A SIMULATED APPROACH TO VALUING KNOWLEDGE CAPITAL

By Felicia Levy

B.S in Business Administration, May 1993, Georgetown University

Master of Management in Hospitality, May 1997, Cornell University

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Dissertation directed by
Michael Duffey
Associate Professor of Engineering and Applied Science
The School of Engineering and Applied Science of The George Washington University certified that Felicia Ann Levy has passed the Final Examination for the degree of Doctor of Philosophy as of November 7, 2008. This is the final and approved form of the dissertation.

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Felicia Levy

Dissertation Research Committee:

Michael R. Duffey, Associate Professor of Engineering and Applied Science, Dissertation Director

Michael A Stankosky, Professor of Engineering and Applied Science, Committee Member

Julie Ryan, Associate Professor of Engineering and Applied Science, Committee Member

Frank Calabrese, Adjunct Professor of Engineering and Applied Science, Committee Member

Vittal S. Anantatmula, Assistant Professor of Global Management and Strategy, Committee Member
Dedication

This is dedicated to my family who supported me through this entire process.

And to my darling daughter Brooklyn, may you always have life filled with curiosity, a love of learning, and a quest for knowledge.
Acknowledgement

This work could not have been accomplished without the help and support of many people.

I would like to thank my advisor, Dr. Michael Duffey. Without him, none of this would have been possible. Thank you for guiding me through this entire process and for helping me select a topic worthy of a dissertation.

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And lastly to my family—thank you for all your support through this process.
Abstract

A SIMULATED APPROACH TO VALUING KNOWLEDGE CAPITAL

Valuing knowledge capital as represented by intangible assets remains one of the most difficult issues to solve. At the heart of the issue is that intangible assets cannot be valued until they are sold. Yet, without knowing the value of the assets, it is difficult to price them for sale. Compounding the issue is the fact that every organization places a different value on knowledge capital. What is important to one organization may not be important to another, thus making it difficult to develop a universal valuation model. One method to address this issue is to simulate a knowledge assets marketplace and allow buyers and sellers to value knowledge assets within a fictional trading market.

The purpose of this research was to develop a simulation model to gather information about the value of knowledge assets. The Knowledge Asset Valuation game was developed as the simulation model. Real option pricing was selected as the financial model to value the knowledge assets. Real option pricing provides the ability to account for the flexibility inherent in every business decision including the option to delay, abandon, or grow an investment. In contrast to traditional capital budgeting techniques, real option models allow businesses to model financial decisions in a manner more closely tied to how they actually conduct business. The Knowledge Asset Valuation game (KAV) allowed players to learn to buy and sell call options on knowledge assets including human, structural, and customer assets. The price of the call option
that the players set is said to be the real option value of the knowledge assets. The value determined by the players was then compared to the true value provided by the trinomial option pricing model.

While the findings from this study were inconclusive, it showed evidence of being an excellent tool for addressing the complexities of valuing knowledge capital. First, the research proved that the trinomial valuation model is an appropriate model for valuing knowledge capital. Second, the research supports the notion that the valuation of knowledge assets using real options is an intricate concept requiring advanced training in the subject. Lastly, the research showed that that the valuation of knowledge assets in a real world environment is subject to economically irrational behavior.
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<th>Description</th>
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<tr>
<td>ARR</td>
<td>Accounting Rate of Return</td>
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<tr>
<td>ASE</td>
<td>American Stock Exchange</td>
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<tr>
<td>CIV</td>
<td>Calculated Intangible Value</td>
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<tr>
<td>EVA</td>
<td>Economic Value Added</td>
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<td>FASB</td>
<td>Financial Standards Accounting Board</td>
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<tr>
<td>FiMIAM</td>
<td>Financial Method of Intangible Assets Measuring</td>
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<td>IDE</td>
<td>Intangibles Driven Earnings</td>
</tr>
<tr>
<td>IRR</td>
<td>Internal Rate of Return</td>
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<tr>
<td>KAV</td>
<td>Knowledge Asset Valuation</td>
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<td>KCE</td>
<td>Knowledge Capital Earnings</td>
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<tr>
<td>MIRR</td>
<td>Modified Internal Rate of Return</td>
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<tr>
<td>NAS</td>
<td>NASDAQ Stock Exchange</td>
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<td>NPV</td>
<td>Net Present Value</td>
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<td>NYS</td>
<td>New York Stock Exchange</td>
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<td>SIC</td>
<td>Standard Industrial Classification</td>
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<td>VAIC</td>
<td>Value Added Intellectual Coefficient</td>
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List of Terms

*Intangible Assets* —the assets of a company that are derived from knowledge, goodwill, or other non physical or financial contributions

*Knowledge Capital* —people’s experience and tacit knowledge, intellectual property, artifacts, communities of practice, collaborative infrastructure, culture, or innovation

*Human Capital* -- is comprised of the people and ideas that create new knowledge from information. An organization’s human capital is not the sum of all employees, but rather it is a subset of the employee base.

*Structural Capital* --provides the foundation that allows organizations to collect, measure, and build knowledge capital. It is the resources and infrastructure used by the organization to support its business and the aspects that allow knowledge to be harnessed and shared

*Customer Capital* --the information that an organization possesses regarding past, present, and future relationships; and the information surrounding its customers.
Chapter I: Introduction

Determining the value of an organization is becoming increasingly complex. In an industrial based economy, a company’s valuation is determined predominately by the value of its physical and financial assets. Organizational physical assets such as furniture, fixtures, and equipment, are relatively easy to quantify, they are tangible, they can be bought and sold in an open market, and over time they tend to decline in value. But the global economy has moved from an industrial based economy to a knowledge based economy. In a knowledge based economy, a company’s valuation should be determined by the value of its knowledge assets. Unlike physical assets, knowledge assets are much harder to quantify; they are not tangible, they are not bought and sold in an open market, and over time, they tend to increase in value.

Lev (2001) estimates that the market value of S&P 500 companies is more than six times what is on their books. In addition, Nakamura (2001) estimates that the investment value in knowledge capital as represented by intangible assets is approximately $1 trillion dollars. Moreover, “the portion of intangible assets has increased from 40 percent of market value of an organization to approximately 80 percent” (Daum 2002). Intangible assets are becoming the drivers for an organization’s competitive advantage (Stewart 2003; Sudarsanam, Sorwar, and Marr 2006) and the true sources of capital within firms (Edvinsson and Malone 1997; Petty and Guthrie 2000; Stewart 1997; Sveiby 1997). Additionally, in 1997, three books (Edvinsson and Malone 1997; Stewart 1997; Sveiby 1997) were released asserting that “economic value had shifted from
investments in fixed assets to investments in intangible assets” (Daum 2002). Yet, the ability to measure intangible assets has not developed as intangible assets have increased (Stewart 2003). Many valuation models have been proposed including performance management models (Kaplan 1992; Sveiby 1989), market based models (Rodov and Leliaert 2002), economic based models (Mintz and Lev 1999; Pulic 2000), and real option models (Chen 2005), but none of these models have been able to provide a methodology for calculating intangible asset value as its own unique number.

1.1 Definition of Intangible Assets
Most researchers agree that an intangible asset is one that is non-financial, non-tangible, and has the ability to produce future income streams or value (FASB 2004, Caddy 2000; Edvinsson and Malone 1997; Luthy 1998). Researchers (Edvinsson and Malone 1997; Petty and Guthrie 2000; Stewart 1997) often state that intangible assets are comprised of three components: customer capital, human capital, and structural capital. Each component of intangible assets represents an aspect of a firm’s ability to be adaptive and flexible. Customer capital encompasses the relationships the firm maintains with its customers. Strong, close relationships with customers provide unique understanding and insight into customer needs and wants; allowing the firm to adapt and further develop brand loyalty. Structural capital is the past experiences, lessons learned, and best practices that, when applied, lead to the development of faster, more efficient methods of achieving the same objectives. Lastly, human capital is the resources within the firm that perform the work, apply structural knowledge,
and create and maintain customer relationships. When taken together these three components are often referred to as knowledge capital (Edvinsson and Malone 1997; Stewart 1997). Lev (2001) offers that three terms are often used interchangeably when discussing intangible assets: accountants use intangible assets, economists use knowledge assets, and lawyers use intellectual capital. In accordance with this assessment, these three terms are used interchangeably throughout this study.

1.2 Identification of Intangible Assets

Just as current assets on the balance sheet can be dissected into specific components (cash and equivalents, accounts receivable, inventory, etc); intangible assets should be able to be dissected into specific components. Many researchers have proposed that intangible assets are comprised of human (people), structural (information networks, databases), and customer capital (customer relationships, brand loyalty) (Daum 2002; Edvinsson and Stenfelt 1999; Edvinsson and Malone 1997; Marr 2005; Roos et al. 1997; Stewart 1997; Sveiby 1997). It has also been suggested that intangible assets should include the discovery/learning process (Lev 2001).

1.3 Intangible Asset Valuation Problem

The fundamental issue with assigning a value to an intangible asset is that it is not measurable. Any given intangible asset may provide different values to different organizations (Melymuka 2004). For example, a hospitality organization would place a high value on an intangible asset such as customer service, while a machine assembly organization would place a lesser value on it. Robert
Kaplan believes that while it is not possible to assign a value to an intangible asset, intangible assets can be measured by estimating how closely aligned they are to the company’s strategic goals (Melymuka 2004). An additional problem with attempting to value intangibles is the lack of information that companies possess about their intangible assets. Most companies would concur that intangible assets provide value to the company, but they cannot pinpoint where the value comes from (Lev 2005). Companies do not know the exact value that employees contribute to the organization, the value of their customers brand loyalty, or the value of their information infrastructure. Companies know how much each of these assets cost to create, but lack information about their potential future earning power. The lack of information in the capital markets also leads to the misevaluation of a company’s worth which is best evidenced by the overvaluation of internet based companies in early part of this century.

With the introduction of Financial Accounting Standard (FAS) 141 and FAS142, the United States is beginning to take steps to require companies to identify and test the values of their intangible assets on a yearly basis. However, a universally accepted model still does not exist. This leaves these regulations open for interpretation and therefore, does not provide investors, stakeholders, and other interested parties a systematic method to compare one company to another with regard to their intangible assets.

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1 See Appendix C
2 See Appendix D
1.1.1 Criticisms of Valuing Intangible Assets

Most of the debate about intangible asset valuation is not in the concept, but rather in the execution. Assets typically are comprised of two components—the amount paid today (book value) and the amount of money that the asset is expected to generate (intangible asset value). Unlike in manufacturing, structural assets such as networks and databases and human assets such as employees do not produce a tangible asset which can be sold for a specific price. Book values, often used as a value indicator, reflect the price paid for an asset at the time of purchase, not the current value. Market values, which are also often used as an indicator, do not remain constant. Furthermore, the ability to separate future potential earnings of assets from their book value is extremely difficult as the two are often closely intertwined (Pike, Roos, and Marr 2005). Pike and Roos (2005) also point out that today’s accounting systems are not equipped to address intangible assets. The lack of information surrounding the valuation of intangible assets is creating an imbalance of information amongst investors (Andriessen 2004; Lev 2000). A systematic valuation model could address the issue of information asymmetry.

1.1.2 Support for Valuing Intangible Assets

Although there are many difficulties associated with being able to value intangible assets, Reilly and Schweihs (1999) cite eight distinct reasons ranging from tax planning and litigation support to strategic planning and management direction. One of the most compelling reasons to develop a method for valuing intangible assets is to meet the impairment testing requirements of FAS142.
(Pike, Roos, and Marr 2005). The other compelling reason is to provide a methodology for calculating a financial metric that all investors have access to and allows investors to compare intangible assets across companies thereby eliminating the problem of information asymmetry.

1.4 Statement of the Problem
A quantitative, relevant, reliable methodology is needed in order to value knowledge capital.

1.5 Key Proposition and Research Objectives
Without an active trading market, it is difficult to value knowledge capital outside of an entire entity sale. One possibility to overcome this limitation is to develop a simulated trading environment. Simulated trading markets have been used by companies such as Best Buy (Dvorak 2008) to develop an internal market that allows “workers to trade imaginary stocks based on answers to managers’ questions.” Additionally, other companies such as Google, General Electric, and Microsoft have all used simulated trading markets to forecast the outcome of their products. However, a simulated trading market alone cannot value knowledge capital. An underlying financial model must be used. The financial model needs to be able to account for the flexibility inherent in every business decision including the option to delay, abandon, or grow an investment. Real option pricing is the only quantitative method that can account for this inherent flexibility.

In 1973, Black and Scholes developed the first model to successfully value financial options (Black and Scholes 1973; Merton 1974). Stewart Myers
(1977) then extended the concept of financial options to capital budgeting under uncertainty and valuation of corporate assets or entire corporations. Thus, real option pricing theory uses the pricing principles from financial markets to value investment opportunities in real markets. Historically, real option pricing theory has been used to value many different types of assets that have future earning potential such as oil and gas leases (Armstrong et al. 2004; Ekern 1985; Paddock, Siegel, and Smith 1988a; Siegel, Smith, and Paddock 1987), research and development efforts (Faulknr 1996; Herath and Bremser 2005), patents (Schwartz 2002) and technology investments (Schwartz and Zozaya-Gorostiza 2000). Knowledge capital is similar to these assets in that they all produce nonphysical claims to future value or benefits. Thus, the key proposition of this study is to determine if knowledge capital can be valued using a simulation methodology supported by real option pricing.

The literature review in Chapter II shows that many knowledge capital valuation models have been proposed (Andriessen 2004; Bounfour 2003; Edvinsson 2002; Edvinsson and Malone 1997; Jacobsen, Hofman-Bang, and Nordby 2005; Rodov and Leliaert 2002), but thus far, no model has gained universal acceptance. One reason for the lack of universal acceptance is the inability for researchers to develop a methodology for the valuation of knowledge capital that is reliable, repeatable, auditable, and validated through scientific testing.

The objectives of this study are to:
1) To design a simulation methodology to determine value of knowledge assets
2) To design a methodology for the valuation of knowledge capital that is reliable, repeatable, auditable, and validated through scientific testing

1.6 Importance of the Study
This study is important to the academics and real world practitioners in the knowledge management community. Academics in the knowledge capital community have attempted numerous methodologies for calculating the value of knowledge capital. A significant criticism of most of these models is that they lack rigorous scientific testing (Andriessen 2001). This study aims to address this criticism by developing a model that is validated through rigorous, scientific testing. Implications of this study include:

- The ability to respond to critics who state that intangible asset valuation models are not properly tested
- The validation of a simulation model supported by real option pricing as a viable method for valuing knowledge capital

For practitioners, the importance of this study has greater implications.

The United States Financial Accounting Standards Board recently offered the following comments.

Analysts and other users of financial statements, as well as company managements, noted that intangible assets are an increasingly important economic resource for many entities and are an increasing proportion of the assets acquired in many transactions. As a result, better information about intangible assets was needed. Financial statement users also indicated that they did not regard goodwill amortization expense as being useful information in analyzing investments (FASB 142).
This excerpt from FASB 142 shows that there is a need to define a proper valuation method for intangible assets. Especially, within the financial community, development of a repeatable measurable and reliable methodology would assist in credentialing the merits and contributions of applied knowledge management practices for improving, efficiency, effectiveness, and innovation initiatives in an enterprise. This study aims to address this issue by developing a valuation model grounded in financial theory, validated against a simulation game using real option pricing, and applicable to any company. Implications of this study for practitioners include the ability to:

- Report more relevant information about intangible assets and knowledge capital to investors
- Compare one company to another using a standardized calculation
- Create an index of knowledge capital across industries
- Calculate new financial ratios such as
  1. Knowledge Capital/Book Value
  2. Knowledge Capital/Total Assets
  3. Net Income/Knowledge Capital
  4. Knowledge Capital/Employee

1.7 Contribution to the Body of Knowledge

A review of the literature identifies many gaps. The first gap continues to be the infancy of the valuation models. This study adds to the maturity of the valuation model literature by continuing to review existing models as well as discussing any limitations and uncertainties with the models. The second gap is
a lack of measurement models validated with rigorous testing. This study addresses this gap though the development of a simulation model correlated to theoretical calculations. The third gap identified in the literature is the limited use of financial theory to value intangible assets. This study addresses this limitation by showing how real option pricing can be used to value knowledge capital.

1.8 Research Methodology

This research designed and developed a simulation game to mimic a public transaction market. The output of the Knowledge Asset Valuation (KAV) game was the actual value of the knowledge capital call options. The trinomial model for pricing real options was used to assess the theoretical value of the knowledge capital.

Using a correlation coefficient test, game participant values for human, structural, and customer assets were correlated to the theoretical option values as determined by the trinomial option pricing model. If a statistically significant correlation exists, it was inferred that the simulation methodology supported by real option pricing could be considered a relevant viable method for valuing knowledge capital.

1.9 Research Outline

This study continues with a review of the existing literature surrounding the valuation of intangible assets in Chapter II. The review presents both qualitative and quantitative models and highlights the strengths and criticism of each model. Chapter III presents the theoretical framework for evaluating the real option pricing model while chapter IV presents the research methodology
and design as well as the design of the simulation game. Chapter V presents the results of the analysis and conclusions are offered in Chapter VI.
Valuing intangible assets is not a science. There is no universally accepted valuation methodology. As a result, many researchers are dedicated to trying to solve the intangible asset valuation problem discussed in Chapter I. This section reviews the existing literature and discusses each model as well as any limitations and uncertainties.

2.1 Valuation Models
During the later part of the 1980’s two independent research groups were attempting to develop models for valuing intellectual capital. In Sweden, the Konrad group was working on a model for knowledge-based companies to “present[ing] their company’s most important resource, its personnel, in a more informative way than through pretty colour photographs” (Sveiby 1989). At the same time, Kaplan and Norton in the United States were developing the Balanced Scorecard Model. Ultimately, both models came to the same conclusion, the value of a company equals financial value plus intangible value; though the organizations differed on their definition of intangible value. Konrad group’s intangible value was comprised of “customer + structural + human capital”; while Kaplan and Norton measured intangible value against three perspectives: “learning and growth, business, and customer.” The models developed by these two companies provide the foundation for the some of the performance-based models such as the Intellectual Capital Rating Model (Edvinsson 2002) and the Intellectual Capital Index Model (Roos et al. 1997) that exist today.
While performance based models provide a methodology for evaluation of intangible assets, they do not provide a methodology to assign a quantitative value to those assets. This problem of assigning value has stumped researchers for many years and produced varying approaches.

- Arthur Anderson (1992) categorized valuation methods as either “cost, market value, or economic value”.
- Lathy (1998) and Williams (2001) segregated the models into four approaches: “direct intellectual capital, market capitalization, return on assets, and scorecard methods”.
- Bontis (2001) and Leliaert et al (2003) found that many models use similar theories and metrics but use different naming conventions.
- Pike and Roos (2004) evaluated the rigor of intellectual capital valuation methodologies compared to measurement theory and advocate the need for a fifth category: proper measurement systems.
- Chang, Hung, Tsai (2005) show how intangible assets can be valued using real options.
- Green and Ryan (2005) developed a strategic framework for valuing intangible assets across companies in a repeatable manner.

Thus far, none of the aforementioned methodologies has proven superior; and researchers are still trying to quantitatively value intangible assets. This research provides a review of existing quantitative and qualitative models and
analyzes their advantages, limitations, and uncertainties. The models that are addressed are presented in Table 2-1.

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2.2 Qualitative Models

Designed to measure the non-financial contributions of a company, the purpose of qualitative models is to identify what is important to the organization and assist the organization in monitoring its progress with regard to those stated objectives.

2.2.1 Konrad Theory: The Invisible Balance Sheet and the Intangible Asset Monitor

The Konrad group identified 40 key indicators for measuring intangible performance in “The Invisible Balance Sheet”. They found that knowledge capital could be segregated into two categories: “individual and organizational”.

According to the Konrad group, individual capital, is the specific “know–how” that a person possesses and uses to solve problems. Individual capital is
increased through years of experience, education level, personal, and social abilities. Not everyone employed by the organization contributes individual capital. Employees who do contribute intellectual capital are considered “pros” or “revenue people”.

Conversely, organizational capital is comprised of the processes that allow the organization to function. Organizational capital includes handbooks, computer programs, and administrative personnel and processes. It represents the way the organization solves a problem.

