility: The case of a dual-fired industrial steam boiler. *Financial Management* 22 (3):271-280.

Kulatilaka, N., and A. Marcus. 1988. A general formulation of corporate operating options. *Research in Finance*:183-200.

Kulatilaka, N., and A. Marcus. 1992. Project valuation under uncertainty: When does DCF fail? *Journal of Applied Corporate Finance* (Fall):92-100.

Kulatilaka, N., and L. Trigeorgis. 1993. The general flexibility to switch: Real options revisited. *International Journal of Finance* (December).

Labovitz, S. 1970. The assignment of numbers to rank order categories. *American Sociological Review* 34 (June):515-524.

Lacava, G. J., and D. S. Tull. 1982. Determining the expected value of information for new product information. *Omega* 10 (4):383-389.

Lamberton, D. M. 1971. *Economics of information and knowledge*. Middlesex, England: Penguin Books.

Land, F. F. 1976. Evaluation of system goals in determining a design strategy for a computer based information system. *Computer Journal* 19 (4):290-294.

Laudon, K. C., and J. P. Laudon. 1996. *Management information systems: Organizations and technology*. Fourth ed. New York City, NY: MacMillan Publishing Company.

Lembersky, M. R., and U. H. Chi. 1984. Decision simulators speed implementation and improve operations. *Interfaces* 14 (2):1-15.

Liberatore, M. J., T. F. Monahan, and D. E. Stout. 1992. A framework for integrating capital budgeting analysis with strategy. *Engineering Economist* 38 (1):31-43.

Litecky, C. R. 1981. Intangibles in cost/benefit analysis. *Journal of Systems Management* 32 (2):15-17.

Lohmann, J. R., and S. N. Baksh. 1993. The IRR, NPV, and payback period and their relative performance in common capital budgeting decision procedures for dealing with risk. *Engineering Economist* 39 (1):17-47.

Changing horizon for insurance: Charting a course for success. 1984. Atlanta, GA: Life Office Management Association and Arthur Andersen.

The new life insurance financial management structure. 1988. Atlanta, GA: Life Office Management Association and Tillinghast.

Loveman, G. 1991. Cash drain, no gain. *Computerworld* 25 (47):69-72.

Lund, D., and B. Oksendal. 1991. *Financial and nonfinancial option valuation.* New York City, NY: North-Holland.

Maglitta, J. 1993. Squeeze play. *Computerworld* 27 (16):86-89+.

Majd, S., and R. Pindyck. 1987. Time to build, option value, and investment decisions. *Journal of Financial Economics* 7 (27):7-27.

Margrabe, W. 1978. The value of an option to exchange one asset for another. *Journal of Finance* 33 (1):177-186.

Marschak, J. 1968. Economics of inquiring, communicating and deciding. *American Economic Review* 58 (2):1-18.

Martin, R. 1989. *The utilisation and efficiency of IS: A comparative analysis.* Oxford, UK: Oxford Institute of Information Management.

Mason, R. M. 1979. *A study of perceived benefits of information analysis center services.* Atlanta, GA: Metrics, Inc.

Mason, S. P., and R. C. Merton. 1985. The role of contingent claims analysis in corporate finance. In *Recent advances in corporate finance*, edited by E. Altman and M. Subrahmanyam. Homewood, IL: Irwin.

Mayewski, L. G., and M. L. Albanese. 1995. Review and strategy: Strength, strategy or both? *BestWeek Life/Health Supplement*, January 12.

McDonald, R., and D. Siegel. 1985. Investment and the valuation of firms when there is an option to shut down. *International Economic Review* 26 (2):331-349.

McDonald, R., and D. Siegel. 1986. The value of waiting to invest. *Quarterly Journal of Economics* 101 (4):707-727.

McDonough, A. 1963. *Information economics and management systems.* New York City, NY: McGraw-Hill Book Company.

McGahan, A. M. 1993. The effect of incomplete information about demand on preemption. *International Journal of Industrial Organization* 11 (3):327-346.