The primary contribution of the Konrad group is the development of the classification schemas and key indicators for examining intangible assets. This laid the foundation for Sveiby’s Intangible Asset Monitor (1997). The premise of the Intangible Asset Monitor (IAM) is that the total market value of a company is comprised of equity and intangible assets. Sveiby believed that most of an organizations value lay in its “invisible knowledge based assets”. For the IAM, Sveiby classifies intangible assets into three categories of inputs: “external structure, internal structure, and competence.” External structure is comprised of relationships primarily customer and supplier. Internal structure is comprised of investments in infrastructure, development of new products and services, and the core values of the company. Competence is comprised of the unique mix of knowledge and know-how than individuals bring to an organization. From these three categories, Sveiby proposes that value is created for the firm through one of four paths: “growth, renewal, stability, and efficiency.” Figure 2-1 illustrates the Intangible Asset Monitor as developed by Sveiby.
Both the Invisible Balance Sheet and the Invisible Asset Monitor provide easy to understand pictures of a company’s knowledge assets. However, the models do not provide a method to comparatively evaluate the intangible assets of one company against those of another. In addition, the models do not have the capability to place financial value on the assets. Furthermore, the assets that are reviewed are those that the company believes are the most critical, which may not be the true knowledge assets of the organization. Despite these limitations, the contribution of these efforts to the intangible asset valuation methods cannot be overlooked.

2.2.2 Kaplan and Norton’s Balanced Scorecard (BSC)

Kaplan and Norton (1992), created the "balanced scorecard" model to assist businesses in transitioning from ideas to actions; achieve long-term goals, and obtaining feedback about strategy. This model is derived from a company’s
vision and strategy and should reflect the core focus of the business. The balanced scorecard as developed by Kaplan and Norton consists of four sections: “clarifying and translating vision and strategy; communicating and linking strategic objectives; measures, planning, setting targets; and aligning strategic initiatives, and enhancing strategic feedback and learning”

The BSC provides leaders with an overall picture of the state of their organization. By segmenting the organization into four perspectives, a leader can identify where the company is excelling, and where the company is failing. The leader can further delve into each perspective and identify specific metrics that need consideration. This ability can help a leader adapt corporate strategies before they become financially harmful. Figure 2-2 illustrates the balanced scorecard model.
While the BSC has been applauded (Marr 2005; Newing 1994; Wu 2005) for its ability to correlate metrics to strategic objectives, it also has critics. Bontis et al (1999) agrees with the concept of a systematic metric system, yet finds that the BSC is too rigid. Additionally, they find that the metrics cannot be used for comparative purposes against other companies. Roos et al (1997) concurs with Bontis regarding external comparisons and comments that for investors to effectively use the BSC, a company would have to divulge too much of its internal information. Andriessen (2004) contends that the BSC does not measure quantitative values of assets or the flows between the assets. Instead, Andriessen claims that it measures improvement in specific strategic areas.

While these critics have a point, the BSC was developed as a management framework for monitoring performance across an organization. It was not designed as a quantitative valuation measurement system. When tools are applied to their non-original purpose, they may not be a perfect fit. Furthermore, the BSC is a set of guidelines, not doctrine. If users find it too rigid, they have the ability to modify it as necessary.

2.2.3 Skandia Navigator

Combing the work of the Konrad group and the BSC, the Skandia Navigator is a collection of intangible asset measurement methods designed to capture a company’s performance and goal achievement. By examining the organization in five different categories: financial; customer; human; process; and renewal and development, the Navigator seeks to identify the hidden assets that are not immediately visible within an organization.
Skandia, a Swedish insurance company, used this model to publish the state of its intellectual capital in its 1994 annual report. The report was a supplementary report to the annual financial statement. Since then, the Skandia model has been used by other companies, such as Dow Chemical, to value its intellectual capital (Edvinsson and Malone 1997; Petty and Guthrie 2000; Sveiby 1997).

Researchers (Andriessen 2004; Strassmann 2000) do not agree on the value of the Navigator model. Andriessen disagrees with the Navigators extensive list of 30 indicators spanning customer, process, human, and development and renewal, claiming there are too many to truly understand what is being measured. He also contends that determining cause and effect from the model is difficult (2004). Strassmann (2000) showed that there is little correlation between market value represented by stock performance and the navigator metrics indicating that the Navigator might not be useful to investors. However, the Navigator was designed as an internal monitoring tool, not a public investor tool. If the Navigator metrics help to drive a company’s performance and goals, then the Navigator can be considered an acceptable valuation model.

2.2.4 Other Qualitative Models

From these base models, many other models were developed. Bontis (2004) showed how the Skandia model could be used to determine a national intellectual capital index by focusing on financial, human, and structural capital. In 2002, Edvinsson developed the Intellectual Capital (IC) Rating model by extending the Skandia model to incorporate concepts from the IAM. This model
attempts to consolidate different indicators into a single index and to correlate changes in intangible assets with changes in market value. Figure 2-3 illustrates the model as developed by Edvinsson (2002).

Roos et al (1997) developed the IC-index. This model is similar to the IC Rating model. The IC-index consolidated all of the individual factors and components of intellectual capital into a single index. Instead of correlating changes in intangible assets with changes in market value, this model proposes that changes in the index could be correlated with changes in market value.

Bounfour (2003) devised the intellectual capital dynamic value (IC-dVAL) to compute indicators of intellectual capital across four dimensions: “resources and competencies, processes, outputs, and intangible assets”. Lev (2001) introduced the Value Chain Scoreboard, a matrix of non-financial indicators segregated into three categories: “discovery and learning, implementation, and commercialization”.

Two major research projects are also worth noting. In 1998, the European Commission (European Commission work on Intangible Assets) commissioned a project to study the development of a low cost solution for the Measuring and Accounting of Intellectual Capital (MAGIC). The primary outcome of this project was a best practices study to measure intellectual capital, a description of the
methods and tools available to measure and account for intellectual capital, and
an information technology (IT) tool to support the available methodologies. Also,
in 1998, the Measuring Intangibles to Understand and Improve Innovation
Management (MERITUM) Study was initiated (European Commission work on
Intangible Assets). This was another European study to examine possibilities to
measure and report intangibles. The main focus of this project was to examine
how intangibles are transformed into wealth and to develop guidelines for the
measurement and disclosure of intangible assets.

2.3 Quantitative Models

Quantitative models are designed to assign a numerical value to intangible
assets. It is these models that have plagued researchers for many years. In
support of these research efforts, three approaches have become accepted to
value intangible assets: cost, market, and income (Reilly and Schweihis 1999;
Smith and Parr 1994). “The cost approach is based on the economic principles
of substitution and price equilibrium” while “the market approach is based on the
economic principles of competition and equilibrium” (Andriessen 2001). In
contrast, the income approach is based upon anticipated future benefits.

2.3.1 Cost-Based

Used primarily by accountants, cost methods attempt to report the
historical cost of developing an intangible asset. Historical cost is similar to book
value—it is the value paid for an asset less any depreciation. Book value is a
good valuation technique for static assets; it is not a good metric for dynamic
assets such as stock equity or intangible assets. Value is created as resources
develop new ideas, new products, or new processes. The cost of developing these new assets is not germane to their potential for producing future income. Furthermore, once a new asset is created, its usefulness can be unlimited. It would be difficult to report the historical cost of an intangible asset against an asset with an indefinite life and still maintain a meaningful metric.

Therefore, for researchers of intangible asset valuation, cost-based methods to value intangible assets are of little importance. However, one proposed methodology is interesting to examine; Brooking’s Technology Broker model (Brooking 1996). This audit model encompasses all entities within an organization that could be considered an asset. In total, this auditing tool presents 178 questions. Once the diagnostic tool is complete, Brooking offers three methods to convert the questionnaire data into dollar values, “cost”, “market”, and “income”.

One of the primary benefits of Brooking and Motta’s study is the development of a measurement model from which a company can assess its intellectual capital. Yet, while the measurement model is a great leap forward, the model still does not place a consistent quantitative value on intangible assets. The model requires the analyst to transform the qualitative results into quantitative numbers. This transformation is a weakness of the model in that different people could transform the qualitative numbers differently. Additionally, the Technology Broker does not offer assistance with the most difficult aspect of the audit: “how to identify relevant intangibles to audit, how to determine what aspect to audit, and how to set a target for each aspect” (Andriessen 2004).
2.3.2 Market-Based
Market-based models seek to value intellectual capital by identifying comparable assets and assessing the value paid for them.

2.3.2.1 Financial Method of Intangible Assets Measuring (FiMIAM)
Developed by Leliaert and Rodov (2002) this model builds on Leliaert’s overlapping three leaf model (Rodov and Leliaert 2002) and is designed to assess monetary values of intellectual capital. It is a combination of both tangible and intangible asset measurements. The model was developed using Leliaert’s overlapping three leaf model, which shows that intellectual capital is a relationship between human, customer, and structural capital. The overlaps in the three leaf model as shown in
Figure 2-4 (Rodov and Leliaert 2002), illustrate the interdependencies of the components of intellectual capital.
The model strives to provide a direct link between intellectual capital and the market value of a company by including interactions and dependencies. To do this requires first the identification of the relevant components (see...
Figure 2-4) that comprise a firm’s intellectual capital and then the assignment of relative weights to those components. The primary issue with this model is that it requires a subjective valuation in order to assign the weights and therefore cannot be used by external investors to value a company’s intellectual capital. However, it does make a good attempt at placing valuing on the intangible assets that are relevant within the organization.

2.3.2.2 Market-to-Book Value

Used by investors to evaluate “company’s past performance and future prospects” (Brigham 1989), the market to book value ratio has been suggested as a simplistic model (Stewart 1997) to value intellectual capital. Financiers define the equation as the market price per share divided by the book value per share while Stewart defines it as “the difference between it’s market value and its book equity” (Stewart 1997). The underlying assumption of Stewart’s definition is that the difference between the two values must be attributed to intangible assets.

The calculation presented by Stewart is not how financiers intended the ratio to be used. In concurrence, it is interesting to note that many researchers comment that calculating the difference is not a useful metric. Instead they comment that the use of a ratio would be a better metric (Bouteiller 2002; Luthy 1998; Stewart 1997).

Not withstanding the equation differences, there are still inherent issues with the market to book value ratio. First, the ratio uses book values which are based on historical costs and market values which are affected by many factors
outside the control of the company (Bouteiller 2002; Luthy 1998; Stewart 1997). Secondly, book values and market values may be understated due to accounting policies such as tax and depreciation and therefore not accurately reflect the true values (Bouteiller 2002; Stewart 1997). Third, the difference between market and book values can be attributed to many more factors than just intangible asset value (Andriessen 2004).

Conversely, Gu and Lev (2001) argue that the two variables —market value and book value, are numbers that an investor already knows and that the metric provides no additional information. They point out that the measure is circular and should not be used to value intangible assets.

Edvinsson and Malone (1997) add an intellectual capital variable to the traditional market to book value equation. This equation was devised to try and explain the difference between the value of a company as expressed by market capitalization and the book value of a company as expressed by accountants. However, Pike and Roos (2002) demonstrated that this equation was flawed since the book value and intellectual capital variables cannot be separated as required by the equation.

The primary criticism of the market-to-book value method is that it does not provide an accurate valuation of intellectual capital. It cannot be said that the difference between historical asset costs (book value) and future earnings and growth (market value) is equal to a company’s intangible assets. Or that the ratio of market to book value accurately reflects the company’s intangible assets. The difference between book value and market value or the market to book value
ratio can be used as a proxy for the value of intangible assets, but not the actual value. The inherent issue with this is that it is an inferred calculation which changes as the fair market value changes. Intangible assets and intellectual capital are increasing becoming the leading source of income from a company (Kay 2001; Nakamura 2001). The leading source of income should not be calculated as a derived value.

2.3.2.3 Tobin’s q

Tobin (1969) developed $q$ in an effort to thwart accountant’s efforts to use differing depreciation policies. Tobin defined $q$ as market value divided by asset replacement value. This model is similar to the market to book value model, save for substituting replacement cost for book value. If $q > 1$, the asset is worth more than its replacement cost, if $q < 1$, the asset is worth less than its replacement cost. When applied to intangible assets, the theory is that if $q > 1$ and/or $q$ is greater than another company’s $q$, than that company has a higher intellectual capital.

There is some argument that Tobin’s $q$ is better than the market-to-book value ratio as it counterbalances the effects of using different depreciation policies (Bouteiller 2002; Stewart 1997). Bouteiller (2002) also states “that Tobin’s $q$ is subject to the same exogenous variables that influence market price as well as the market-to-book value method.” Stewart (2003) argues that it retains many of the same fallacies as the market to book value ratio: that $q$ is affected by forces beyond the control of the company and that both book and market value are often understated.
It order for Tobin’s \( q \) to be an accurate measurement of intangible asset value, the argument must be made that the difference between market value and replacement value must be attributable to intangible assets. Since there are many exogenous factors that affect market value and many different ways to estimate replacement value, this cannot be a valid assumption. Furthermore, \( q \) was developed in order to analyze monetary policy as an aggregate function. In his work, Tobin shows how the decisions of both the private sector and government policies affect overall monetary value. Using \( q \) to value an individual company’s intangible asset value violates this assumption. As defined, \( q \) could be used as a measure of an industry or national intangible asset value, but not that of an individual company.

### 2.3.3 Income Models

Income-based models seek to value intangible assets in terms of potential future earnings.

#### 2.3.3.1 Economic Value Added (EVA)

Developed by Stern Stewart & Co. in 1997, the EVA model arrives at an intangible asset value by subtracting capital times the cost of capital from net operating profit after taxes. One of the underlying premises of this model is that the goal of the company is to maximize shareholder value. It incorporates principles of financial accounting, capital budgeting, performance measurement, and strategic planning to arrive at a single financial metric which Stern Stewart & Co believes is easy for non-financial managers to comprehend. From this metric, managers have a common starting ground for financial discussions. The
simplicity of the EVA model is that managers understand that there is a charge for using company capital assets.

The issue with this model is that non-financial managers may not understand "cost of capital". Furthermore, while the of "cost of capital" concept could be explained, the "cost of capital" does not remain constant. As such, the EVA number is subject to change thereby negating the very common starting ground effect that Stern Stewart & Co. was attempting to achieve. The model also requires choosing between "accuracy and complexity" (Bontis et al. 1999). The EVA model allows managers to make adjustments to their variable inputs. However, as the number of adjustments increase, the complexity of the model increases. While the resulting number is more accurate, it is often too complicated for managers to comprehend. Another limitation is the use of book values. Book values reflect historic costs, not current market values. In addition, the underlying premise that the goal of the company is to maximize shareholder value may be an invalid assumption (Bontis et al. 1999). Lastly, as designed, EVA was not intended to be used as a valuation model for intangible assets (Andriessen 2004). Applying this methodology to intangible assets may provide a proxy for the intangible asset value, but it does not provide the actual value.

2.3.3.2 Calculated Intangible Value (CIV)

Developed by NCI Research and Northwestern University’s Kellogg School of Business, this method is based on methods traditionally used to value brand equity. Brands confer economic benefits such as pricing power, customer loyalty, distribution channels, and the ability to launch new products, which gives
companies a competitive edge over those that do not have brand recognition. Using a net present value model, the CIV\(^3\) measures a company’s excess capital compared to its competitors. Galbreath (2002) claims that the “The CIV doesn’t measure market value, but rather measures a company’s ability to use its intangible assets to outperform other companies in its industry”.

Since this model requires capitalization of excess earnings, the model does not work for companies that do not have a profit (Stewart 2003). For example, Amazon.com did not report a profit until 2003; however, the business was founded in 1994 and went public in 1997. The Initial Public Offering (IPO) price was $18.00 per share and they raised $54 million dollars (Galante 1997) indicating that even though Amazon.com was not expected to turn a profit for four years (Hof 1998), investors still placed a significant value on the company.

This model is a strong attempt to attribute intangible asset values to the unique knowledge capabilities of a firm. However, it requires identifying a peer group to benchmark performance against (Roos 2003). Depending upon the industry, a peer group may or may not be available. The model also requires an assumption that excess growth and improved performance are solely attributable to intangible asset value. Additionally, proper benchmarking requires that companies conduct business in a similar fashion. The CIV calculation may not be accurate if one company makes investments while the other companies remain static (Bouteiller 2002). The CIV model also does not consider individual companies tax and depreciation policies, which again may impact the timing of

\(^3\) Stewart (1997, pp.228-229) provides detailed instructions for applying this model to value Merck & Co.
earnings (Bouteiller 2002). Lastly, the CIV attributes a company’s excess earnings solely to intangible assets. The CIV ignores the tangible assets that also contribute to the intangible assets and the excess earnings (Bouteiller 2002). For example, human resources are tangible assets, but create intangible knowledge. The primary benefit of this model is that it uses public data and comparisons can be made across companies (Stewart 1997).

2.3.3.3 Knowledge Capital Earnings (KCE)

Mintz and Lev (1999) comment that “after several hundred years of double-entry bookkeeping, accountants still do not treat knowledge assets as assets.” In response to this outdated approach, Lev developed the Knowledge Capital Earnings methodology. Lev’s first premise is that anything not related to physical or financial assets must be tied to knowledge and therefore knowledge assets. The second premise is that unlike tangible physical and financial assets, intangible assets cannot simply be counted by aggregating the amount spent on the assets since there is no transactional market for the assets. Furthermore, a mark to market model is not effective since there is no market for intangible assets except for in a merger or acquisition. Lev’s model is similar to the CIV methodology; it strives to discern the value of intangible assets from the returns they produce. However, unlike the CIV method, which compares a company’s intangible assets to its peer group and values the assets based on how much they outperform the peer group, Lev’s method allocates profits amongst the revenue producing assets.
In 1999, Lev and Mintz applied this methodology to 27 chemical companies and 20 pharmaceutical companies. They found that knowledge capital varies across industries and that the size of a company has an impact on its knowledge capital. The largest companies own more knowledge assets than smaller ones and pharmaceutical companies have more knowledge capital than chemical companies. The study was repeated the following year, but expanded to 18 industries. The expanded study also identified three critical drivers of performance: “research & development, advertising, and capital expenditure.”

Gu, along with Lev (2001), validated this methodology by correlating annual stock returns with annual growth in firm’s intangible-driven earnings over a ten year period (1989-1999). Lev defines intangible-driven earnings (IDE) as “the contribution of intangible assets to the enterprise performance” (Gu and Lev 2001). They found that the correlations between stock returns were 11 percent and between reported cash flows or earnings was 29 percent. They further found that correlations between returns and IDE (based on sales’ growth) was 40 percent, and between returns and IDE (based on analysts’ forecasts) 53 percent.

While Lev’s methodology has been widely received in the knowledge management community, some researches believe it has its limitations. Strassmann (2001) cautions against the validity of the measure since it uses analysts forecasts. Analyst forecasts are predictions about the future surrounded by uncertainty. Often they are incorrect; using them to calculate intangible asset value could lead to incorrect and/or inconsistent results. Furthermore, Bouteiller (2002) finds that the model does not make an adjustment for the expenses spent
to develop the knowledge assets. He argues for a model based on Lev’s methodology that adjusts for expenses and terms this “Adjusted Normalized Earnings and Adjusted Comprehensive Value”.

Lev’s methodology for calculating knowledge earnings uses returns on tangible and financial resources. While returns are a good indicator, they are not the value of the contribution of these resources. The methodology also aggregates tangible, financial, and intangible assets. The aggregation of these values does not consider the value of the synergies created between the three resources (Andriessen 2004).

Lev’s first premise that everything not related to physical or financial assets must be related to knowledge assets is not reasonable. It is not possible for everything in an organization to be allocated to either knowledge, physical, or financial assets as Lev’s model dictates.

2.3.3.4 Value Added Intellectual Coefficient (VAIC)

VAIC was “designed to provide information about the value creation efficiency of tangible and intangible assets within a company.” (Pulic 2000) It measures the depth and breadth of intellectual capital efficiency. The premise of this measure is that labor in modern economic times is vastly differently from the industrial era. During the industrial era, labor productivity was a function of machinery, tools, and hours worked. However, in modern times, productivity levels are determined by knowledge which cannot be measured by output; Pulic argues it needs to be measured by the value added to the organization.
VAIC is calculated based on three components: “capital employed, human capital, and structural capital”. For each component, Pulic calculates the amount that that component adds to the value of the company. The three components are then aggregated to create the VAIC.

The benefit of the model is that it can be calculated from public data and therefore can be used to compare companies (Stewart 2003). In addition the methodology is easy to understand (Andriessen 2001). However, some researchers find fault with this model. Pulic argues that the human capital coefficient shows “how much value added was created by one dollar spent on the employees.” (Pulic 2000) Stewart (2003) disagrees with this premise and states that pay percentage is not a measure of investment, it is just the cost of labor. It can also be argued that a one dollar investment in payroll can be attributed to many factors beyond an increase in value added. Examples include cost of living adjustment, pay grade adjustment, or locality adjustment. None of these examples provide an increase in the value added to the company, yet using Pulic's model, it would appear that there is an increase in value added.