McKeown, P. G., and R. A. Leitch. 1993. *Management information systems: Managing with computers*. Forth Worth, TX: The Dryden Press.

McLean, E. R., and G. Riesing. 1977. The MAPP system: A decision support system for financial planning and budgeting. *Database* 8 (3):9-14.

Melone, N. P., and T. J. Wharton. 1984. Strategies for MIS project selection. *Journal of Systems Management* 35 (2):26-33.

Menon, A. 1993. Are we squandering our intellectual capital? *Marketing Research: A Magazine of Management & Applications* 5 (3):18-22.

Merton, R. C. 1973. Theory of rational option pricing. *Bell Journal of Economics and Management Science* 4 (1):141-183.

Michel, A., and G. Ostertag. 1974. The Role Of Sensitivity-Analysis In a Capital-Expenditure Planning Information System. *Management International Review*:23-29.

Money, A., D. Tromp, and T. Wegner. 1988. The quantification of decision support benefits within the context of value analysis. *MIS Quarterly* 12 (2):223-236.

Morck, R., E. Schwartz, and D. Stangeland. 1989. The valuation of forestry resources under stochastic prices and inventories. *Journal of Financial and Quantitative Analysis* 24 (December):473-487.

Morrison, C. J., and E. R. Berndt. 1990. Assessing the productivity of information technology equipment in the U.S. manufacturing industries: National Bureau of Economic Research.

Morrissey, J. 1995. Info systems refocus priorities. *Modern Healthcare* 25 (7):65-72.

Myers, S. C. 1974. Interactions of corporate finance and investment decisions — implications for capital budgeting. *Journal of Finance* 29 (1):1-25.

Myers, S. C. 1977. Determinants of corporate borrowing. *Journal of Financial Economics* 5:147-175.

Myers, S. C. 1984. Finance theory and financial strategy. *Interfaces* 14 (1):126-137.

Myers, S. C., and S. Majd. 1990. Abandonment value and project life. *Advances in Futures and Options Research*:1-21.

Nairn, G. 1988. Going for IT. *Infomatics* (July):34-44.

Neises, S. J., and R. E. Bennett. 1989. Automan — decision support software. *Management Accounting* 71 (November):58-60.

Nelson, K. L. 1995. Underwriters go high-tech. *Best's Review (Prop/Casualty)* 95 (12):30-34.

Newton, D. P., and A. W. Pearson. 1994. Application of option pricing to R&D. *R&D Management* 24 (1):83-89.

Nichols, N. A. 1994. Scientific management at Merck: An interview with CFO Judy Lewent. *Harvard Business Review* 72 (1):89-99.

Noyelle, T., Ed. 1990. *Skills, wages, and productivity in the service sector.* Boulder, CO: Westview Press.

Osterman, P. 1986. The impact of computers on the employment of clerks and managers. *Industrial and Labor Relations Review* 39 (2):175-186.

Ott, S. H. 1992. Valuing and timing R&D using a real options pricing framework; including an application to the development of Lunar Helium-3 Fusion. Ph.d., The University of Wisconsin - Madison.

Oxenfeldt, A. R. 1979. Cost benefit analysis for executive decision making. In *American Management Association Proceedings*: American Management Association.

Paddock, J., D. Siegel, and J. Smith. 1988. Option valuation of claims on real assets: The case of offshore petroleum leases. *Quarterly Journal of Economics* 103 (3):479-508.

Panko, R. R. 1991. Is office productivity stagnant? *MIS Quarterly* 15 (6):190-203.

Pant, S., and L. Ruff. 1995. Issues in economic justification for flexible manufacturing systems and some guidelines for managers. *Information Resources Management Journal* 8 (1):26-34.

Parker, M. M., and R. J. Benson. 1987. Information economics: An introduction. *Datamation* 33 (23):86-96.

Parker, M. M., and R. J. Benson. 1989. Enterprisewide information economics: Latest concepts. *Journal of Information Systems Management* 6 (4):7-13.

Parker, M. M., R. J. Benson, and H. E. Trainor. 1988. *Information economics: Linking business performance to information technology.* Englewood Cliffs, NJ: Prentice-Hall.