Andriessen (2004) offers many criticisms of this model. He claims that it does not “properly separate expenses from assets” using labor expense as an example. He also comments that the objective of the methodology is to measure the efficiency of intellectual capital, yet efficiency “does not provide information about the contribution of these types of intellectual capital to value creation” (Andriessen 2004). He then offers that value is an aggregate measure of
structural, human, and customer capital, but the VAIC does not provide a method for calculating “the synergies between these three” (Andriessen 2004).

In contrast to these criticisms, Pike and Roos (2004) believe that VAIC is a good methodology, but cite that it still “fails as a measurement system due to internal difficulties with the distinctness and independence of the defined resources.”

2.4 Other Models

Other models to value intangible assets are slowly emerging. Andriessen & Tiessen (2001) in conjunction with KPMG developed the Value Explorer which examines where intangible value stems from. Sullivan (2000) developed the Intellectual Asset Valuation to assess the value of intellectual property. Still other researchers (Bontis 1996; Liu 2000) have explored using patents as a proxy for intellectual capital. This model works well in industries such as biotechnology, chemical, and pharmaceutical where patents are prevalent. It does not work for industries such as management consulting which is knowledge intensive, but not patent intensive. Caddy (2000) questions the validity of the intellectual capital equation constructs. He contends that organizations cannot truly evaluate their intellectual capital since only assets are considered. The traditional accounting capital equation subtracts liabilities from assets. Therefore, he believes that the intellectual capital equation should follow a similar format. While all of these models are interesting, the most interesting to note are index and real option models.
2.4.1 Index Models

The Knowledge Management Performance Index (KPMI) is garnering significant attention. Two independent research teams have developed a KPMI designed to measure a firm's performance at a certain point in time. Lee et al (2005) suggest that firms work to accumulate and apply knowledge to create a competitive advantage. They propose that KPMI is a logistical function comprised of five components: “knowledge creation, knowledge accumulation, knowledge sharing, knowledge utilization, and knowledge internalization”. Through a survey of 101 Korean firms listed on the KOSDAQ market, they find that KMPI can represent the knowledge circulation process.

Chen and Chen (2005) also propose the development of a KPMI, but base it on “knowledge creation, knowledge conversion, knowledge circulation and knowledge completion”. Their index is created using the Black Scholes model for option pricing. They find that option pricing can be used as a measurement guideline for the value of knowledge management activities that a firm undertakes.

2.4.2 Real Options

An option is a right, but not a requirement to buy or sell something in the future for a predetermined price. Financial markets have long understood that this type of flexibility has an inherent value. In 1973, Black and Scholes published their study on option pricing theory (Black and Scholes 1973; Merton 1974). This study was the first successful attempt at pricing options. The model showed how stocks could be used to determine the price of a European call option by assuming that the underlying stock price follows geometric Brownian
motion with constant volatility. Other assumptions of the model incorporate the constant price variation of the stock, the time value of money, the option's strike price and the time to the option's expiration.

Cox, Ross, and Rubinstein (1979) expanded this theory by developing the binomial tree model. The binominal model uses a discrete time framework to trace the progression of the options underlying the stock price. The model uses an iterative process to determine the option price beginning with the last node of the tree and working backwards. Each node in the binomial tree represents a potential value of the underlying asset at a specific point in time. The evolution of this price is the foundation for determining the option price. When the first node is finally calculated, this represents the calculated of the value of the option.

As each change in value can be readily observed, the binomial model depicts the structure of an option better than the Black Scholes formula. The binomial model uses assumptions similar to the Black Scholes model. Therefore, the binomial model is often used as a discrete approximation of the continuous Black Scholes process. As such, as the number of nodes in the tree increases, the binomial model converges with the Black Scholes for European options.

2.4.2.1 Description of Real Options

Stewart Myers (1977) first coined the term “real options”. He extended the concept of financial options to capital budgeting under uncertainty and valuation of corporate assets or entire corporations. Thus, the concept of real options uses the principles from financial markets to value investment opportunities in real markets. Therefore, a real option is the right, but not the obligation, to undertake
a business decision. This decision is usually related to capital investments, but recent research has applied real option valuation techniques to valuing research and development efforts as well as intangible assets.

Real option pricing has long been used to value natural resources such as oil and gas leases (Armstrong et al. 2004; Ekern 1985; Paddock, Siegel, and Smith 1988a; Siegel, Smith, and Paddock 1987). It has also been used to value research and development efforts, (Faulkner 1996; Herath and Bremser 2005), patents (Schwartz 2002) and technology investments (Schwartz and Zozaya-Gorostiza 2000). This extension is important for intangible asset valuation as these categories are similar to intangible assets in that they all produce nonphysical claims to future value or benefits.

As a result of this work, researchers are now attempting to apply these same concepts to valuing intangible assets. Lint and Pennings (2001) studied how real options can be used to capture the value of flexibility at each stage of a new product development. Frigo (2003) examined the usefulness of real option theory and Banerjee (2003) illustrated how using real options to value research and development in a pharmaceutical company could explain a high stock price.

Baek, Dupoyet, and Prakash (2005 ) examined how the equity in a growth firm could be evaluated using real options. Bouteiller (2002) advocated an option based approach to acknowledge the flexibility that intangible assets provide. Unfortunately, while Bouteiller advocates this approach, he does not provide a methodology for capturing the flexibility. Marr et al (2005) suggested that
intangible assets represent growth and abandonment opportunities and therefore can be priced using option pricing theory.

The fundamental problem with using real options to value intangible assets is that both are abstract. Real options depend upon inputs which do not have an active market to provide consistent values. Intangible assets, by their very definition, are not tangible and are also not actively traded. Yet, this problem has not impeded researchers in trying to find a way to value intangible assets using real options.

2.4.2.2 Validation of Real Options

There are very few methods for validating the accuracy of real option prices for intangible assets. Real option pricing has been used to value oil and gas investments, patents, and technology. In all of these cases, the outcome of the investment is tangible and the true costs associated with the investment are eventually able to be determined. The true value can then be assessed against the real option value to determine if the real option pricing model was accurate. For intangible assets such as human, structural, and customer capital, this is not a possibility. The contributions of these assets to future revenue can not be allocated with accuracy.

One method of validating intangible asset values was devised by Baruch Lev (2001). In his study of knowledge capital earnings, he associated his findings with the annual growth rate from three financial statistics: annualized stock returns annual cash flow from operations, and annual net income (earnings). According to Lev, these are the most widely used corporate performance
measures. This methodology could be used to validate real option value by employing the same quantitative, correlation approach.

Another way to examine the validity of real options is to simulate the value. Two widely accepted simulation methods are Monte Carlo and game theory. Monte Carlo simulation relies upon computer generated values that follow investigator-specified parameters. The benefit to this simulation method is that the computer can run the model repeatedly thereby creating large amounts of data for analysis. The disadvantage to Monte Carlo simulation is that its strict reliance on investigator specified parameters likely will fail to adequately capture the complexity of human interaction. Since real option values are based on an assessment of underlying asset values which is made by rational investors, human interaction is a necessary component of real option valuation.

Real options are based on flexibility and strategic decision making—both which require human decisions. Game theory or simulation using real people in a game environment, allows data to be collected based on human reactions to different scenarios. The validity of the data is based on the assumption that the players will exercise rational behavior. Rational behavior means that the players strive to maximize their own success within the parameters of the game (Baird 2003). While extensive research has been conducted on different types of games and their associated strategies (Brennan 1985; Kulatilaka 1998; McGrath 1997; Trigeorgis 1988), limited research has been conducted on the intersection of game theory and real options. Grenadier (2000) offers two theories for the limited research. First, he claims that because options are “side-bets between
agents external to the underlying firm”, their exercise does not impact the value of the underlying assets. Since the exercise of the options does not impact the underlying assets, their value is not widely considered. Second, Grenadier comments that “the application of game theory to continuous-time models is not well developed, and often quite tricky.”

Acknowledging the benefits that game simulation could have to value intangible assets, Sveiby developed the Tango business simulation. In this game, each team of four players tries to maximize their profitability over a seven period game. The game mimics the real world in that the teams complete against each other for the same employees and customers (Sveiby).

Often, games developed by commercial entities lack academic rigor. However, in 2000, Bontis and Giradi validated the Tango business simulation. Bontis and Giradi (2000) studied the ability of the Tango business simulation to transform the way participants view intellectual capital. They proposed that participants would be “more favorably disposed to IC after the simulation as compared to before”(Bontis 2000). To test their theory, the researchers conducted a pre and post simulation survey with the simulation participants. Three separate groups of executives in Australia were asked to participate in the simulation and survey. Counting only the participants that completed both a pre and post survey, they received a 59% response rate.

The survey evaluated three intellectual capital perspectives: human capital, knowledge, and Chief Knowledge Officer. The study found that participants were more “favorably disposed” towards intellectual capital after
participating in the Tango business simulation. The researchers point out that there are some limitations of their study. First, the sample size was limited. The initial population included 56 participants. Since only 59% responded to both surveys, the sample size was 33 participants. The second limitation of this study is that all participants were members of the same organization, the Queensland Public Sector Agency. The study should be expanded to other organizations and industries in order to eliminate organizational biases.

2.5 Literature Review Summary

In 2004, Andriessen conducted a survey of existing models and identified the existence of over 30 different measurement systems. The results of this review indicated that many methods have been proposed, but researchers are not satisfied with the results and are still struggling to find an acceptable model that can be implemented, audited, and understood by investors, employees, customers, and other stakeholders.

The two major types of valuation methodologies addressed were qualitative and quantitative. The primary qualitative methodologies include the Balanced ScoreCard and the Skandia Navigator, as well as the contributions of the Konrad Group and the Intangible Asset Monitor. While these methods illustrate where a company’s knowledge assets reside, they do not allow for the assignment of a numerical value. The primary quantitative methodologies include cost, market, and economic models. While these models attempt to place a numerical value on intangible assets, the lack of transaction markets, differences in valuation methods for book and market value, and inability to
accurately associate activities with revenues, do not allow investors to use these models to compare one company to another. New models such as index and real option models are beginning to emerge as possible valuation methods, yet the research using these models is still in its infancy. The infancy of this research creates a gap in the literature, suggesting the need for future evaluation of real option pricing models as a method to value intangible assets.
Chapter III: Theoretical Framework

As demonstrated by previously referenced literature, researchers have applied many methods to value intangible assets. What is apparent is that no single method has emerged superior. One of the main reasons valuing knowledge capital is so difficult is because “intangible assets are worth different things to different people” (Kaplan and Norton 2004); that is, what is valuable to one firm may have little to no value to another firm.

Most strategic management researchers (Hamel and Prahalad 1994; Kaplan and Norton 1996; Porter 1988) agree that having a competitive advantage contributes directly to a company’s value. Hall (1992) expanded this concept and argued that intangible assets could lead to a sustainable competitive advantage. In addition, many researchers believe that knowledge assets have superseded physical assets as the primary driver of developing a competitive advantage (Quinn, Anderson, and Finkelstein 1996; Stewart 1997; Youndt, Subramaniam, and Snell 2004).

Flexibility and agility also contribute to knowledge capital. This contribution occurs through the ability to respond to expected or unexpected changes, efficiently and effectively, and the ability to exploit and take advantage of opportunities as they arise. Companies that do not possess these abilities are often doomed for failure. Hamel and Prahalad (1994) cite numerous examples of companies that struggled to survive because of their inability to respond to changes in the market: Wal-Mart versus Sears and Kmart, Microsoft versus IBM, and Japan versus Detroit. Thus in addition to intangible assets, flexibility and
agility are increasingly becoming drivers of competitive advantage. This concept is illustrated in Figure 3-1.

**Figure 3-1, New Economy Value Chain**

In order to value flexibility, one must first define and understand the concept of flexibility. The concept of flexibility appears in many disciplines. Investors in the banking and finance disciplines use liquidity, or the lack of effort required to transform assets, to represent flexibility. In operations management, concepts such as Lean Belt and Flexible Manufacturing Systems replace older material-push logic. Employers in the labor market permit adjustable work hours as an incentive to attract better skilled workers. In all of these examples, flexibility is a change capability that improves the company’s ability to perform.

For the purpose of this paper, the definition of flexibility will be limited to its application of real options as applied to intangible assets; that is, flexibility is defined as the ability to expand, contract, defer, or abandon an intangible asset.

Using this premise, I propose applying a different approach to asset valuation. Instead of attempting to quantify the intangible asset value of a
company, I propose valuing intangible assets in terms of their ability to create knowledge capital from flexibility. In turn, the value of the knowledge capital creates a sustainable competitive advantage thereby increasing the value of the firm.

3.1 The Value of Flexibility

For many companies, developing competitive advantage is the path to success. A competitive advantage occurs when a company is able to sustain profits beyond industry averages. Porter (1988) identified three types of competitive advantages: “differentiation, overall cost leadership, and focus.”

A competitive advantage based on differentiation exists when a company is able to provide better products or services than the competition. A cost based competitive advantage exists when a company is able to provide the same products or services at a lower cost than the competition. A focus based competitive advantage occurs when the company singularly works to create a product or service aimed at a unique segment of the market. While Porter offers this as a third generic strategic, it is really a type of differentiation strategy whereby the company differentiates itself by providing a unique product or service or to a specific sub-segment of the market.

In all cases, competitive advantage creates value for customers, which leads to increased sales revenue and profits for the company. Today’s shrinking global economy has increased competition and put additional constraints on companies. A company’s cost advantage is no longer as advantageous as it
once was. Thus, the importance of differentiated advantage has become increasingly crucial in competitive environments.

Flexibility is a way to create both cost and differentiation competitive advantages. Often viewed as the ultimate competitive advantage, flexibility enables a company to rapidly adapt to changes in the external market, global economy, emerging technology, and changing human resource needs. Firms that have the ability to scale up or down or change direction as the market dictates are considered to have a competitive advantage. Trigeorgis (2005) reiterates this idea, stating that “managerial flexibility has become essential for firms to successfully take advantage of favorable future investment opportunities, respond effectively to technological changes or competitive moves, or otherwise limit losses from adverse market developments.”

Therefore, a firm that is able to quickly change/reverse investment decisions with minimal cost impacts is able respond to changes in the market faster; scale up or down as required; and develop additional differentiators will ultimately create a superior competitive advantage. It then follows that a firm with superior competitive advantage is more valuable.

3.2 Conceptual Framework
The proposed knowledge capital valuation model is created using two constructs: intangible assets and real options for the financial model. Intangible assets are comprised of three components: customer capital, human capital, and structural capital as shown in Figure 3-2. Each component of intangible assets represents an aspect of a firm’s ability to be adaptive and flexible. Customer
capital encompasses the relationships the firm maintains with its customers. Strong, close relationships with customers provide unique understanding and insight into customer needs and wants; allowing the firm to adapt and further develop brand loyalty.

![Knowledge Capital Constructs](image)

**Figure 3-2, Knowledge Capital Constructs**

Structural capital is the past experiences, lessons learned, and best practices that, when applied, lead to the development of faster, more efficient methods of achieving the same objectives. Lastly, human capital consists of the resources within the firm that perform the work, apply structural knowledge, and create and maintain customer relationships. When taken together these three components are often referred to as knowledge capital (Edvinsson and Malone 1997; Stewart 1997).

Real options are also comprised of three components: the option to expand, the option to abandon or contract, and the option to defer as shown in Figure 3-3. Real option pricing theory is derived from the principles of financial option pricing. A financial option is a contract which provides the right, but not the obligation, to buy or sell an underlying asset. When applied to real options, the assets become investment decisions, rather than financial assets. At the core of real option valuation is flexibility (Brekke and Schieldrop 2000). Using
this premise, real option pricing theory can be used to value knowledge capital derived from flexibility.

**Figure 3-3, Real Option Constructs**

### 3.3 Intangible Assets Create Flexibility

Manufacturing has long viewed flexibility as the ability of production and operations to scale up, down, or change direction. In contrast, a consulting firm does not have a production or operations department. Their equivalent of a manufacturer’s machinery is the sum total of their intellectual capital. Based on this association, the same principles applied to valuing manufacturing flexibility can be used to value intangible assets in the form of knowledge capital.

Youndt *et al* (2004) define knowledge capital as the “the sum of all knowledge an organization is able to leverage in the process of conducting business to gain competitive advantage”. It is this definition that is used throughout the remainder of this paper.

Developing a framework for identifying the various components of knowledge capital and measuring it is extremely challenging. Fortunately, beginning in the early 1990’s, many researchers (Bontis 1996; Edvinsson and Malone 1997; Stewart 1997; Sveiby 1997) set forth to solve this issue and developed potential conceptual frameworks. While each researcher presented a
slightly different framework, there was also a lot of convergence. Most knowledge management researchers agree that knowledge capital resides in multi-dimensions. Thus the convergence among researchers is that knowledge capital is not restricted to the knowledge held by individuals, but rather it encompasses the knowledge stored within technology, business processes, and social relationships.

### 3.3.1 Customer Capital

Customer capital is the information that an organization possesses regarding past, present, and future relationships; and the information surrounding its customers. Luthy (1998) argued that customer capital is demonstrated by the “strength and loyalty of customer relations”. Lev (2005) offered that the value of customer capital is evident when the loyalty of customers enables a company to charge higher prices or secure a larger market share. Duffy (2000) concurred, stating that the value of customer capital is its contribution to future growth opportunities.

“The knowledge of marketing channels and customer relationships is the main resource for customer capital,” according to Bontis (1998). He further recognized that as customer capital is the most external form of capital in the organization, it is the most difficult to develop. He purported that the value of a customer increases with the passage of time and that a new customer is more expensive to acquire than an old one is to retain. Marr et al (2003) commented that customer capital encompass more than just relationships, customer capital also includes the perceptions that customers’ hold about a particular company.
3.3.2 Structural Capital

Structural capital provides the foundation that allows organizations to collect, measure, and build knowledge capital. It is the resources and infrastructure used by the organization to support its business and the aspects that allow knowledge to be harnessed and shared. Structural capital can be identified through the codified knowledge that the organization possess and is therefore sometimes classified as an asset on the balance sheet. For Edvinsson and Malone, structural capital is “everything left at the office when the employees go home” (1997).

3.3.3 Human Capital

Human capital is a knowledge organization’s most important resource. It is comprised of the people and ideas that create new knowledge from information. An organization’s human capital is not the sum of all employees, but rather it is a subset of the employee base. It represents the select few whose thought leadership, ideas, and innovative thinking creates value for the organization (Bontis et al. 1999; Edvinsson and Malone 1997; Sveiby 2001).

Edvinsson and Malone further believe that human capital includes the ability for an organization to effectively use its human resources to develop creative and innovative solutions (1997). Sveiby (2001) concurred and commented that employees are “the only true agents in business; all tangible physical products, assets as well as the intangible relations, are results of human action and depend ultimately on people for their continued existence”, while Bontis
(1996/98) views human capital as individual contributions to the core of the organization—innovation, culture, or values.

3.3.4 Intangible Asset Summary
Section 3.3 provided an overview of the three components that support the intangible asset construct. Customer capital is developed through customer relationships. It is comprised of brand loyalty, brand recognition, and other information about its customers. Structural capital provides the building blocks for a company’s process, innovation, and organizational capital. Human capital provides the ability to translate information into knowledge. The next section provides an overview of financial and real options.

3.4 Options
A financial option gives the holder the right to buy or sell an underlying asset at a given price (strike or exercise price) at or before the expiration date of the option. The option holder can choose to either exercise the option or to let the option expire (Damodaran *Real Options: Fact and Fantasy* 2005). There are two option styles: European, in which the option may only be exercised at the expiration date; and American, where an option can be exercised at any time up to or on the expiration date.

In addition, two option types exist: calls and puts. A call option gives the holder the right to buy the underlying asset at a fixed price (exercise price), by a certain date (expiration date). While a call option grants the holder the right to buy, a put option, grants the holder the right, but not the obligation, to sell the
underlying asset at a fixed price (exercise price) by a predetermined date (expiration date) (Damodaran 2006). Each option type is discussed below.

3.4.1 Call Options

A call option gives the holder the right to buy the underlying asset at a given price (exercise price), by a specific date (expiration date) (Damodaran 2006). In exchange for this option, the buyer pays a premium. If at the time of expiration the value of the underlying asset is less than the strike price, then exercising the option will not benefit the investor and a rational investor will allow the option to expire. If however, the value of the underlying asset is greater than the exercise price; the buyer will exercise the option (call) and make a profit equal to the difference between the asset value and exercise price (Damodaran 2006).

It is important to remember that the holder of the call option is not required to exercise it; and as a result, the loss from purchasing the option cannot exceed the price paid for it. This creates a flat payoff function, beginning at an underlying asset price of zero and continuing to the strike price; with a loss equal to the call premium. As the price of the underlying asset increases beyond the strike price, the call becomes increasing valuable and the payoff rises, one for one, against the price of the underlying asset. The payoff diagram illustrated in Figure 3-4 is helpful to illustrate this concept.
The payoff for a long position such as illustrated in Figure 3-4 is:

\[ C = \max (S-X,0) \]

where \( S \) is the price of the underlying asset and \( X \) is the strike price.

For call options, if \( S > X \), the call is valuable and should be considered for exercise. If \( S = X \), then the underlying asset value is equal to the strike price and it is not necessary to exercise the call as there would be no positive cash flow. However, if \( S < X \), then the call expires worthless and a rational investor would not exercise the call.

**3.4.2 Put Options**

In contrast to a call option, a put option, grants the holder the right, but not the obligation, to sell the underlying asset at a given price (exercise price) by a specific date (expiration date). The purchaser of a put option pays a premium for this right. A rational investor will only exercise the option if the strike price is greater than the value of the underlying asset (Damodaran 2006).
The net profit from this transaction is determined by deducting the initial premium paid for the put from the profit made. Figure 3-5 summarizes the payoff of the put.

![Figure 3-5, Long Put Payoff](image)

The payoff for a long position such as illustrated in Figure 3-5 is:

\[ P = \max(X - S, 0) \]

where \( X \) is the strike price and \( S \) is the underlying asset value.

Put options are just the opposite view of call options. For put options if \( S < X \), then the put is valuable and should be exercised. If \( S = X \), then the underlying asset value is equal to the strike price and it is not necessary to exercise the put as there would be no positive cash flow. When \( S > X \), the put expires worthless and there is no need to exercise the put.

### 3.4.3 Factors Affecting Option Prices

There are six (6) factors that affect the price of an option:

1. Current Value of the Underlying Asset, \( S \)
(2) Strike Price, $X$

(3) Time to Expiration, $T$

(4) Volatility of the underlying asset, $\sigma$

(5) Risk-free interest rate, $r$

(6) Expected dividends

Each factor, and its impact on call and put prices, is discussed below.

**Current Value of the Underlying Asset, $S$**

The underlying asset determines the value of an option. It follows that changes in the value of the underlying asset impact the value of the option. For a call option, the payoff on exercise is the amount by which the underlying asset value exceeds the strike price. For a put option, the payoff on exercise is the amount by which the strike price exceeds the underlying asset value.

**Strike Price, $X$**

A key attribute of an option is the strike price. Call options become more valuable as the underlying asset value increases and less valuable as the strike price increases. Conversely, put options become less valuable as the underlying asset value increases and increase in value as the strike price increases.

**Time to Expiration, $T$**

Both put and call options increase in value as the time to expiration increases. This is simply a function of time: the more time there is until the option expires, the more time there is for the value of the underlying asset to change. Additionally, in the case of a call, the option holder pays a predetermined price at expiration; therefore, the present value of this predetermined price decreases as the life of the option increases and which in turn, increases the value of the call.
Volatility of the underlying asset, $\sigma$

The volatility of the underlying asset is a measure of uncertainty about future movements in the asset value. As volatility increases, the likelihood for the underlying asset value to change increases. Therefore, the value of both a put and call option increases as the variance in the value of underlying asset increases (Damodaran 2006). The owner of a call will benefit from price increases, but has limited risk in the event of price decreases, since the owner’s loss is limited to the amount paid for the call option. Accordingly, the owner of a put benefits from price decreases, but has limited risk in the event of price increases because the owner’s loss is also limited to the amount paid for the put option.

Risk-free interest rate, $r$

The risk-free rate can be determined by examining the Treasury bill rate. The models for pricing call and put options are relatively insensitive to changes in interest rates. Selecting an incorrect interest rate will not impact the results of the model significantly, unless the pricing is for an interest rate option. As economic interest rates rise, the expected return required by investors also rises. Simultaneously, the present value of any future cash flow received by the option holder will decrease. The combined impact of these two (2) effects creates an increase in the value of call options and decrease in the value of puts.

Expected dividends

If dividends are paid on the underlying asset, the option value is likely to decrease (Damodaran 2006). Consequently, the value of a call is negatively
correlated to amount of the anticipated future dividend and the value of a put is positively correlated to the amount of the anticipated future dividend.

Table 3-1 summarizes the input variables and their effects on call and put prices.

Table 3-1, Summary Of The Effect On The Price Of A Stock Option Of Increasing One Variable While Keeping All Others Fixed

(reproduced from Hull 1997)

<table>
<thead>
<tr>
<th></th>
<th>European Call</th>
<th>European Put</th>
<th>American Call</th>
<th>American Put</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Value of the Underlying Asset, $S$</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Strike Price, $X$</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Time to Expiration, $T$</td>
<td>?</td>
<td>?</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Volatility of the underlying asset, $\sigma$</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Risk-free interest rate, $r$</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

3.5 Option Valuation Models

With the development of the Black Scholes model, the pricing of options was revolutionized. The Black Scholes (1973) model showed mathematically how to price the theoretical value of call and put options. Cox, Ross and Rubinstein (1979) then proved how the discrete binomial model could be used as an approximation of the continuous Black Scholes model. The advantage of the binomial model is that the price of the option can be valued at any point prior to exercise. This makes the binomial model ideal for pricing American style options as well as real options. The simplicity of using an option model is that once the inputs have been defined, the process is simply a matter of plugging the values into the mathematical formula. The difficulty is in identifying the inputs.
3.5.1 Black Scholes Model

Fisher Black and Myron Scholes published the Black Scholes model in 1973. They developed a mathematical formula to evaluate the theoretical value of European put and call stock options. The model illustrates the varying price over time of financial instruments. The primary contribution that Black and Sholes made is that the call option is implicitly priced if the stock is traded. This insight led to one of the most accurate financial models for pricing options. The Black Scholes formula for the price at time 0 of a European call option on a non dividend paying stock and a European put option on a non dividend paying stock are: (Hull)

\[ c = S_0 N(d_1) - Ke^{-rT} N(d_2) \]  

(3.1)

and

\[ p = Ke^{-rT} N(-d_2) - S_0 N(-d_1) \]  

(3.2)

where

\[ d_1 = \frac{\ln(S_0/K) + (r + \sigma^2/2)T}{\sigma \sqrt{T}} \]  

(3.3)

\[ d_2 = \frac{\ln(S_0/K) + (r - \sigma^2/2)T}{\sigma \sqrt{T}} \]  

(3.4)

The function \( N(x) \) is the cumulative probability function for a standardized normal distribution. It is the probability that a variable with a standard normal
distribution, \( \phi(0,1) \), will be less than \( x \). The variable \( c \) and \( p \) are the European call and European put price. \( S_0 \) is the stock price at time 0. \( K \) is the strike price, \( r \) is the continuously compounded risk-free rate, \( \sigma \) is the stock price volatility, and \( T \) is the time to maturity for the option.

The key assumptions of the Black-Scholes model are:

1. The price of the underlying instrument is a geometric Brownian motion, in particular with constant drift and volatility
2. The option is European
3. The market is considered frictionless which allow for continuous trading
   a. It is possible to short sell the underlying stock
   b. There are no transaction costs or taxes
   c. All securities are perfectly divisible
   d. It is possible to borrow or lend the stock
4. There are no riskless arbitrage opportunities
5. The price of the underlying asset is log-normally distributed. Since the asset value cannot fall below zero, the asset cannot follow a normal distribution, therefore a log normal distribution must be assumed
6. The risk free interest rate is constant, and the same for all maturity dates

An example of the Black Scholes pricing model is presented below (reproduced from Hull 1997).

The stock price 6 months from the expiration of an option is $42, the exercise price of the option is $40, the risk-free rate is 10% per annum, and the volatility is 20% per annum. This means that \( S_0=42, K = 40, r = 0.1, \sigma=0.2, T=0.5 \),
\[ d_1 = \frac{\ln(42/40) + (0.1 + 0.2^2 / 2)x0.5}{0.2\sqrt{0.5}} = 0.7693 \]
\[ d_2 = \frac{\ln(42/40) + (0.1 - 0.2^2 / 2)x0.5}{0.2\sqrt{0.5}} = 0.6278 \]

and

\[ K e^{-rT} = 40e^{0.05} = 38.049 \]

Hence, if the option is a European call, is value \( c \) is given by

\[ c = 42N(0.7693) - 38.049N(0.6278) \]

If the option is a European put, is value \( p \) is given by

\[ p = 38.049N(-0.6278) - 42N(-0.7693) \]

Using the polynomial approximation,

\[ N(0.7693) = 0.7791, \quad N(-0.7693) = 0.2209 \]
\[ N(0.6278) = 0.7349, \quad N(-0.6278) = 0.2651 \]

so that

\[ c = 4.76, \quad p = 0.81 \]

Ignoring the time value of money, the stock price has to rise by $2.76 for the purchase of the call to break even. Similarly, the stock price has to fall by $2.81 for the purchaser of the put to break even.

### 3.5.2 Binomial Model

The Binomial model is a simplistic model for valuing complex options. First proposed by Cox, Ross and Rubinstein (1979) it provides a generic numerical method for the valuation of options. The binomial model uses a “discrete-time” model rather than a continuous time framework as is used in the
Black Scholes model. The difference is that, in the discrete time model, the time to maturity is divided into $n$ discrete intervals. As a result, the binomial model can be used to value options that may be exercised prior to maturity such as an American style option.

The use of a "discrete-time framework" allows the model to follow the development of the option's key underlying variables via a binomial lattice (tree), for a given number of time steps between valuation date and option expiration. Each node in the lattice represents a possible price of the underlying variable, at a particular point in time. This price evolution forms the basis for the option valuation. The valuation process is iterative, beginning at each final node, and then working backwards through the tree to the first node (valuation date), where the calculated result is the value of the option.

The binomial tree shown in Figure 3-6 illustrates the different possibilities that an asset might follow over the life of an option.

*Figure 3-6, Binomial Model Two Step Tree*
The underlying assumption is that the asset prices follow a random path. At each point, there is a probability of moving either up or down by a certain percentage. As the time steps become smaller, the binomial model approaches a limit, which leads to the lognormal assumption for asset prices used in the Black Scholes model. At each interval, the stock price is assumed to have only two (2) possible movements: upward or downward. Other key assumptions in the binomial model are:

- The stock price follows a multiplicative binomial process over discrete periods
- The interest rate is constant
- There are no taxes, transaction costs, or margin requirements and no short selling restrictions exist
- No arbitrage opportunities exist

An example of the binomial option pricing model is presented below (reproduced from Lord 2002).

\[ S = \$49 \quad K = \$50 \quad t = 3 \text{ months} \quad r = 0.10 \]

Assume that over a one and a half month period there is a 52% chance stock price will rise by 12%, and a 48% chance price will go down 10%.
If the stock price ends up at $61.4656, the call will be worth $61.4656-50=$11.4656, on that day; otherwise the option will be worthless (all of the other nodal values are less than $50).

The present value of $11.4656 is $11.4656 e^{-rT} = $11.1825

There is a \([0.52 \times 0.52 = 0.2704]\) 27.04% chance the call will wind-up in-the-money

\[
c = \$11.4565 e^{-0.10 \times 0.25 (0.2704)} = \$3.02
\]

### 3.6 The Use of Real Options to Value Flexibility

Capital budgeting is used to determine if a company should undertake an investment project. Traditional capital budgeting techniques state that a project should only be accepted if the net cash flow at the end of the project exceeds the amount required for investment. Traditional valuation methods include payback period, accounting rate of return (ARR), net present value (NPV), internal rate of return (IRR), and modified internal rate of return (MIRR). All of these methods are widely used in corporate capital budgeting, but they all also lack the ability to account for the embedded options within company’s investments such the ability to delay the start of a project, the ability the abandon a project, or the ability to
invest further in a project (Benniga and Tolkowsky 2002; Damodaran 2006; Triantis and Borison 2001). Real option valuation addresses this issue and allows companies to assess capital budgeting decisions in a manner more similar to the way they actually conduct business.

Real option valuation applies the evaluative concepts of financial options to tangible assets. It provides an alternative to traditional capital budgeting techniques in that it allows a firm to evaluate a project while capturing the firm’s flexibility to abandon, defer, contract, expand or otherwise modify its actions. Copeland and Keenan (1998) in Figure 3-7 show that the value of flexibility is derived from the ability to respond to information as it becomes available. The real option value becomes apparent in the cases when the newly learned information causes a change in management direction.

Figure 3-7, Value of Managerial Flexibility
(reproduced from Copeland and Keenan 1998)

As with financial options, real options can have both puts and calls. Unlike traditional financial options, real options have two unique characteristics that make them more complicated to value. First, often there is no market for the
underlying asset, making it difficult to determine a market value. Second, the underlying assets may or may not have a correlation to other traded assets. This uncertainty again makes it difficult to determine some of the necessary inputs for the option model. For the purpose of this paper, the underlying assets that will be evaluated are the intangible assets of a company.

3.6.1 Inputs under Real Options

Applying option-pricing models to intangible assets first requires identifying the corresponding inputs. The variables for either the Black Scholes or Binomial model when applied to real options are as follows:

- \( S \) = present value of the underlying assets
- \( X \) = cost required to acquire the future assets
- \( T \) = length of time a decision may be deferred
- \( \sigma \) = the volatility of the investment
- \( r \) = the risk free rate has the same connotation as in the financial asset case.

The output of this model would be the value of the knowledge capital. One of the advantages of the Black Scholes model is that it provides a quick method to calculate the value of a simple option. However, intangible assets are not simple options. Furthermore, Black Scholes is based upon European options. European options may be exercised by only at the maturity of the option. Intangible assets are based upon staged decisions, not a single point in time decision. An option model to value intangible assets needs to account for these
possibilities. Lastly, the Black Scholes Model calculates the value of an option using the stock price, the exercise price, volatility, option term, and the risk-free rate. Since it calculates the option value using a defined formula, it is viewed as a closed form model. While the use of the Black Scholes model would be easy, these limitations do not make it a viable model to use to value real options related to intangible assets. The binomial model with its ability to value staged decisions and complex options is the more appropriate model to use.

3.6.2 Types of Real Options

This section presents three types of options that are embedded in capital budgeting decisions and can therefore be applied to real option valuation techniques. The first type is the option to delay and is usually available to companies who have exclusive rights to something such as a patent, supply chain, or customer relationship. The second type is the option to abandon; or the ability to walk away from a project when the project is no longer viewed as profitable. The last type is an option to expand. This type of option is exercised when the project is more successful than originally anticipated. These three option types contribute to firm flexibility because they are used to react to both internal (profits, resources, management decisions) and external factors (interest rates, analyst forecasts, competition). A flexible company exercises real options to create a competitive advantage. Copeland and Keenan (1998) provided examples of real option types as shown in Figure 3-8.
3.6.2.1 Option to Expand

Copeland and Keenan (1998) refer to the option to expand as an opportunity to invest or grow. If a company makes an initial investment and that investment gives the company the right to expand and invest in a future project, then the company has an option to expand. These options could be investments in advertising, employee education, marketing, customer service, or developing a new process.

The option to expand, or scale up arises when early adopters create the opportunity to grow thorough sequential investments made as the market grows. A switch up opportunity occurs when a company has already invested in the base product and therefore has the ability to quickly take advantage of the next
generation of technology. The switch up option can also be applied to processes (structural capital). For example, a company who had successfully used the Balanced Scorecard Model might find it quicker and easier to implement Six Sigma than a company who had not.

The option to expand is similar to an American call option on the value of the expansion. The strike price is the cost of the expansion opportunity discounted to the option exercise time. Companies have options to expand in all three sub-categories of intangible assets as shown in Table 3-2.

<table>
<thead>
<tr>
<th>Table 3-2, Option to Expand Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Customer Capital</strong></td>
</tr>
<tr>
<td><strong>Structural Capital</strong></td>
</tr>
<tr>
<td><strong>Human Capital</strong></td>
</tr>
</tbody>
</table>

### 3.6.2.2 Option to Abandon

Copeland and Keenan (1998) refer to an abandonment option as an opportunity to divest or shrink. An abandonment option is an option to reduce the amount of investment in a project. A company can scale down efforts during a project if new information arises that changes the expected payoffs. Alternatively, a company can switch down their efforts. This refers to the feasibility of switching to more cost effective assets as new information becomes available. Lastly, a firm may decide to abandon a project fully. In this case, the company recognizes that there is no future business opportunity.

The option to abandon is similar to an American put option on the value of the project. The strike price of the option is equal to the liquidation value of the
project less any necessary costs to terminate the project. An investor purchases a put option if they believe that the underlying asset will decline in value. The put option limits their losses to the purchase price of the option, while providing them with unlimited upside potential if the value of the underlying asset should increase. For an abandonment option, the investor can limit losses to the initial amount invested, while gaining the opportunity for unlimited upside potential should the project be successful. Table 3-3 presents examples of intangible asset abandonment options.

**Table 3-3, Option to Abandon Examples**

<table>
<thead>
<tr>
<th>Customer Capital</th>
<th>Option to end a contract with a customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Capital</td>
<td>Option to give up patents, trademarks, or other proprietary business processes</td>
</tr>
<tr>
<td>Human Capital</td>
<td>Option to terminate employees</td>
</tr>
</tbody>
</table>

**3.6.2.3 Option to Defer**

The option to defer captures the ability to wait to invest until more information or skills are acquired. By delaying an investment, more information can be gathered and the level of uncertainty reduced. As shown in this paper earlier, traditional valuation models do not capture the value of the ability to wait. The option to defer is similar to an American call option on the value of the project. Examples of deferral options for intangible assets are provided in Table 3-4.

**Table 3-4, Option to Defer Examples**

<table>
<thead>
<tr>
<th>Customer Capital</th>
<th>Option to delay the start of a project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Capital</td>
<td>Option to delay the investment in new technology such as networks or databases.</td>
</tr>
<tr>
<td>Human Capital</td>
<td>Option to delay hiring employees</td>
</tr>
</tbody>
</table>
3.7 Real Options and Intangible Assets

Recognizing that competitive advantage stems from organizational flexibility and that flexibility is created by real options embedded in intangible assets makes it possible to examine the value of intangible assets using real option pricing theory. The goal of this research is to model the value of intangible assets options using financial option models.

Figure 3-9, Intangible Asset Real Options

With the framework constructs developed, it is now possible to explore how real options can be used to value intangible assets. The matrix shown in Figure 3-9, illustrates each intangible asset category (human, structural, and customer) which can be associated with the three (expand, defer, abandon) real option categories. Figure 3-9 shows that each intangible asset category can have multiple options at each decision point. This illustration, coupled with the American style of these options to allow for early exercise, again supports the
use of the binomial model to value intangible asset options. However, the binomial model would only provide an upward and downward movement analysis. There would be no node for continuing at the status quo. A trinomial tree, as shown in Figure 3-10, would provide that ability.

Figure 3-10, Trinomial Tree Model

### 3.8 Real Options Summary

This section provided an overview of option pricing. The factors that affect option prices were introduced as well as the Black Scholes model and the Binomial pricing model. Real options were shown to be a viable method for valuing the flexibility embedded in corporate decisions as well as for valuing intangible assets. The trinomial pricing model was then presented as a model that would allow options to be valued upwards, downwards, and at the status quo. Finally, the challenge of valuing real options due to a lack of a transaction market and possible lack of correlation to other traded assets was
acknowledged. One method for overcoming this challenge is to simulate a transaction market using game theory. The principles of game theory are addressed below.

3.9 Game Theory

Game theory was first introduced in 1944 by John von Neumann and Oskar Morgenstern in *Theory of Games and Economic Behavior*. The authors observe that business and economics have many of the same similarities as playing a game. In business, economics, and games, the decision making process of a player is dependant upon and impacts the other players. Using this analogy, von Neumann and Morgenstern developed the foundations of game theory which are still used today. Since their seminal work, many different types of games have been proposed. The most common types of games are discussed briefly below.