Pastore, R. 1992. Justifying technology: Many happy returns. *CIO* 5 (14):66-74.

Pellow, A., and T. D. Wilson. 1993. The management information requirements of heads of university departments: A critical success factors approach. *Journal of Information Science Principles & Practice* 19 (6):425-437.

Pickles, E., and J. L. Smith. 1993. Petroleum property valuation: A binomial lattice implementation of option pricing theory. *Energy Journal* 14 (2):1-26.

Pieptea, D. R., and E. Anderson. 1987. Price and value of decision support systems. *MIS Quarterly* 11 (4):515-528.

Pike, R. 1989. Do sophisticated capital budgeting approaches improve investment decision-making effectiveness. *Engineering Economist* 21 (4):149-161.

Pindyck, R. 1988. Irreversible investment, capacity choice, and the value of the firm. *American Economic Review* 78 (5):969-985.

Pollalis, Y. A., and I. H. Frieze. 1993. A new look at critical success factors in IT. *Information Strategy: The Executive's Journal* 10 (1):24-34.

Porter, M. 1985. *Competitive advantage*. New York City, NY: Free Press.

Porter, M. E., and V. E. Millar. 1985. How information gives you competitive advantage. *Harvard Business Review* 63 (4):149.

Quigg, L. J. 1991. Option based land valuation. Ph.d., University Of California, Berkeley.

Quigg, L. J. 1993. Empirical testing of real option-pricing models. *Journal of Finance* 48 (2):621-640.

Quinlan, T. A. 1990. Here's what's missing from MIS cost control. *Software Magazine* 10 (12):59-67.

Rackoff, N., C. Wisemann, and W. Ullrich. 1985. Information system for competitive advantage: Implementation of a planning process. *MIS Quarterly* 10 (2):107-119.

Radner, R. 1968. Competitive equilibrium under uncertainty. *Econometrica* 36 (1):31-58.

Repo, A. J. 1989. The value of information: Approaches in economics, accounting, and management science. *Journal of the ASIS* 40 (2):68-85.

Ritchken, P. 1987. *Options: Theory, strategy and applications*. Glenview, IL: Scott, Foresman and Company.

Rivard, E., and K. Kaiser. 1989. The Benefit of Quality IS. *Datamation* 35 (2):53-58.

Roach, S. S. 1991. Services under siege. *Harvard Business Review* 69 (5):82.

Roach, S. S. 1994a. Best case study of all. *Forbes* Aug. 29:27.

Roach, S. S. 1994b. Premier 100: Lessons of the productivity paradox. *Computerworld*:55.

Rockart, J. F. 1979. Chief executives define their own data needs. *Harvard Business Review* 57 (2):81-93.

Ross, S. A. 1995. Uses, abuses, and alternatives to the net present value rule. *Financial Management* 24 (3):96-102.

Rummel, R. J. 1970. *Applied factor analysis*. Evanston, IL: Northwestern University Press.

Sagar, I. 1995. Do you know where your PCs are? *Business Week*, March 6, 73-74.

Sanchez, R. A. 1991. Strategic flexibility, real options, and product-based strategy. Ph.d., Massachusetts Institute of Technology.

Sarper, H. 1993. Capital rationing under risk: A change constrained approach using uniformly distributed cash flows and available budgets. *Engineering Economist* 39 (1):49-76.

Sassone, P. G. 1986. Cost benefit analysis of information systems: A survey of methodologies. In *Third International Conference in Enterprise-Wide Information Systems*. St. Louis, MO.

Sassone, P. G. 1992. Three approaches for estimating the value of work. *Information Technology & People* 6 (1):49-63.

Sassone, P. G., and A. P. Schwarz. 1986. Cost justifying OA. *Datamation* 32 (2):83-88.

Schnitt, D. L. 1993. Reengineering the organization using information technology. *Journal of Systems Management* 44 (1):14-20+.