3.9.1 Zero sum and Non-Zero Sum

A zero sum game is a game where the payoffs of all the players net to zero. A non-zero sum game is just the opposite (Rasmusen 1994). No matter how the payoffs are architected, they will never net to zero. The Battle of the Bismarck developed by Rasmusen (1994) is an example of a zero sum game. In this game, the two players can choose from exactly the same actions, but their payoffs are not the same. What one player gains, the other player loses. The classic Prisoners' Dilemma game is an example of a non-zero sum game. In this game, two players are given the option to betray or remain silent about the other player. The best outcome for both players is for both players to remain silent.
This is known as the dominant strategy. However, given the assumption of rational behavior⁴, this is not always the outcome selected by the players.

### 3.9.2 Symmetric and Asymmetric

A symmetric game is a game where the actions available to the players are not dependent upon whom the players are. All players in the game are equal and have the same opportunity to select the various actions (Rasmusen 1994). The prisoners’ dilemma game is an example of a symmetric game. Both players have the option to betray or remain silent. The actions available to the players are not dependent upon their role in the game. An asymmetric game is one where the actions available to the players are dependent upon the role of the players (Rasmusen 1994). For example, in the Ultimatum game, one player decides how a sum of money should be split. The second player has the option to reject or not reject the proposed split. The option to negotiate a different split of the money is not an action available to the second player.

### 3.9.3 One Stage and Two Stage

A one stage game is one that is played only once and not repeated. A two or more stage game is one that repeats the baseline stage for as many stages as the game requires.

### 3.9.4 Simultaneous and Sequential

In a sequential game, each player alternates making moves. Since one player begins play in the game, the optimal game path can be found by

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identifying the largest payoff strategy. Dixit and Nalebuff cite this as “Rule 1: Look forward, and reason backward” (Dixit 1993). This can be achieved by constructing a decision tree and following the path to the optimal payoff. In contrast, in a simultaneous game, all players make moves at the same time. The prisoners’ dilemma game is an example of a simultaneous game. Since neither player moves first, a decision tree cannot be used to determine the optimal payoff for each player. Instead, a game payoff matrix is used to illustrate the various possible outcomes for each player (Dixit 1993). The prisoners’ dilemma payoff matrix is illustrated in Table 3-5.

<table>
<thead>
<tr>
<th>Pr 1</th>
<th>2</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 years</td>
<td>1 year</td>
</tr>
<tr>
<td>2</td>
<td>25 years</td>
<td>3 years</td>
</tr>
</tbody>
</table>

### 3.9.5 Perfect Information and Imperfect Information

A perfect information game occurs when all players immediately know the moves and decisions of the other players (Rasmusen 1994). Chess and checkers are the most well known examples of perfect information games. In contrast, imperfect information games are those where the players do not immediately know the decisions of the other players (Rasmusen 1994). The prisoners’ dilemma game is an example of an imperfect information game. The player’s decisions are made independently of one another and not revealed until the end of the game.
3.9.6 Game Theory and Intangible Assets

The nature of intangible assets makes them difficult to value. Yet, intangible assets are becoming increasingly valuable to companies. The need to develop a valuation technique and model is obvious. However, due to a lack of a transaction market, the ability to assign a value to intangible assets is difficult. One method of solving this problem is to simulate the value of intangible assets using a simulation game based on the game theories presented above.

3.10 Theoretical Framework Summary

This chapter presented the conceptual framework for evaluating knowledge capital. Flexibility as a component of knowledge capital was introduced. Real options were shown to be a viable methodology for evaluating flexibility and three constructs of real options were presented: the option to expand, the option to abandon, and the option to defer. Additionally, the three constructs of intangible assets were presented: customer capital, structural capital, and human capital. The trinomial model was presented as the candidate model for valuing a firm's knowledge capital. Finally, the concepts underlying game theory were presented. Chapter IV defines the methodology and design for this examination.
Chapter IV: Methodology

A review of existing valuation model literature, as presented in Chapter II, shows that real option valuation is beginning to be considered a viable valuation methodology. The relevant constructs, variables, underlying assumptions, and simulation methods were further described in Chapter III. This research study aims to determine if knowledge capital can be valued using a simulation methodology supported by real option pricing. The following section presents the research methodology and design of this study.

4.1 Research Methodology
This study used game theory and real option pricing to examine the ability of a simulation model to value intangible assets. Without a public transaction market, it is difficult to assess the true value of intangible assets. This research will use game theory to simulate a public transaction market. The Knowledge Asset Valuation (KAV) Game is further described in the research design section. The trinomial option pricing model is used to assess the theoretical value of the real options. Real options are said to be useful for valuing human, structural, and customer assets if the theoretical calculated real option value using the trinomial option pricing model has a strong correlation to human, structural, and customer assets as determined by the game participants.

4.2 Research Question
The review of the literature illustrated that there are many methods available for valuing intangible assets. It also highlighted, that no one method has emerged superior or universally accepted. This provides an opportunity to
continue to explore methods of valuing knowledge assets. Research has been conducted (Chen 2005; Marr and Moustaghfir 2005; Sudarsanam, Sorwar, and Marr 2006) to determine how real options can be used to value knowledge assets. However, while a theoretical value can be determined from implementing the Black Scholes model (Chen 2005) or hypothesizing a link between intangible assets, business value, and managerial flexibility (Sudarsanam, Sorwar, and Marr 2006), the research has not provided methodology for assessing the validity of the real option models. This research aims to answer the following question:

*Can a simulation model supported by real option pricing be used to evaluate the knowledge capital of a firm?*

From this question, three hypotheses are created:

1. **There is a statistically significant correlation between customer capital asset value determined by participants in a simulated transaction market using rational behavior and customer capital asset value determined by the trinomial real option pricing model.**

   The literature showed that customer assets are one component of knowledge asset value. Customer assets are comprised of customer backlogs, customer relationships, and brand loyalty. Evaluating customer assets with a backlog is a relatively easy task. The value of the customer asset is simply the value of the future projected revenue streams. However, the true value of customer assets cannot be determined until they are sold to another company. While future projected revenue streams discounted back to present value may provide the value of customer assets, it fails to consider the flexibility of actions that
management or customers may take such as expanding the scope of work, canceling the contract, or delaying the start of a project. Real option valuation allows these types of management decisions to be taken into consideration.

2. There is a statistically significant correlation between structural capital asset value determined by participants in a simulated transaction market using rational behavior and structural capital asset value determined by the trinomial real option pricing model.

Structural assets are comprised of “everything that gets left behind at the office when employees go home” (Bontis 2001; Edvinsson and Malone 1997). This includes processes, databases, trademarks, copyrights, and patents. Processes and databases are difficult to value. Inherently they are valuable and business cannot function without them. However, like customer assets, these structural assets cannot be valued until they are sold to another company. Evaluating copyrights and patents is more straightforward. Their value is the future value of the proprietary products or processes that they help to create discounted to the present value. Yet, similarly to customer assets, using the net present value method does not consider potential actions that management might take such as renewing the patent, creating a first mover advantage in the marketplace, or selling the patent or copyright. Real option valuation allows these types of management decisions to be taken into consideration.

3. There is a statistically significant correlation between human capital asset value determined by participants in a simulated a transaction market using
rational behavior and human capital asset value determined by the trinomial real option pricing model.

Human assets are the most difficult of the knowledge assets to value. Unlike customer and structural assets, a company can never truly own a human asset. In addition, not all employees contribute to the core of the business which means that not all employees can be considered human capital (Bontis et al. 1999; Edvinsson and Malone 1997; Sveiby 2001). It is difficult to isolate which employees contribute to the core of the business, which employees contribute to the support of the business, and which employees are merely employed to have a job. One method for assessing human capital is to examine the cost of salaries on the company income statement. That number would then have to be modified to account only for those employees who truly contribute to the core of the business and can be considered human capital. This can be very difficult. Yet, if a company follows activity based cost accounting, this can be achieved. In contrast to customer and structural assets, net present value is not an appropriate method for assessing the value of human assets. Since the amount paid for the assets is determined by the employee salaries and benefits, this number should be used. Real options can still assist in valuing human capital. Real options can be used to account for management decisions such as increasing or decreasing staffing as project requirements change or the ability to delay hiring personnel if needed.

The first research objective is to design a simulation methodology to determine the value of knowledge assets. The first hypothesis seeks to
determine if there is a high correlation between game participant valuation findings for customer assets and the values provided by the theoretical trinomial real option model. The second hypothesis seeks to determine if there is a high correlation between game participant valuation findings for structural assets and the values provided by the theoretical trinomial real option model. The third hypothesis seeks to determine if there is a high correlation between game participant valuation findings for human assets and the values provided by the theoretical trinomial real option model. Combined, these three hypotheses support the design objective to develop a simulation methodology to validate real options as a method for valuing knowledge assets.

The second research objective is to design a methodology for the valuation of intangible assets that is repeatable, auditable, and validated through rigorous scientific testing. Using the KAV simulation game and an accepted mathematical options pricing model, this analysis can be replicated by academics, analysts, and investors. Thus, the methodology is repeatable and auditable. Validation for the findings is provided through correlation tests. Through the design of the methodology the second research objective is supported.

4.3 Research Design
This section presents the research design for KAV game and for the theoretical real option valuation model that was used to validate the results of the game.
4.3.1 Knowledge Asset Valuation (KAV) Game Research Design

The KAV game is designed to learn how rationally behaved players value knowledge assets. The objective of the game is for players to make as much money for their company as possible. In order to do so, players write and buy call options in an effort to make money through call premiums and by taking advantage of changing asset prices.

Each game requires four players. The objective is for each player to maximize the money they earn. Players accomplish this by competing with the other companies (players) for resources (human or structural assets) and customers. In addition, nature is a player in this game. “Nature is a pseudo-player who takes random actions at specified points in the game with specified probabilities” (Rasmusen 1994). In the KAV game, nature functions to change the cost—either up or down, of the available assets.

4.3.1.1 Simulation Design

The purpose of the game is to determine what rationally behaved people would be willing to pay for an option on a knowledge asset. This serves as the actual value of the real option. In order to avoid unrealistic pricing or arbitrary pricing, a brief illustration of option pricing will be presented to the students prior to the beginning of the simulation game. The real option values provided by the students were then compared to the theoretical value determined by the trinomial option pricing model.

The KAV game is a non-zero sum game. It is impossible for all parties to maximize profitability equally. There are a limited number of resources available and all players must compete for the same resources. The game is a symmetric
game. All the actions in the game are available to all players; available actions are not dependent upon the player’s role in the game. The game is designed as a two stage game; each round repeats the same baseline game. It is a sequential game where players alternate take turns and it is a game of perfect information. All players immediately know the outcome of the actions that an individual player takes. Appendix A provides the complete game directions, game board, and the call information data sheet.

4.3.1.2 Participant Selection

This study used multiple games to gather data. Game participants will be graduate students in the School of Engineering at George Washington University. Student enrolled in the School of Engineering are typically professional adults working towards a master’s degree. Most of them maintain full time positions outside of their university work. This experience and maturity makes them an appropriate audience in which to play the simulation game to gather data. It is anticipated that the class will have approximately 10-12 students providing approximately two or three simulation opportunities.

4.3.1.3 Data Analysis

While the game simulation has many elements, the data required for this research study will be provided by the Call Premium documented on the Call Information Sheet. The amount paid and received for the knowledge assets will become the stock price in the real option model. The player’s views of acceptable call values will become the true option value while the real option
model value will become the theoretical value. The data will be analyzed to determine if there is a correlation between:

1) Structural asset value as determined by participants in a simulated transaction market using rational behavior and structural asset value determined by the trinomial real option pricing model.

2) Human asset value as determined by participants in a simulated transaction market using rational behavior and human asset value determined by the trinomial real option pricing model.

3) Customer asset value as determined by participants in a simulated transaction market using rational behavior and customer asset value determined by the trinomial real option pricing model.

For each pair of variables identified, the strength of the linear relationship between them will be evaluated using parametric correlation analysis. If there is a strong correlation, it can be concluded that real option modeling is an appropriate method for valuing knowledge assets.

4.3.2 Real Option Research Design

As illustrated in Chapter III, this analysis lends itself to the trinomial model.

The underlying assumption of this model is that management’s ability to modify decisions (flexibility) at various points in time creates value. Since companies report earnings quarterly, it is assumed that management has the right to modify decisions at any time during the year, but at a minimum they will modify decisions quarterly.
4.3.2.1 Variables
The inputs to the trinomial real option model are as follows

<table>
<thead>
<tr>
<th>Trinomial Model</th>
<th>Real Option Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>S Stock price</td>
<td>Structural: as reported from the Call Information Sheet</td>
</tr>
<tr>
<td></td>
<td>Customer: as reported from the Call Information Sheet</td>
</tr>
<tr>
<td></td>
<td>Human: as reported from the Call Information Sheet</td>
</tr>
<tr>
<td>K Exercise price</td>
<td>The Strike Price from the Call Information Sheet</td>
</tr>
<tr>
<td>T Days till expiration</td>
<td>Based on expiration time on the Call Information Sheet</td>
</tr>
<tr>
<td>R Risk free rate</td>
<td>The associated treasury bill rate</td>
</tr>
<tr>
<td>σ Stock volatility</td>
<td>Average four year historical stock volatility from SIC 8742</td>
</tr>
</tbody>
</table>

The Call Information Sheet from the KAV game provides most of the data for both the theoretical model and the actual model values. The theoretical value is calculated using the trinomial pricing model, while the actual value is determined by the game participants.

$S$ is the Asset Cost on the Call Information sheets as reported by the game participants. $K$ is the strike price as reported on the Call Information sheet by the game participants. $T$ will be determined by the round in which the option was written and the time to expiration on the Call Information Sheet. $R$ will be determined by the length of time to expiration. For calls that are written and expire within four rounds, the 90 day Treasury bill index rate at the time the game is played will be used. For calls that expire within eight rounds after they are written, the 180 day Treasury bill index rate at the time the game is played will be used. For calls that expire after 12 rounds, the one year constant maturity index
at the time the game is played will be used. The risk free rate used to calculate
the trinomial option price is not known to the players.

While most inputs to the model are readily available, volatility, \( \sigma \), is the
most difficult variable to determine since it is a measure of uncertainty about the
returns from the underlying asset (Hull 1997). The standard calculation for
estimating volatility from historical data is

\[
s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (u_i - \bar{u})^2}
\]  

(4.1)

In order to assess volatility in this manner, it must be observable in the
financial markets. Since volatility related to real options cannot be readily
observed, Luehrman (1998) suggests three methods for calculating volatility:
make an educated guess by examining the range of \( \sigma \), use historical investment
return data, or simulate \( \sigma \) by using future cash flows and Monte Carlo simulation.
For this study, the second approach will be used. In order to determine historical
investment returns, a data set must be identified. Management consulting
environments typically do not manufacture or create tangible products. They are
more interested in selling intangible assets such as subject matter expertise,
processes, and customer relationships. Therefore, the management consulting
companies are an appropriate data set to use in order to identify historical return
data.

Management consulting Companies were screened for inclusion using the
Mergent database. The search was run using two criteria: Primary SIC = 8742,
Management Consulting Services and Stock Exchange = "NAS" OR "NYS" OR "ASE".

In order to calculate volatility, daily historical stock prices were collected over the study period (January 2, 2002-December 29, 2006). The Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model was then used to calculate the historical annualized volatility. The GARCH model developed by Bollerslev (1986) is one of most widely used models for forecasting volatility (Akgiray 1989; Anderson 1998; Calvet 2004; Hansen 2005; Pagan 1990; West 1995). In its simplest form, the GARCH (1, 1) model uses past volatility as a predictor of future volatility. The equation for GARCH (1, 1) is

\[ \sigma_n^2 = \omega + \alpha \mu_{n-1}^2 + \beta \sigma_{n-1}^2 \]  

(4.2)

The volatility used to calculate the trinomial option price is not known to the players.

4.3.2.2 Population Description

The population for the real options evaluation will be all data collected from the multiple KAV game simulations. Outliers will be screened and considered bad data. These data points will not be included.

4.3.2.3 Sampling Strategy

The sample for the real options analysis will include all the simulations of the KAV game. With a confidence interval of ten percent and a confidence level of 95 percent, the acceptable sample size is 96. Each Call Information Sheet

\[ \sigma_n^2 \] in GARCH (1, 1) indicates that \( \sigma_n^2 \) is based on the most recent observation of \( \mu^2 \) and the most recent estimate of the variance rate" Hull, J. C. 1997. Options, Futures and Other Derivatives New Jersey: Prentice Hall.
represents one data point. The call premium data from the KAV game are assumed to be independent, identically, distributed data points. While the call premiums are based on other information in the Call Information sheet, one call premium does not impact the value of another call premium.

4.3.2.4 Data Collection
Data for the real options analysis will be collected from the KAV game.

4.3.3 Outputs

The output of this model will be the call value for each construct.

4.4 Data analysis
The study data will be analyzed to assess the relationship between pairs of calculated and observed capital estimates including:

1) Human Capital from the Knowledge Asset Game and Human Capital from the Trinomial Option Pricing Model.
2) Structural Capital from the Knowledge Asset Game and Structural Capital from the Trinomial Option Pricing Model.
3) Customer Capital from the Knowledge Asset Game and Customer Capital from the Trinomial Option Pricing Model.

For each proposition identified, a correlation coefficient will be calculated. A high correlation coefficient indicates a strong linear relation, and would suggest that the simulation methodology supported by the trinomial option pricing model could be used to value knowledge assets; while a low correlation coefficient would indicate that the simulation methodology as developed in this study, is not a valid method for valuing knowledge assets.
4.4.1 Statistical Model

Correlations are identified by using the parametric Pearson Product Moment Correlation and the non parametric Spearman Rank Order Correlation. Correlation theory measures how well any two variables vary together. Since this study seeks to determine if intangible asset values as determined by participants in the Knowledge Asset Valuation game varies with the intangible asset values as determined by the trinomial option pricing model, correlation theory is appropriate. The correlation coefficient, $r$, quantifies the direction and magnitude of the correlation. Since all of the variables in this study are measured outcomes, the use of correlation theory is further justified.

4.4.2 Analysis Procedures

The analysis seeks to determine a correlation between values derived by the game participants and values derived from the trinomial option pricing model. For each intangible asset construct: structural, human, and customer assets, a correlation coefficient is calculated to determine the strength of the correlation. Each analysis begins with a scatter plot of the observed data constructed in Minitab. The null hypotheses for the correlation tests are as follows:

1. $H_1$: There is no linear correlation between human capital from the Knowledge Asset Game and human capital from the trinomial option pricing model.
2. $H_2$: There is no non-parametric correlation between human capital from the Knowledge Asset Game and human capital from the trinomial option pricing model.

3. $H_3$: There is no linear correlation between structural capital from the Knowledge Asset Game and structural capital from the trinomial option pricing model.

4. $H_4$: There is no non-parametric correlation between structural capital from the Knowledge Asset Game and structural capital from the trinomial option pricing model.

5. $H_5$: There is no linear correlation between customer capital from the Knowledge Asset Game and customer capital from the trinomial option pricing model.

6. $H_6$: There is no non-parametric correlation between customer capital from the Knowledge Asset Game and customer capital from the trinomial option pricing model.

Each hypothesis will be tested using two-tailed tests with $\alpha = .05$. The Pearson formula is given by:

$$ r = \frac{\sum XY - \left( \frac{\sum X}{n} \right) \left( \frac{\sum Y}{n} \right)}{\sqrt{\left( \sum X^2 - \frac{\left( \sum X \right)^2}{n} \right) \left( \sum Y^2 - \frac{\left( \sum Y \right)^2}{n} \right)}} $$

(5.1)

The Spearman formula is given by:

$$ 1 - \frac{6\sum D^2}{N(N^2 - 1)} $$

(5.2)
where: \( N \) is the number of pairs (XY) and \( D \) is the difference between each pair (X - Y).

### 4.4.3 Critical Assumptions

Assumptions of the Pearson model include:

1. The joint distribution of the variables is Gaussian
2. The relationship between the variables is linear
3. \( X \) and \( Y \) are metric variables, measured on an interval or ratio scale of measurement.
4. The variables are independently identically distributed

Relaxations of the assumptions of the Spearman model include:

1. Data is not normally distributed
2. Relationship between the variables does not have to be linear
3. Variables may be measured on ordinal scale

### 4.4.4 Justification of the Model

The process used for knowledge capital valuation in this study is shown in Figure 4-1.
The financial model that is used to value the flexibility and agility is the trinomial option pricing model. This is the appropriate model to use because:

- It can be used to value American options—this addresses management’s ability to make decisions and change the course of action prior to the end of the asset life.
- It has three paths per decision node—this addresses management’s ability to expand, contract or abandon, or remain at the status quo.

Validation for the findings is provided through the evaluation of the correlation coefficient for the three different constructs. Evaluating the correlation coefficients between the game results and the trinomial option pricing model using three different hypotheses will enable a conclusion to be drawn about the ability of real options to be used as a valuation model for knowledge capital.

4.5 Research Reliability and Validity

This section examines the threats to reliability and validity within this study.
4.5.1 Threats Reliability

Data for volatility for the real options model will be collected from historical stock prices. The threat to reliability for this information is that while is representative of the volatility of the stock price, it may not represent the volatility of the option. Additionally, since the GARCH (1, 1) model uses historical volatility to predict future volatility, volatility may not be accurate as a result of a significant change in the stock market. The threat from the game is that participants might not exercise rational behavior. However, since the trinomial real options model is an accepted valuation model and this research treats the model as a black box, there are no threats to reliability stemming from the evaluation model.

4.5.2 Threats to Design Validity

Internal validity focuses on cause and effect relationships. This study does not seek to determine a cause and affect relationship, merely, that the two measurement approaches have a strong linear, or non-linear association. For this correlation analysis to be relevant to the real world, it is important that the knowledge asset valuation game simulation model real world behaviors and provide realistic estimates of knowledge capital. The primary threat to the internal validity of the knowledge asset valuation game is that it might fail to produce data that reflect how people actually value knowledge capital. In that case, the correlation between the trinomial option pricing model and the game participant’s values of knowledge capital would produce a false correlation and would not be generalizable to the real world.
External validity focuses on the ability to generalize the findings to real world companies. The sample population for this study is constrained to students currently enrolled in classes in the Engineering Management and Systems Engineering program at George Washington University. It is possible that this study population is not reflective of everyone in the real world. Students may value knowledge differently than non-students. In this case, the study may find a strong correlation between the trinomial option pricing model and the knowledge asset value game simulation results, but it would not be valid in the real world because of this non-generalizability.

4.6 Methodology and Design Summary

This chapter presented the research methodology and design of the study. The research will utilize a quantitative, correlation approach to frame the analysis. Data will be collected from two independent sources—the Knowledge Asset Valuation simulation and the trinomial option pricing model. The data sets will then be analyzed using correlation theory to determine if a statistically significant correlation exists indicating that the trinomial option pricing model is a relevant method for valuing knowledge assets.
Chapter V: Data Analysis

5.1 Game Play Development

The KAV game was developed through multiple iterations. The development and refinement of the game is described below.

5.1.1 Iteration One

The game was first developed as a flow chart as shown in Figure 5-1 using a management consulting framework. Players were to bid on consulting work and earned revenue by progressing through the game. The game required players to function as the CEO of a company starting with $750,000. The objective of the game was to maximize profitability; but revenue was only realized if an engagement was completed. Players competed with the other companies (players) for resources (human or structural assets) and customers. Players had the option to hire employees if they were available in the resource pool or they had the option to hire them away from one their competitors. Players could also purchase tools that would make their engagements easier to complete. If a player’s competitor owned a tool that they wanted, players had the option to negotiate a purchase for that tool.

Scoring in iteration one was done using three score sheets--one for customer capital, one for structural capital, and one for human capital. Each time a player made a purchase, they were required to record various information on the score sheet. At the end of each quarter, players were asked to record the call price they would be willing to accept for the asset and the put price they
would be willing to pay for the asset. A summary of the score sheet detail is provided below.

a. For Human Capital, players need to record:
   i. The quarter in which the resource was acquired
   ii. The quarter in which the resource was released (if any)
   iii. The price paid to acquire the resource
   iv. The salary listed on the resource card
   v. The amount received to let the resource go (if applicable)

b. For Structural Capital, players need to record:
   i. The quarter in which the asset was acquired
   ii. The quarter in which the asset was sold (if any)
   iii. The price paid to acquire the asset
   iv. The price of the asset listed on the structural capital card
   v. The price received for the asset if sold (if applicable)

c. For Customer Capital, players need to record
   i. The quarter the engagement was won
   ii. The quarter in which the revenue is recognized. Remember, revenue can only be recognized when an engagement is complete.
   iii. The amount of the revenue from the engagement listed on the Proposal Card.
iv. The price received if you sell the relationship to another player

The game was tested using four knowledge management doctoral students at George Washington University. However, students found the game play and the directions to be very confusing. The original game design is shown in Figure 5-1. Using their input, the KAV game was refined to cover two distinct phases—proposal and execution as shown in Figure 5-2.
5.1.2 Iteration Two

The second iteration of the game was very similar to the first iteration.

The primary difference was the delineation between the proposal phase and the execution phase. The test players from iteration one felt that it was difficult to comprehend when they would start earning revenue so this delineation was necessary.
Figure 5-2, KAV game Iteration 2

Phase I—Proposal Phase

Start

Pick Proposal Card

Do you have staff capable of writing the proposal?

Yes

Write proposal

Did you win the proposal? (Flip Coin)

Yes (continue to next decision block)

No

Hire Resources from Staffing Pool or from other companies

Yes

Buy assets from game administrator other companies

No

Phase II—Execution Phase

Begin Engagement

Is the engagement going well? (Pick Engagement Card)

Yes

Take Corrective Action. Follow directions on engagement activity card.

No

Is the engagement going well? (Pick Engagement Card)

Yes

Take Corrective Action. Follow directions on engagement activity card.

No

Is the engagement going well? (Pick Engagement Card)

Yes

Take Corrective Action. Follow directions on engagement activity card.

No

Is the engagement going well? (Pick Engagement Card)

Yes

Take Corrective Action. Follow directions on engagement activity card.

No

Engagement End. Recognize Revenue

Fill out Score Sheet

Does the client want to book another engagement with you? (Flip Coin)

Yes

Congratulations—you have established a relationship

Fill out Score Sheet

Yes

No

No
The other change to the game a simplification of the score sheets. The score sheet was reduced from three sheets to one sheet. The new scoring directions were as follows:

1) Every transaction must be recorded.
2) Record every transaction as either Human (H), Structural (S), or Customer (C)
3) Record each transaction in the Phase (I or II) in which it occurs.
4) At the end of each phase, record the price you would be willing to accept in order to give someone else the **RIGHT** to purchase the asset at a fixed price 1 year from now.

Test players for iteration two were four management consulting professionals. Comments from these test players continued to emphasize the difficulty in understanding option pricing, the flow of the game, and the difficulty in keeping score.

5.1.3 Iteration Three

Based on the comments from the previous two iterations, it was obvious that a flow chart style game would not be effective. Test players suggested using a more familiar game board to reduce some of the learning curve. Using that advice, the KAV game was redesigned as a square board game with colored squares that represent companies those players can own. The new game board is depicted in Figure 5-3. Additionally, the game objective was simplified from

The objective of the game is to maximize profitability; however revenue is only realized if an engagement is completed. You will compete with the other companies (players) for resources (human or structural assets) and customers. You may hire employees if they are available in the resource pool or you may try to hire them away from one of your competitors. You may also purchase tools that will make your engagements easier to
complete. If your competitor owns a tool that you would like, you may try to negotiate a purchase for that tool.

At the end of play, be the player with the most money. There are two ways to make money in this game:

1) Add structural and/or human assets to your colored company space to increase consulting and customer fees
2) Write call options and collect call premiums when sold from other players.

Test players felt this game board was more familiar to them and that they could concentrate on the specific game objective of buying and selling options. Options for iteration three were further simplified by eliminating the ability to buy and sell put options—only call options were available. In this iteration, players throw dice to move their colored pawns around the board game. Money is made by collecting consulting fees from other players and revenue from customers. Scoring was further simplified by the introduction of the Call Information Sheet (CIS). The CIS asks players to record a number of data points.

1. Company Letter—Write the company letter that this call option is being written for in this box. You may select any company that you own to write the call option for.

2. Type of Asset (H,S,C)—As the writer of the call option, you may select what asset you are willing to write the call option for. However, you must own the asset in order to write a call option against it. You may select from Human Assets, Structural Assets, or Customer Assets.

3. Asset Cost (from Company Card)—Once you decide what asset you are willing to write the call option against, look up the asset cost on you
company card. Remember to look to see if the Invisible Hand has changed the base asset price. Write that price here. If you select a Customer Asset, the Asset Cost is the Base Project Revenue plus any additional revenue from Human or Structural Assets as shown on the Customer Card.

4. *Expiration Date (from drawn card)*—from the Expiration Card that you drew, record when this call option will expire (Q1, Q2, Q3, or Q4)

5. *Strike Price (from drawn card)*—from the Strike Price Card that you drew, record the strike price of your asset.

6. *Call Premium*—The premium is the price you are willing to sell the RIGHT for another player to buy the asset at the strike price before the expiration—see additional direction sheet “how to price a call” for more information. It is NOT the amount you are willing to sell the asset for at a later date. Remember the longer the time to expire the more opportunity for a player who has purchased the call from you to exercise it. There is also more opportunity for the invisible hand to change asset costs. Price your call accordingly.

7. *Exercised (Y/N)*—If the call option is exercised, mark as Y. If it expires unexercised, mark as N.

Another change to this iteration was the inclusion of buying and writing call option boxes. An issue with the previous iterations was that players had the option to write and buy calls, but were not required to do so. Since they were
having difficulty understanding call options, the tendency was to not write them. This significantly impacted the ability to collect data.

The CIS data sheets became the data collection mechanism. Test players for this round included two financial professionals and two engineers. Players still struggled to understand the concept of real options, but were able to play the game without too many challenges.

Test players understood the concept of the game much better and were successfully able to play the full game. Forcing players to write call options facilitated both their understanding of call options and the data collection objective.
Figure 5-3, KAV game Iteration 3

1. **Start**

2. **Options**
   - Buy Call Option
   - Write Call Option

3. **Companies**
   - Company A
   - Company B
   - Company C
   - Company D

4. **Assets**
   - Human Asset
   - Customer Asset
   - Structural Asset

5. **Actions**
   - Invisible Hand
   - Buy Call Option
   - Write Call Option
   - Choose Cards

6. **Cards**
   - Expiration Date Cards
   - Strike Price Cards
   - Customer Cards

7. **Invisible Hand Cards**
   - Invisible Hand Card

8. **Decision Points**
   - Decide based on market analysis and strategic planning.

9. **Outcomes**
   - Evaluate the impact on the company's financial health.

10. **Feedback Loop**
    - Iterate and adjust strategies accordingly.

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5.1.4 Iteration Four

Iteration four was a beta test of iteration three. There were no changes to the game structure, only the test players changed. For this iteration, two George Washington University professors and two George Washington University School of Engineering doctoral students participated. One professor and one doctoral student were familiar with option pricing.

The results of this iteration highlighted some additional opportunities for improvement.

1. One professor used most of his money to buy out all of the available resources. This revealed that $2,000 for starting money was too much.

2. The volatility did not change often enough. The volatility of the game only changed every 15 minutes. Players felt the game would be more realistic if the volatility changed every round.

3. There were not enough opportunities to write and buy call options.

4. Players wanted the option to write a call option on more than one asset (human or structural) if they owned more than one asset on a specific company.

5. Expiration dates based on time were not working. Players suggested changing expiration to number of rounds.

This input lead to the creation of iteration five.
One outcome of iteration four was the collection of test data. Seven CIS data sheets were collected. A quick correlation analysis showed a moderate correlation between the trinomial calculated values and the KAV game values.

5.1.5 Iteration Five

This iteration is based on the input from iteration four. Changes to this iteration include:

1. Adding a column for the number of options available for sale to the CIS.
2. Adding more volatility to the game by eliminating the invisible hand corners. At the beginning of each round, the first player will change the volatility by turning over an invisible hand card for Customer, Human, and Structural assets.
3. The amount of money each player starts with was reduced from $2,000 to $200.
4. Expiration dates were changed to “Expires in xxxx rounds”.
5. Strike price cards were modified so that the strike price could never go below $5.00.
6. The Write Call Option, Buy Call Option, and Invisible Hand spaces were replaced with more colored company spaces.
7. Players were given the option to exercise options at any time instead of only at the beginning of their turn.
5.2 Game Play Analysis

The results of the three game simulations are presented below. In addition, a comprehensive analysis is presented.

5.2.1 Game Play Results

The results below came from the first scenario of the KAV game in its final form. This scenario was played using 12 students in a finance class. 25 valid CIS were collected from the 12 players. 7 additional CIS were returned with large X's drawn through them. These were interpreted as invalid CIS. The descriptive statistics from this game are shown in Table 5-1.
Table 5-1, Game Play One Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>SE Mean</th>
<th>St. Dev</th>
<th>Minimum</th>
<th>Q1</th>
<th>Medium</th>
<th>Q3</th>
</tr>
</thead>
<tbody>
<tr>
<td>KAV Value</td>
<td>25</td>
<td>19.68</td>
<td>5.27</td>
<td>26.36</td>
<td>1.00</td>
<td>4.00</td>
<td>8.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Call Value</td>
<td>25</td>
<td>8.85</td>
<td>1.79</td>
<td>8.93</td>
<td>0.04</td>
<td>4.33</td>
<td>7.49</td>
<td>11.63</td>
</tr>
</tbody>
</table>

5.2.1.1 Game Play One Inferential Statistics

The 25 CIS were first analyzed using a probability plot. Figure 5-5 shows that the data is not normally distributed. This indicates the need to use the Spearman Rank Order Correlation for further analysis.

![Figure 5-5, Game Play One Probability Plot]

The Spearman Rank Order Correlation shows a correlation between the two data sources of .022. This indicates little to no correlation between the two data sources. A careful analysis of the CIS shows that many students believed the call premium to be the amount they hoped to receive from the sale of the call.
option. The results of this iteration show that it is necessary to clearly explain the concept of options to the players prior to starting the play of the game.

Using box plots of both the KAV game Value and the Call Value, outliers can be identified. Figure 5-6 and Figure 5-7 show the box plots of these two variables.

After removing the outlying data points, a new probability plot can be run as shown in Figure 5-8. With the seven outlying data points removed, the data is normally distributed. Using the Pearson Product Moment Correlation, the data has a correlation of .303. This shows a low correlation between the data.
5.2.1.2 Game Play One Post Hoc Analysis

Students in the class acknowledged that they enjoyed playing the game. Many stated that they would like to play it again. While the data shows a low correlation between the KAV game and Call Values, the students felt it was a valuable learning tool for understanding a method to value knowledge assets. It was interesting to see the students’ progress from not understanding call options to developing an appreciation for the role they play in the market. Students commented that it was challenging to learn how to play the game and understand option values. Based on this feedback, the game should include a demonstration round prior to the start of play.

It is interesting to note that there was an increase in the correlation between the KAV game and Call values as the rounds progress. The overall correlation was -0.049. The correlation between the two values increased to .227 when only
considering CIS from round six forward. This indicates that the students are able to use the KAV game as an option learning tool. It would be interesting to play the game for a longer duration to see if the correlation continued to increase.

5.2.2 Game Play Two

This game was played using eight students in a doctoral research class. 32 valid CIS were collected from the eight players. Two additional CIS were returned with large X’s drawn through them. These were interpreted as invalid CIS. The descriptive statistics from this game are shown in Table 5-2

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>SE Mean</th>
<th>St Dev</th>
<th>Minimum</th>
<th>Q1</th>
<th>Medium</th>
<th>Q3</th>
</tr>
</thead>
<tbody>
<tr>
<td>KAV Value</td>
<td>32</td>
<td>17.31</td>
<td>3.93</td>
<td>22.21</td>
<td>0.25</td>
<td>5.00</td>
<td>10.00</td>
<td>16.75</td>
</tr>
<tr>
<td>Call Value</td>
<td>32</td>
<td>7.608</td>
<td>.992</td>
<td>5.611</td>
<td>0.000</td>
<td>2.498</td>
<td>6.815</td>
<td>12.140</td>
</tr>
</tbody>
</table>

5.2.2.1 Game Play Two Inferential Statistics

The 32 CIS were first analyzed using a probability plot. Figure 5-9 shows that the data is not normally distributed. This indicates the need to use the Spearman Rank Order Correlation for further analysis.
The Spearman Rank Order Correlation shows a correlation between the two data sources of .039. This indicates a slight correlation between the two data sources. This iteration achieved a higher correlation than game play one between the KAV game and the actual call value. For this game, it was clearly explained that the call value is not the value the player expected to receive from the sale of the asset. While most players understood this concept, a review of the raw data indicates that some players did not fully understand this concept. The increase in the correlation coefficients from game play one to game play two suggests that with additional instruction, the KAV game simulation may prove to be a viable valuation model.
Using box plots of both the Call value and the KAV game value, outliers can be identified. Figure 5-10 and Figure 5-11 show the box plots of these two variables.

After removing the outlying data points, a new probability plot can be run as shown in Figure 5-12. With the seven outlying data points removed, the data is normally distributed. Using the Pearson Product Moment Correlation, the data has a correlation of .135. This shows a low correlation between the data.
5.2.2.2 Game Play Two Post Hoc Analysis

Students in this class were doctoral candidates. As such, they were very interested in the research that was being conducted. The students acknowledged that the game was interesting, taught them about valuing knowledge capital, and provided insight into other types of research that they could conduct. Again, while the data shows a low correlation between the KAV game and Call Values, the students felt it was a valuable learning tool for understanding how knowledge capital could be valued and about option pricing. Incorporating suggestions from game play one, game play two began with an introductory teaching lesson about options as well as a trial round. Game play one had a correlation of .022 between the KAV game and the Call Value. Game play two increased the correlation to .039 between the KAV game and the Call...
Value. Continued explanations and increased round play should increase the correlations even more.

### 5.2.3 Game Play Three

This game was played using seven students in a doctoral research class. 13 valid CIS were collected from the seven players. 53 additional CIS were completed. However, these CIS had call values greater than $50. When asked why the players were completing their call sheets in the manner, they replied that they wanted to write a call, but had no desire to sell the call and thus were pricing it so high so as to be worthless. These 53 CIS will not be included in this analysis. The descriptive statistics from this game are shown in Table 5-3.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>SE Mean</th>
<th>St Dev</th>
<th>Minimum</th>
<th>Q1</th>
<th>Medium</th>
<th>Q3</th>
</tr>
</thead>
<tbody>
<tr>
<td>KAV Value</td>
<td>13</td>
<td>9.54</td>
<td>2.71</td>
<td>9.76</td>
<td>1.00</td>
<td>4.00</td>
<td>5.00</td>
<td>11.00</td>
</tr>
<tr>
<td>Call Value</td>
<td>13</td>
<td>7.47</td>
<td>1.29</td>
<td>4.66</td>
<td>0.67</td>
<td>3.20</td>
<td>8.12</td>
<td>10.77</td>
</tr>
</tbody>
</table>

### 5.2.3.1 Game Play Three Inferential Statistics

The 13 CIS were first analyzed using a probability plot. Figure 5-13 shows that the data is normally distributed.
Using the Pearson Product Moment Correlation, the data has a correlation of -0.058. This indicates a very slight inverse relationship between the two variables.

5.2.3.2 Game Play Three Post Hoc Analysis

This game was played by two different groups. One group understood the game very well and played it accordingly. They understood the concept of option pricing and valuing intangible assets. The other group played the game using a very unique strategy. Two players bought approximately 90% of the assets at the beginning of the game. This left the other two players with enough assets to continue to stay in the game, but certainly not enough to win. The players that owned all the assets then wrote calls on the assets. But they priced the call
options so high that it would not be rational for the other players to purchase the calls. It was an interesting strategy, but one that does not help in the data analysis for this research. As a result of this strategy, the KAV game should be modified to only allow the purchase of a specific number of assets at the beginning of each round.

5.2.4 Consolidated Analysis

Each game play has been analyzed separately. The purpose of this analysis is to provide a comprehensive analysis. In total, 27 independent students participated in this research. 134 CIS were collected and of those, 70 are considered valid CIS. Had the last game play not included an unforeseen strategy, the number of valid CIS probably would have been higher.

5.2.4.1 Consolidated Analysis Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>SE Mean</th>
<th>St Dev</th>
<th>Minimum</th>
<th>Q1</th>
<th>Median</th>
<th>Q3</th>
</tr>
</thead>
<tbody>
<tr>
<td>KAV Value</td>
<td>67</td>
<td>14.18</td>
<td>2.24</td>
<td>18.30</td>
<td>0.25</td>
<td>5.00</td>
<td>7.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Call Value</td>
<td>67</td>
<td>7.981</td>
<td>0.822</td>
<td>6.730</td>
<td>0.000</td>
<td>4.060</td>
<td>7.494</td>
<td>11.10</td>
</tr>
</tbody>
</table>

5.2.4.2 Consolidated Analysis Inferential Statistics

The 70 CIS were first analyzed using a probability plot. Figure 5-14 shows that the data is not normally distributed. This indicates the need to use the Spearman Rank Order Correlation for further analysis.
The Spearman Rank Order Correlation shows a correlation between the two data sources of .0023. This indicates little to no correlation between the two data sources.