Schoderbek, P. P., C. G. Schoderbek, and A. G. Kefalas. 1990. *Management systems: Conceptual considerations*. Fourth ed. Boston, MA: BPI Irwin.

Schwartz, A. P. 1987. When you're asked to cost-justify systems . . . A good benefit analysis model can satisfy the bottom line. *Computerworld* 21 (31):47-52.

Schwartz, S. 1995. The next generation. *Insurance & Technology* 20 (10):24-28.

Semich, J. W. 1994. Here's how to quantify IT investment benefits. *Datamation* 40 (1):45-48.

Sercu, P., and R. Uppal. 1994. International capital budgeting using option pricing theory. *Managerial Finance* 20 (8):3-21.

Sethi, V., K. T. Hwang, and C. Pegels. 1993. Information technology and organizational performance: A critical evaluation of Computerworld's index of information system effectiveness. *Information and Management* 25:193-205.

Shank, M. E., A. C. Boynton, and R. W. Zmud. 1985. Critical success factor analysis as a methodology for MIS planning. *MIS Quarterly* 9 (2):121-129.

Shannon, C. E., and W. Weaver. 1949. *A mathematical theory of communication.* Urbana, IL: University of Illinois Press.

Shillinglaw, G. 1982. *Managerial cost accounting.* Homewood, IL: Irwin.

Sievert, R. W., Jr. 1991. A review of value engineering as an effective system for planning building projects. *Project Management Journal* 22 (1):31-38.

Sippel, E. W. 1989. Change and continuity in financial services. *California Management Review* 31 (3):51-74.

Slevin, D. P., P. A. Stieman, and L. W. Boone. 1991. Critical success factor analysis for information systems performance measurement and enhancement. *Information & Management* 21 (3):161-174.

Slovic, P., B. Fischoff, and S. Lichtenstein. 1977. Behavioral decision theory. *Annual Review of Psychology* 28 (1-39):2-6.

Smit, H. T. J., and L. A. Ankum. 1993. A real options and game-theoretic approach to corporate investment strategy under competition. *Financial Management* 22 (3):241-250.

Smith, J. E., and R. F. Nau. 1995. Valuing risky projects: Option pricing theory and decision analysis. *Management Science* 41 (5):795-816.

Solt, M. E. 1993. SWORD financing of innovation in the biotechnology industry. *Financial Management* 22 (2):173-187.

Spence, M. 1976. Informational aspects of market structure: An introduction. *Quarterly Journal of Economics* 90 (4):591-597.

Stern, G. T. 1976. SOSOping or sophistical obfuscation of self-interest and prejudice. *Operational Research Quarterly* 27 (4):915-929.

Stiegert, K. W. 1993. Optimal capacity in the anhydrous ammonia industry. Ph.d., Purdue University.

Stigler, G. 1952. *The theory of price.* New York City, NY: MacMillan.

Stigler, G. 1961. The economics of information. *The Journal of Political Economy* 69 (3):213-225.

Stout, D. E., M. J. Liberatore, and T. F. Monahan. 1991. Decision support software for capital budgeting. *Management Accounting* 73 (July):50-53.

Strassman, P. A. 1985. *Information payoff: The transformation of work in an electronic age.* New York City, NY: Free Press.

Strassman, P. A. 1988. Management productivity as an IT measure. In *Measuring Business Value of Information Technologies*, edited by I. R. S. T. #2. Washington, DC: ICIT Press.

Sullivan, W. G., and J. M. Reeve. 1988. Xventure: Expert systems to the rescue. *Management Accounting* 73 (July):50-53.

Survey forecasts future I/T expenditures. 1995. *Health Management Technology* 16 (2):54.

Technology and ratings. 1994. *Best's Review [Prop/Casualty]* 94 (12):73.

Thomas, R., and L. Edwards. 1993. How HOLT methods work: For good decisions, determine business values more accurately. *Corporate Cashflow* 14 (10):37-40.

Thurow, L. 1987. Economic paradigms and slow American productivity growth. *Eastern Economics Journal* 13:333-343.

Titman, S. 1985. Urban land prices under uncertainty. *American Economic Review* 75 (3):505-514.