Using box plots of both the Call value and the KAV game value, outliers can be identified. Figure 5-15 and Figure 5-16 show the box plots of these two variables.
After removing the outlying data points, a new probability plot can be run as shown in Figure 5-17. With the seven outlying data points removed, the data is normally distributed. Using the Pearson Product Moment Correlation, the data has a correlation of .015. This shows a low correlation between the data.

After removing the outlying data points, a new probability plot can be run as shown in Figure 5-17. With the seven outlying data points removed, the data is normally distributed. Using the Pearson Product Moment Correlation, the data has a correlation of .015. This shows a low correlation between the data.

**Figure 5-17, Consolidated Probability Plot--No Outliers**

![Consolidated Probability Plot--No Outliers](image1)

**Figure 5-16, KAV Box Plot**

![KAV Box Plot](image2)
5.2.4.3 Consolidated Analysis Post Hoc Analysis

The data did not show a strong correlation between the KAV game and the Call value. However, many students stated that the simulation helped them to understand how to price calls and how call options work. As shown in Figure 5-18, starting in round 3, students began to develop an understanding of pricing call values.

![Figure 5-18, Learning Curve](image)

This is indicative of the presence of a learning curve. Learning curves explain increased efficiency or accuracy as a result of a repetitive behavior. Most often, learning curves are used in manufacturing as a method to estimate potential cost reductions. In this case, the learning curve can be used to show that as rounds progress and students become more familiar with option pricing and the game simulation, students KAV game responses are more closely correlated with the actual trinomial call price.

In reviewing the data, round six had two outliers. Once they were removed the learning curve in Figure 5-19 shows that strong correlations begin to
occur by round three and remain high. This may indicate that the KAV game should be played in two sessions. The first session could be dedicated to learning to play the game as well as learning to price the options. The follow-on session could then be used for actual pricing of the options.

![Learning Curve--No Outliers](image)

5.2.5 Sensitivity Analysis

The data used the risk free rate at the time the game was played and a calculated volatility rate to determine the trinomial option price. It is interesting to examine how sensitive the data might be to changes in these variables. Figure 5-20 shows the changes in the correlation between the KAV game value and the calculated call option value when volatility changes. As volatility increases, the correlation between the KAV game and the calculated call value also increases. However, even with a correlation value of 8.58%, it still cannot be concluded that there is a strong correlation between the two variables.
Figure 5-20, Volatility Sensitivity

Figure 5-20 shows the relationship between the KAV game value and changes in interest rates. Interest rate sensitivity was calculated based on .05% and 1% changes as that is the most common change that the federal reserve makes to the risk free rate. Again, while the correlation between the KAV game and the revised calculated call values increases, it is not a significant change.

Figure 5-21, Interest Rate Sensitivity
Chapter VI: Conclusions

Valuing intangible assets remains one of the most difficult issues to solve. At the heart of the issue is that intangible assets cannot be valued until they are sold. Yet, without knowing the value of the assets, it is difficult to price them for sale. Compounding the issue is the fact that every organization places a different value on intangible assets. What is important to one organization may not be important to another, thus making it difficult to develop a universal valuation model.

This research attempted to correlate intangible asset value from the Knowledge Asset Game and the trinomial option pricing model. The results of the research hypothesis are shown below.

1. $H_1$: There is no linear correlation between human capital from the Knowledge Asset Game and human capital from the trinomial option pricing model.

   Finding: Do not reject—there is no linear correlation

2. $H_2$: There is no non parametric correlation between human capital from the Knowledge Asset Game and human capital from the trinomial option pricing model.

   Finding: Do not reject—there is no non parametric correlation

3. $H_3$: There is no linear correlation between structural capital from the Knowledge Asset Game and structural capital from the trinomial option pricing model.

   Finding: Do not reject—there is no linear correlation
4. H₄: There is no non parametric correlation between structural capital from the Knowledge Asset Game and structural capital from the trinomial option pricing model.

**Finding: Do not reject—there is no non parametric correlation**

5. H₅: There is no linear correlation between customer capital from the Knowledge Asset Game and customer capital from the trinomial option pricing model.

**Finding: Do not reject—there is no linear correlation**

6. H₆: There is no non parametric correlation between customer capital from the Knowledge Asset Game and customer capital from the trinomial option pricing model.

**Finding: Do not reject—there is no non parametric correlation**

The research indicates that no statistically valid correlation can be determined from the Knowledge Asset Valuation game and the trinomial model. That does not mean that this research is without merit. As shown by the Michelson-Morely (Michelson 1887) experiment, identifying what is not true is as important as identifying what is true. In their experiment, Michelson and Morley were confident that they could detect the presence of aether wind in space. At the conclusion of their experiment, the research team was forced to acknowledge that their experiment had failed and they could not state that they had found aether wind in space. While the experiment itself was not a success, it laid the foundation for additional research including Einstein’s theory of relativity.
The first objective of this study was to design a simulation methodology that can be used to determine the value of knowledge assets. Players learned to buy and sell call options on knowledge assets including human, structural, and customer assets. The price of the call option that the players set mimicked the real option value of the knowledge assets. The value determined by the players was then compared to the true value provided by trinomial option pricing model. The data from the study showed that the values were not closely correlated. There are a few possible reasons for this lack of correlation:

1. The methodology for determining the input variable values may be flawed. The input variables are given by the trinomial model. However, the value assigned to these variables may not be correct. Developing a better methodology for defining the input variables would be an interesting follow-on research project.

2. Players were unfamiliar with the pricing model. Players who have not been exposed to the concept of option pricing and subsequently, real options, had difficulty grasping the idea that the option price was a price paid for the right to purchase something in the future, not the actual purchase price.

3. Players did not always exercise rational behavior. One of the assumptions of this study was that players would act rationally. It was observed that sometimes players acted not in their best financial interests in order to financially hurt another player in the game. The game directions could be modified to prevent this behavior from occurring.
The second objective of the study was to develop a methodology that is reliable, repeatable, and auditable. The design of the KAV game is reliable and the methodology is repeatable; however the results are not and therefore are not auditable. Therefore, it cannot be concluded that this methodology as currently designed can be used a valuation model for knowledge assets.

While the KAV game did not show a correlation to the trinomial model values, it did prove to be a valuable tool for teaching students about option pricing. The KAV game, as designed, can also be used as a prediction market game for knowledge asset values. Prediction markets are fictional markets created solely for the purpose of gathering information and making predictions about future events. Prediction markets have been used to gather information about sports, politics, consumer technology, entertainment, energy and military policies. Information in the prediction markets is gathered by creating a position and allowing players to take a for or against position in the prediction market.

Recently Best Buy (Dvorak 2008) developed an internal market that allowed “workers to trade imaginary stocks based on answers to managers’ questions.” Best Buy found that the outcomes of prediction markets were often more accurate than the forecasts of its experts. In addition to Best Buy, other companies such as Google, General Electric, and Microsoft have all used prediction markets to forecast the outcome of their products. There is no reason why the KAV game could not be used as a prediction market to determine knowledge asset values.
6.1 Post Hoc Analysis

The KAV game proved to be very successful at teaching students about real options and knowledge capital valuation. It also highlighted many of the difficulties that have plagued researchers and real world companies when trying to value knowledge capital. As shown in the learning curve analysis, it took players a few rounds to understand what knowledge capital is and how to potentially value it. This mimics the issue that companies face when trying to value knowledge capital. First they must identify what it is they are trying to value and then they must learn how to value it. Neither of those tasks are easily accomplished.

The game also showed that while most people behave in a rational manner, some people choose to behave irrationally. Again, this is similar to the real world valuation issues. In December 2007, Google stock traded as high as $700\(^6\) per share. Is it rational for an investor to purchase the stock at that price? Approximately 3.8 million shares were traded that day so it can be inferred that many people purchased the stock at this price. People purchased the stock in hopes that the stock would continue to rise even while the fundamentals showed that the company was valued much higher than its assets could support. The thought process behind the purchase is a rational thought—buy the stock now and hopefully the price will continue to increase. However, by ignoring the fundamentals, investors showed their irrational behavior. The players in the game also displayed irrational behavior. They purchased assets at high prices in

\(^6\) Google Historical Stock Prices
hopes that the invisible hand would continue to increase prices; they purchased multiple assets in a single purchase thereby reducing their available cash for future less expensive purchases; and they tried to create monopolies within the game by purchasing all the available assets. Occasionally these strategies paid off for the player. But more often, the player found himself short of cash and holding investments that other people had no interest in purchasing. If the player had written and sold a call against the higher priced assets, they found that other players did not exercise the calls because less expensive assets were available directly from the game administrator.

These behaviors mimic the real world difficulties in prices knowledge capital. By further refining and defining the limitations of the simulation game, more information can be captured surrounding players ability to identify and value knowledge capital and rational and irrational behavior. This information could then be used to assist companies in attempting to value their knowledge capital.

### 6.2 Recommendations for Future Research

The KAV game has been shown to be an excellent starting point for learning how to value knowledge assets and about option pricing. It has not proven to be a valid method for valuing knowledge assets in its current state.

While the framework of the KAV game has been developed, many additional opportunities exist to expand upon this research.
1. Further refine the KAV game. The KAV game has shown to be an excellent teaching tool for explaining options, real options, and the value of knowledge assets. It could be developed further by:
   a) Adding put options to the game which would allow participants to sell the right to their assets
   b) Further refining the directions so that players must behave in a rational manner.
   c) Develop a mechanism to capture player irrationality and external irrationality surrounding the game
2. Play the KAV game with the same group of students to see if the learning curve improves.
3. Automate the KAV game so as to develop it into a true prediction market.
4. Further refine the methodology for determining the input variables. Each of the five input variables could be expounded upon. Future research in this area should focus on identifying the input assumptions to the trinomial model. The inputs need to be repeatable and auditable in order for a real option methodology to be successful.

Knowledge assets remain one of the greatest assets of any company while at the same one of the most ill-defined. It is no longer acceptable to randomly assign a value to knowledge assets. A quantitative, auditable method for valuing knowledge assets still needs to be developed.
Of all the quantitative methods available, real options still provides the most hope for developing an auditable solution. Real options are the only quantitative method that accounts for the inherent flexibility that management has the right to make surrounding knowledge assets. However, finding the inputs to the real option model remains elusive. Perhaps the KAV game can be further developed into a prediction market that will allow employees to determine stock price, volatility, exercise price and strike price. As long as all companies are using the same predictive market model, the information will be useful to value its knowledge assets.
References


Frigo, M. 2003. "Real Options Valuation: Taking out the Rocket Science".  


Federal Reserve Bank of Philadelphia Working Paper No. 01-15,).


Appendix A-Knowledge Asset Valuation Game

Object:
At the end of play, be the player with the most money. There are two ways to make money in this game:
1. Add structural and/or human assets to your colored company space to increase consulting and customer fees
2. Write call options and collect call premiums from other players.

Game Equipment
- Game board
- Dice
- 16 colored company cards
- 24 structural assets
- 40 human assets
- Round counter

Game Setup
1. Select a game administrator
2. Put the Customer, Expiration Time, Strike Price, and Invisible Hand cards on their allocated board spaces face down.
3. Each player selects a color pawn to represent them as they move around the board
4. Each player is given 4 company cards corresponding to their colored pawn. The player is the owner of these companies.
5. The company cards received by each player have identical values.
6. Each player is given $300 divided as follows: 10 20s, 7 10s, 5 5s, 5 1s
7. Coins are used to provide change by the game administrator, they are not distributed as part of the game setup
8. All remaining money is held by the game administrator

Rules
1. Roll dice to determine who goes first. The player with the highest number goes first. Play moves to the left of that player. This player is the starting player.
2. All players place their colored pawn on one of their companies marked “A”.
3. The starting player throws the dice and moves the appropriate number of spaces.
4. Begin the game by FIRST purchasing assets

At the Beginning of Each Round
- When play returns to the game administrator, the game administrator will change the asset prices by flipping an Invisible Hand card over for each of the 3 Invisible Hand Card Spaces.
- The starting player will also keep track of the round by crossing off the round numbers on the round counter.
- All players can write and buy call options if they have purchased human or structural assets or have a customer card. Since the first round does not have the invisible hand in play, assets are purchased at the base cost.
- Only 1 call option per asset may be written
- Buy, sell, and write call option and assets

Adding Human and Structural Assets:
Human and Structural Assets increase the amount you can:
- Collect as consulting fees from other players
- Collect as revenue when you draw a customer card.

Landing on a colored company space you own:
- When you land on a colored company space you own, you can:
  1. Draw a customer card/Earn customer fees from the game administrator OR
  2. Exercise (redeem) a call

Landing on a colored company space another player owns:
- If you land on a colored company space another player owns, the owner of the colored company space collects a consulting fee.
- If the colored company space does not have any human or structural assets on it, no consulting fee is paid.

Consulting Fees
1. When a player lands on a colored company space that you own, they must pay you a consulting fee. Consulting fees are shown on the back of the colored company cards.
2. You may only collect a consulting if you have previously added human and/or structural assets to that colored company space. Customer assets do not impact consulting fees.

Writing Calls
Calls are another way to earn money. When you have a call to sell another player can buy the call from you at the Call Premium price you have set. You will immediately receive the call premium from the player.

If the call expires and it not exercised (redeemed), the seller (writer) gets to keep the call premium as profit. However, if the other player exercises the call, the seller (writer) must sell the asset to the player for the Strike Price. The Strike Price could be more or less than the other player can currently purchase assets for. The seller (writer) still retains the call premium.
The risk in writing calls is that the invisible hand will change the price of assets making your assets more economical than purchasing them directly from the game administrator.

- Calls can only be written if you have purchased Human or Structural Assets or if have a customer card in your possession.

If you are able to write a call:
- The player may write the call for any company that they own.
- Draw an Expiration Round card AND a Strike price card.
- Fill out the Call Information Sheet—see additional directions below
- Calls expire at their expiration date. Do NOT throw these calls away.

Filling out the Call Information Sheet (CIS)
When writing a call, fill out a CIS. Keep all of your CIS face up in front of you for other players to read.

The CIS asks for a number of data points.
8. **Company Letter**—Write the company letter that this call option is being written for in this box. You may select any company that you own to write the call option for.
9. **Type of Asset (H,S,C)**—As the writer of the call option, you may select what asset you are willing to write the call option for. However, you must own the asset in order to write a call option against it. You may select from Human Assets, Structural Assets, or Customer Assets.
10. **Asset Cost** (from Company Card)—Once you decide what asset you are willing to write the call option against, look up the asset cost on you company card. Remember to look to see if the Invisible Hand has changed the base asset price. Write that price here. If you select a Customer Asset, the Asset Cost is the Base Project Revenue plus any additional revenue from Human or Structural Assets as shown on the Customer Card.
11. **Current Round**—record the round number shown on the round counter sheet.
12. **Expiration Round (from drawn card)**—from the Expiration Round Card that you drew, record when this call option will expire. Add the number of rounds on the card to the Current Round.
13. **Strike Price (from drawn card)**—from the Strike Price Card that you drew, record the strike price of you asset.
14. **Call Premium**—The premium is the price you are willing to sell the RIGHT for another player to buy the asset at the strike price before the expiration. It is NOT the amount you are willing to sell the asset for at a later date. Remember the longer the time to expire the more opportunity for a player who has purchased the call from you to exercise it. There is also more
opportunity for the invisible hand to change asset costs. Price your call accordingly.

15. **Exercised (Y/N)**—If the call option is exercised, mark as Y. If it expires unexercised, mark as N.

**Buying Calls**
- The player from whom you purchased the call will give you the Call Information Sheet indicating that you have purchased the call.
- Reasons to buy calls include:
  - The invisible hand might make the cost of resources increase. If you own a call, you may exercise it and obtain resources for less than the current asset price
  - You can exercise the call and take away a resource from another player, thereby reducing the fee they receive from a customer
- The risk is that your call expires worthless and you have lost the amount paid for the call—the call premium.

**Exercising Calls**
- Calls may only be exercised when you land on a company you own. To exercise a call, give the CIS to the writer of the call and pay the asset strike price listed on the CIS
- The writer of the call must then give you the asset you have purchased.
- Place this asset on your colored company space that you are currently on. The asset is now valued as the same value as other assets for that space.

**Running out of Money**
If a player runs out of money, they may negotiate the sale of any of their assets to another player or they may sell their assets to the game administrator for 50% of the current asset price. Current Asset Price = Base Asset Values +/- changes by the invisible hand.

**Cards in the Game:**

**Invisible Hand**
The invisible hand is a card that changes the values of customer, structural, and human assets. Values can either increase or decrease.

**Customer Cards**
- These cards provide revenue to your company.
- A base project revenue exists on the customer card. If the invisible hand is in play, the base revenue is changed based on the percentage increase or decrease shown on the Invisible Hand—Customer card in the center of the board.
- The fee, either base or revised as a result of the invisible hand, can further be increased by the number of human and structural assets you own. The
additional revenue received by owning human and structural assets can not be increased or decreased by the invisible hand.

- Your fee is paid by the game administrator.

Expiration Round Cards
These cards are drawn when you write a call. They tell you how long the call is valid for. The longer the time to expiration, the higher the call price should be. This is because there is more opportunity for asset cost fluctuations. You should be compensated for this risk.

Strike Price Cards
These cards are drawn when you write a call. They tell you how much to add or subtract from your asset cost to determine the strike price. The Strike Price is the price at which you will sell your asset to another player.

Colored Company Cards
These cards represent the companies each player owns. The cards show human and structural asset values at their base cost and at costs changed by the invisible hand.

To determine the current assets, first look at the game board to determine if the invisible for that asset is in effect.

- If it is, the asset value is shown in the column under the associated invisible hand percentage increase or decrease
- If the invisible hand is not in effect, the asset value is equal to the base value.

Sample Cards and Call Information Sheet

<table>
<thead>
<tr>
<th>Company A</th>
<th>Invisible Hand Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base</td>
</tr>
<tr>
<td>Human Assets</td>
<td>$35.00</td>
</tr>
<tr>
<td>Structural Assets</td>
<td>$20.00</td>
</tr>
<tr>
<td></td>
<td>Base</td>
</tr>
<tr>
<td>Human Assets</td>
<td>$35.00</td>
</tr>
<tr>
<td>Structural Assets</td>
<td>$20.00</td>
</tr>
</tbody>
</table>
Consulting Fees

Company A

Invisible Hand Changes

<table>
<thead>
<tr>
<th>For Each:</th>
<th>Base</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
<th>25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Asset Add</td>
<td>$50.00</td>
<td>$52.50</td>
<td>$55.00</td>
<td>$57.50</td>
<td>$60.00</td>
<td>$62.50</td>
</tr>
<tr>
<td>Structural Asset Add</td>
<td>$25.00</td>
<td>$26.25</td>
<td>$27.50</td>
<td>$28.75</td>
<td>$30.00</td>
<td>$31.25</td>
</tr>
</tbody>
</table>

Strike Price Card

The Strike Price is $3 greater than the base asset cost.

Expiration Time Card

This call option will expire at the end of 4 rounds.

Call Information Sheet

<table>
<thead>
<tr>
<th>Company Color (R, B, Y, G)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Company Letter</td>
<td></td>
</tr>
<tr>
<td>Type of Asset (H,S,C)</td>
<td></td>
</tr>
<tr>
<td>Asset Cost (from Company Card)</td>
<td></td>
</tr>
<tr>
<td>Expiration Date (from drawn card)</td>
<td></td>
</tr>
<tr>
<td>Strike Price (from drawn card)</td>
<td></td>
</tr>
<tr>
<td>Call Premium</td>
<td></td>
</tr>
<tr>
<td>Exercised</td>
<td>Y/N</td>
</tr>
</tbody>
</table>
Figure 8-1, Knowledge Asset Valuation Game

Expiration Date Cards

Customer Cards

Strike Price Cards

Company D

Company B

Company C

Company D

Company A

Company C

Company D

Company A

Invisible Hand Card

Invisible Hand Card

Invisible Hand Card

Invisible Hand

Customer Assets

Invisible Hand

Invisible Hand

Invisible Hand Card

Invisible Hand Card

Invisible Hand Card

Invisible Hand

Structural Assets

Invisible Hand

Invisible Hand

Invisible Hand Card

Invisible Hand Card

Invisible Hand Card

Invisible Hand
Appendix B-Options

The following examples provide participants an introduction to option pricing.