Too many computers spoil the broth. 1991. *Economist* 320 (7721):30.

Trigeorgis, L. 1986. Valuing real investment opportunities: An options approach to strategic capital budgeting. Dissertation, Harvard University.

Trigeorgis, L. 1988. A conceptual options framework for capital budgeting. *Advances in Futures in Options Research* 3:145-167.

Trigeorgis, L. 1993a. The nature of options interactions and the valuation of investments with multiple real options. *Journal of Financial and Quantitative Analysis* 28 (1):1-20.

Trigeorgis, L. 1993b. Real options and interactions with financial flexibility. *Financial Management* 22 (3):202-224.

Trigeorgis, L., and S. P. Mason. 1987. Valuing managerial flexibility. *Midland Corporate Finance Journal* (Spring):14-21.

Tucker, G., and J. Wallace. 1995. Insurers better not miss the electronic boat. *Best's Review (Life/Health)* 96 (3):80-81.

Turner, J., and H. C. Lucas. 1985. Developing strategic information systems. In *Handbook of Business Strategy*, edited by W. Guth. Boston, MA: Warren, Gorham and Lamont.

Vaid-Raizda, V. K. 1983. Incorporation of intangibles in computer selection decisions. *Journal of Systems Management* 34 (11):30-46.

Van Gilder, G. T. 1995. Technology is vital to good underwriting. *Best's Review (Prop/Casualty)* 96 (1):42.

Van Mieghem, J. A. 1995. Multi-resource investment strategies under uncertainty. PhD, Stanford University.

van Nievelt, M. C. 1993. Managing with information technology - A decade of wasted money? *Information Strategy: The Executive's Journal* 9 (4):5-17.

Wagner, G. R. 1980. Decision support systems: The real substance. *Datamation* 26 (5):209-214.

Wagner, M. 1995. Aetna IS seeks to ensure speedy reimbursements. *Computerworld* 29 (48):74.

Waldman, R. A. 1992. A misguided effort. *CIO* 5 (15):22.

Weaver, S. C., et al. 1989. Panel discussions on corporate investment: Capital budgeting. *Financial Management* 18 (1):10-17.

Weill, P. 1990. *Do computers pay off?* Washington, DC: ICIT Press.

Weill, P. 1992. The relationship between investment in information technology and firm performance: A study of the value manufacturing sector. *Information Systems Research* 3 (4):307-333.

Weill, P., and M. Olson. 1989. Managing investment in information technology: Mini case examples and implications. *MIS Quarterly* 13 (2):3-17.

Whistler, T. L. 1970. *Information technology and organizational change.* Belmont, CA: Wadsworth.

Wilcox, J. 1995. Tapping technology's toolbox. *Life Association News* 90 (6):50-64.

Willcocks, L. 1992. IT evaluation: Managing the catch 22. *European Management Journal* 10 (2):220-229.

Willcocks, L., and S. Lester. 1991. Information systems investments: Evaluation at the feasibility stage of projects. *Technovation* 11 (5):283-301.

Williams, J. T. 1991. Real estate development as an option. *Journal of real estate finance and economics* 4:191-208.

Wind, Y., and T. L. Saaty. 1980. Marketing applications of the analytical hierarchy process. *Management Science* 26 (July):641-658.

Wisemann, C. 1985. *Strategy and computers: Information systems as competitive weapons.* Homewood, IL: Dow Jones-Irwin.

Wisemann, C., and I. MacMillan. 1984. Creating competitive weapons from information systems. *Journal of Business Strategy* Fall:386-401.

Young, L. F. 1984. Justifying information systems: Value acquisition versus cost reduction. *Journal of Information Systems Management* 1 (3):93-95.

Zahedi, F. 1987. Reliability of information systems based on the critical success factors. *MIS Quarterly* 11 (2):187-203.

Zink, R. A. 1993. Strategic systems classification. *Information Systems Management* 10 (2):59-61.

Zottola, L. 1991. When it pays to spend money. *Computerworld* 25 (45):84.