From this information, participants should gain an understanding of option pricing and be able to make rational decisions when playing the KAV game.

Example 1: Stock Market Call Option (reproduced from Hand 2001)

Let’s start with a simple stock market example. Suppose we wanted to evaluate the price for a call option for XYZ stock. The current stock price is $100, and the call option has a strike price (or exercise price) of $95, with a life of 90 days. In a simple deterministic (or absolutely certain) world, the call option would be worth exactly $5, since that is the difference between the current price and the strike price. However, in the real world of uncertainty, there is a reasonable chance that the stock could be worth more than $100 in the next 90 days. Hence, the option is worth more than $5.

The risk-free interest rate is the U.S. Treasury rate for notes of 90-day maturity (the same length of time as the option), which is currently around 2.2%. The stock does not have a dividend and the standard deviation of the ln(stock price) is 0.20…..

The actual input parameters are as follows:

- $S = 100$ the current stock price
- $K = 95$ the current exercise price
- $r = 0.022$ risk-free interest rate
- $\sigma = 0.20$ standard deviation of ln(stock price)
- $y = 0.0$ dividend rate of the stock
- $t = 0.25$ time to expiration of option in years

Plugging these values into the Black-Scholes Formula gives us a call option value of $7.247. Note that this is higher than the difference between the stock and exercise prices, which is due to the effect of interest rates and the fluctuation of stock prices. If the interest rate and the standard deviation were both set to zero in the formula, then the option price would be $5. Conversely, the higher the interest rate and the standard deviation are, the more the option is worth. Greater uncertainty makes options more valuable. (Hand 2001)
Example 2: Valuing Product Patents as Options (reproduced from Damodaran Packet 3: Real Options, Acquisition Valuation and Value Enhancement 2005)

- A product patent provides the firm with the right to develop the product and market it.
- It will do so only if the present value of the expected cash flows from the product sales exceed the cost of development.
- If this does not occur, the firm can shelve the patent and not incur any further costs.
- If I is the present value of the costs of developing the product, and V is the present value of the expected cash flows from development, the payoffs from owning a product patent can be written as:

\[
\text{Payoff from owning a product patent} = V - I \quad \text{if } V > I \\
= 0 \quad \text{if } V \leq I
\]

Obtaining Inputs for Patent Valuation

<table>
<thead>
<tr>
<th>Input</th>
<th>Estimation Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Value of the Underlying Asset</td>
<td>▪ Present Value of Cash Inflows from taking project now</td>
</tr>
<tr>
<td></td>
<td>▪ This will be noisy, but that adds value.</td>
</tr>
<tr>
<td>2. Variance in value of underlying asset</td>
<td>▪ Variance in cash flows of similar assets or firms</td>
</tr>
<tr>
<td></td>
<td>▪ Variance in present value from capital budgeting simulation.</td>
</tr>
<tr>
<td>3. Exercise Price on Option</td>
<td>▪ Option is exercised when investment is made.</td>
</tr>
<tr>
<td></td>
<td>▪ Cost of making investment on the project; assumed to be constant in present value dollars.</td>
</tr>
<tr>
<td>4. Expiration of the Option</td>
<td>▪ Life of the patent</td>
</tr>
<tr>
<td>5. Dividend Yield</td>
<td>▪ Cost of delay</td>
</tr>
<tr>
<td></td>
<td>▪ Each year of delay translates into one less year of value-creating cash flows</td>
</tr>
<tr>
<td></td>
<td>▪ Annual cost of delay = 1/n</td>
</tr>
</tbody>
</table>
**Valuing a Product Patent: Avonex**

- Biogen, a bio-technology firm, has a patent on Avonex, a drug to treat multiple sclerosis, for the next 17 years, and it plans to produce and sell the drug by itself. The key inputs on the drug are as follows:

  - PV of Cash Flows from Introducing the Drug Now = $S = $3.422 billion
  - PV of Cost of Developing Drug for Commercial Use = $K = $2.875 billion
  - Patent Life = $t = 17$ years
  - Riskless Rate = $r = 6.7\%$ (17-year T.Bond rate)
  - Variance in Expected Present Values = $\sigma^2 = 0.224$ (Industry average firm variance for bio-tech firms)
  - Expected Cost of Delay = $y = 1/17 = 5.89\%$

  \[
  d_1 = 1.1362 \quad N(d_1) = 0.8720 \\
  d_2 = -0.8512 \quad N(d_2) = 0.2076
  \]

  Call Value = $3,422 \exp(-0.0589)(17)(0.8720) - 2,875 \exp(-0.067)(17)(0.2076) = $907 million
The classic model of valuing an oil reserve was created by Paddock, Siegel, and Smith (1988b). Damodaran (2003) simplified their example for teaching purposes.

**Example 3: Valuing Natural Resource Options (reproduced from Damodaran Packet 3: Real Options, Acquisition Valuation and Value Enhancement 2005)**

- In a natural resource investment, the underlying asset is the resource and the value of the asset is based upon two variables - the quantity of the resource that is available in the investment and the price of the resource.
- In most such investments, there is a cost associated with developing the resource and the difference between the value of the asset extracted and the cost of the development is the profit to the owner of the resource.
- Defining the cost of development as $X$, and the estimated value of the resource as $V$, the potential payoffs on a natural resource option can be written as follows:
  - Payoff on natural resource investment
    - $V - X$ if $V > X$
    - $0$ if $V \leq X$

**Estimating Inputs for Natural Resource Options**

<table>
<thead>
<tr>
<th>Input</th>
<th>Estimation Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Value of Available Reserves of the Resource</td>
<td>Expert estimates (Geologists for oil); The present value of the after-tax cash flows from the resource are then estimated.</td>
</tr>
<tr>
<td>2. Cost of Developing Reserve (Strike Price)</td>
<td>Past costs and the specifics of the investment</td>
</tr>
<tr>
<td>3. Time to Expiration</td>
<td>Relinquishment Period: if asset has to be relinquished at a point in time.</td>
</tr>
<tr>
<td></td>
<td>Time to exhaust inventory - based upon inventory and capacity output.</td>
</tr>
<tr>
<td>4. Variance in value of underlying asset</td>
<td>based upon variability of the price of the resources and variability of available reserves.</td>
</tr>
<tr>
<td>5. Net Production Revenue (Dividend Yield)</td>
<td>Net production revenue every year as percent of market value.</td>
</tr>
<tr>
<td>6. Development Lag</td>
<td>Calculate present value of reserve based upon the lag.</td>
</tr>
</tbody>
</table>
Valuing an Oil Reserve

Inputs to Option Pricing Model

- Current Value of the asset = $S = Value of the developed reserve discounted back the length of the development lag at the dividend yield = $12 \times 50 / (1.05)^2 = $544.22
- (If development is started today, the oil will not be available for sale until two years from now. The estimated opportunity cost of this delay is the lost production revenue over the delay period. Hence, the discounting of the reserve back at the dividend yield)
- Exercise Price = Present Value of development cost = $12 \times 50 = $600 million
- Time to expiration on the option = 20 years
- Variance in the value of the underlying asset = 0.03
- Riskless rate = 8%
- Dividend Yield = Net production revenue / Value of reserve = 5%

Valuing the Option

- Based upon these inputs, the Black-Scholes model provides the following value for the call:

\[ d_1 = 1.0359 \quad N(d_1) = 0.8498 \]
\[ d_2 = 0.2613 \quad N(d_2) = 0.6030 \]

\[ \text{Call Value} = 544.22 \times \exp(-0.05)(20) \times (0.8498) - 600 \times \exp(-0.08)(20) \times (0.6030) = $97.08 \text{ million} \]

- This oil reserve, though not viable at current prices, still is a valuable property because of its potential to create value if oil prices go up.
Appendix C-FAS 141

Summary of Statement No. 141

(reproduced from Federal Accounting Standards Board "FAS141—Business Combinations" 2001)

Business Combinations (Issued 6/01)

Summary

This Statement addresses financial accounting and reporting for business combinations and supersedes APB Opinion No. 16, Business Combinations, and FASB Statement No. 38, Accounting for Preacquisition Contingencies of Purchased Enterprises. All business combinations in the scope of this Statement are to be accounted for using one method, the purchase method.

Reasons for Issuing This Statement

Under Opinion 16, business combinations were accounted for using one of two methods, the pooling-of-interests method (pooling method) or the purchase method. Use of the pooling method was required whenever 12 criteria were met; otherwise, the purchase method was to be used. Because those 12 criteria did not distinguish economically dissimilar transactions, similar business combinations were accounted for using different methods that produced dramatically different financial statement results. Consequently:

- Analysts and other users of financial statements indicated that it was difficult to compare the financial results of entities because different methods of accounting for business combinations were used.
- Users of financial statements also indicated a need for better information about intangible assets because those assets are an increasingly important economic resource for many entities and are an increasing proportion of the assets acquired in many business combinations. While the purchase method recognizes all intangible assets acquired in a business combination (either separately or as goodwill), only those intangible assets previously recorded by the acquired entity are recognized when the pooling method is used.
- Company managements indicated that the differences between the pooling and purchase methods of accounting for business combinations affected competition in markets for mergers and acquisitions.

Differences between This Statement and Opinion 16
The provisions of this Statement reflect a fundamentally different approach to accounting for business combinations than was taken in Opinion 16. The single-method approach used in this Statement reflects the conclusion that virtually all business combinations are acquisitions and, thus, all business combinations should be accounted for in the same way that other asset acquisitions are accounted for—based on the values exchanged.

This Statement changes the accounting for business combinations in Opinion 16 in the following significant respects:

- This Statement requires that all business combinations be accounted for by a single method—the purchase method.
- In contrast to Opinion 16, which required separate recognition of intangible assets that can be identified and named, this Statement requires that they be recognized as assets apart from goodwill if they meet one of two criteria—the contractual-legal criterion or the separability criterion. To assist in identifying acquired intangible assets, this Statement also provides an illustrative list of intangible assets that meet either of those criteria.
- In addition to the disclosure requirements in Opinion 16, this Statement requires disclosure of the primary reasons for a business combination and the allocation of the purchase price paid to the assets acquired and liabilities assumed by major balance sheet caption. When the amounts of goodwill and intangible assets acquired are significant in relation to the purchase price paid, disclosure of other information about those assets is required, such as the amount of goodwill by reportable segment and the amount of the purchase price assigned to each major intangible asset class.

This Statement does not change many of the provisions of Opinion 16 and Statement 38 related to the application of the purchase method. For example, this Statement does not fundamentally change the guidance for determining the cost of an acquired entity and allocating that cost to the assets acquired and liabilities assumed, the accounting for contingent consideration, and the accounting for preacquisition contingencies. That guidance is carried forward in this Statement (but was not reconsidered by the Board). Also, this Statement does not change the requirement to write off certain research and development assets acquired in a business combination as required by FASB Interpretation No. 4, Applicability of FASB Statement No. 2 to Business Combinations Accounted for by the Purchase Method.

**How the Changes in This Statement Improve Financial Reporting**

The changes to accounting for business combinations required by this Statement improve financial reporting because the financial statements of entities that engage in business combinations will better reflect the underlying economics of
those transactions. In particular, application of this Statement will result in financial statements that:

- **Better reflect the investment made in an acquired entity**—the purchase method records a business combination based on the values exchanged, thus users are provided information about the total purchase price paid to acquire another entity, which allows for more meaningful evaluation of the subsequent performance of that investment. Similar information is not provided when the pooling method is used.

- **Improve the comparability of reported financial information**—all business combinations are accounted for using a single method, thus, users are able to compare the financial results of entities that engage in business combinations on an apples-to-apples basis. That is because the assets acquired and liabilities assumed in all business combinations are recognized and measured in the same way regardless of the nature of the consideration exchanged for them.

- **Provide more complete financial information**—the explicit criteria for recognition of intangible assets apart from goodwill and the expanded disclosure requirements of this Statement provide more information about the assets acquired and liabilities assumed in business combinations. That additional information should, among other things, provide users with a better understanding of the resources acquired and improve their ability to assess future profitability and cash flows.

Requiring one method of accounting reduces the costs of accounting for business combinations. For example, it eliminates the costs incurred by entities in positioning themselves to meet the criteria for using the pooling method, such as the monetary and nonmonetary costs of taking actions they might not otherwise have taken or refraining from actions they might otherwise have taken.

**How the Conclusions in This Statement Relate to the Conceptual Framework**

The Board concluded that because virtually all business combinations are acquisitions, requiring one method of accounting for economically similar transactions is consistent with the concepts of representational faithfulness and comparability as discussed in FASB Concepts Statement No. 2, *Qualitative Characteristics of Accounting Information*. In developing this Statement, the Board also concluded that goodwill should be recognized as an asset because it meets the assets definition in FASB Concepts Statement No. 6, *Elements of Financial Statements*, and the asset recognition criteria in FASB Concepts Statement No. 5, *Recognition and Measurement in Financial Statements of Business Enterprises*.

The Board also noted that FASB Concepts Statement No. 1, *Objectives of Financial Reporting by Business Enterprises*, states that financial reporting
should provide information that helps in assessing the amounts, timing, and uncertainty of prospective net cash inflows to an entity. The Board noted that because the purchase method records the net assets acquired in a business combination at their fair values, the information provided by that method is more useful in assessing the cash-generating abilities of the net assets acquired than the information provided by the pooling method.

Some of the Board's constituents indicated that the pooling method should be retained for public policy reasons. For example, some argued that eliminating the pooling method would impede consolidation of certain industries, reduce the amount of capital flowing into certain industries, and slow the development of new technology. Concepts Statement 2 states that a necessary and important characteristic of accounting information is neutrality. In the context of business combinations, neutrality means that the accounting standards should neither encourage nor discourage business combinations but rather, provide information about those combinations that is fair and evenhanded. The Board concluded that its public policy goal is to issue accounting standards that result in neutral and representationally faithful financial information and that eliminating the pooling method is consistent with that goal.

The Effective Date of This Statement

The provisions of this Statement apply to all business combinations initiated after June 30, 2001. This Statement also applies to all business combinations accounted for using the purchase method for which the date of acquisition is July 1, 2001, or later.

This Statement does not apply, however, to combinations of two or more not-for-profit organizations, the acquisition of a for-profit business entity by a not-for-profit organization, and combinations of two or more mutual enterprises.
Appendix D-FAS 142
Summary of Statement No. 142
(reproduced from Federal Accounting Standards Board "FAS142—Goodwill and Other Intangible Assets" 2001)

Goodwill and Other Intangible Assets (Issued 6/01)
Summary

This Statement addresses financial accounting and reporting for acquired goodwill and other intangible assets and supersedes APB Opinion No. 17, Intangible Assets. It addresses how intangible assets that are acquired individually or with a group of other assets (but not those acquired in a business combination) should be accounted for in financial statements upon their acquisition. This Statement also addresses how goodwill and other intangible assets should be accounted for after they have been initially recognized in the financial statements.

Reasons for Issuing This Statement

Analysts and other users of financial statements, as well as company managements, noted that intangible assets are an increasingly important economic resource for many entities and are an increasing proportion of the assets acquired in many transactions. As a result, better information about intangible assets was needed. Financial statement users also indicated that they did not regard goodwill amortization expense as being useful information in analyzing investments.

Differences between This Statement and Opinion 17

This Statement changes the unit of account for goodwill and takes a very different approach to how goodwill and other intangible assets are accounted for subsequent to their initial recognition. Because goodwill and some intangible assets will no longer be amortized, the reported amounts of goodwill and intangible assets (as well as total assets) will not decrease at the same time and in the same manner as under previous standards. There may be more volatility in reported income than under previous standards because impairment losses are likely to occur irregularly and in varying amounts.

This Statement changes the subsequent accounting for goodwill and other intangible assets in the following significant respects:

- Acquiring entities usually integrate acquired entities into their operations, and thus the acquirers' expectations of benefits from the resulting synergies usually are reflected in the premium that they pay to acquire those entities. However, the transaction-based approach to accounting for
goodwill under Opinion 17 treated the acquired entity as if it remained a stand-alone entity rather than being integrated with the acquiring entity; as a result, the portion of the premium related to expected synergies (goodwill) was not accounted for appropriately. This Statement adopts a more aggregate view of goodwill and bases the accounting for goodwill on the units of the combined entity into which an acquired entity is integrated (those units are referred to as reporting units).

- Opinion 17 presumed that goodwill and all other intangible assets were wasting assets (that is, finite lived), and thus the amounts assigned to them should be amortized in determining net income; Opinion 17 also mandated an arbitrary ceiling of 40 years for that amortization. This Statement does not presume that those assets are wasting assets. Instead, goodwill and intangible assets that have indefinite useful lives will not be amortized but rather will be tested at least annually for impairment. Intangible assets that have finite useful lives will continue to be amortized over their useful lives, but without the constraint of an arbitrary ceiling.

- Previous standards provided little guidance about how to determine and measure goodwill impairment; as a result, the accounting for goodwill impairments was not consistent and not comparable and yielded information of questionable usefulness. This Statement provides specific guidance for testing goodwill for impairment. Goodwill will be tested for impairment at least annually using a two-step process that begins with an estimation of the fair value of a reporting unit. The first step is a screen for potential impairment, and the second step measures the amount of impairment, if any. However, if certain criteria are met, the requirement to test goodwill for impairment annually can be satisfied without a remeasurement of the fair value of a reporting unit.

- In addition, this Statement provides specific guidance on testing intangible assets that will not be amortized for impairment and thus removes those intangible assets from the scope of other impairment guidance. Intangible assets that are not amortized will be tested for impairment at least annually by comparing the fair values of those assets with their recorded amounts.

- This Statement requires disclosure of information about goodwill and other intangible assets in the years subsequent to their acquisition that was not previously required. Required disclosures include information about the changes in the carrying amount of goodwill from period to period (in the aggregate and by reportable segment), the carrying amount of intangible assets by major intangible asset class for those assets subject to amortization and for those not subject to amortization, and the estimated intangible asset amortization expense for the next five years.

This Statement carries forward without reconsideration the provisions of Opinion 17 related to the accounting for internally developed intangible assets. This Statement also does not change the requirement to expense the cost of certain acquired research and development assets at the date of acquisition as required
by FASB Statement No. 2, Accounting for Research and Development Costs, and FASB Interpretation No. 4, Applicability of FASB Statement No. 2 to Business Combinations Accounted for by the Purchase Method.

How the Changes in This Statement Improve Financial Reporting

The changes included in this Statement will improve financial reporting because the financial statements of entities that acquire goodwill and other intangible assets will better reflect the underlying economics of those assets. As a result, financial statement users will be better able to understand the investments made in those assets and the subsequent performance of those investments. The enhanced disclosures about goodwill and intangible assets subsequent to their acquisition also will provide users with a better understanding of the expectations about and changes in those assets over time, thereby improving their ability to assess future profitability and cash flows.

How the Conclusions in This Statement Relate to the Conceptual Framework

The Board concluded that amortization of goodwill was not consistent with the concept of representational faithfulness, as discussed in FASB Concepts Statement No. 2, Qualitative Characteristics of Accounting Information. The Board concluded that nonamortization of goodwill coupled with impairment testing is consistent with that concept. The appropriate balance of both relevance and reliability and costs and benefits also was central to the Board’s conclusion that this Statement will improve financial reporting.

This Statement utilizes the guidance in FASB Concepts Statement No. 7, Using Cash Flow Information and Present Value in Accounting Measurements, for estimating the fair values used in testing both goodwill and other intangible assets that are not being amortized for impairment.

The Effective Date of This Statement

The provisions of this Statement are required to be applied starting with fiscal years beginning after December 15, 2001. Early application is permitted for entities with fiscal years beginning after March 15, 2001, provided that the first interim financial statements have not previously been issued. This Statement is required to be applied at the beginning of an entity’s fiscal year and to be applied to all goodwill and other intangible assets recognized in its financial statements at that date. Impairment losses for goodwill and indefinite-lived intangible assets that arise due to the initial application of this Statement (resulting from a transitional impairment test) are to be reported as resulting from a change in accounting principle.

There are two exceptions to the date at which this Statement becomes effective:
• Goodwill and intangible assets acquired after June 30, 2001, will be subject immediately to the nonamortization and amortization provisions of this Statement.
• The provisions of this Statement will not be applicable to goodwill and other intangible assets arising from combinations between mutual enterprises or to not-for-profit organizations until the Board completes its deliberations with respect to application of the purchase method by those entities.