Chapter IX
The Value of Flexibility

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ABSTRACT

Though IT investments are risky by nature, most of the traditional investment valuation models do not have risk in account, leading to erroneous choices. This chapter bases itself in the dogma that flexibility is the key to handle the uncertainty and risk of the future, and therefore is also a philosophy that must be in the very foundations of IT investments, since IT is the basic foundation of so many businesses. How do we value a risky IT investment is the underlying subject of this chapter. Having the previous dogma as a basis, the authors state that flexibility is a vaccine against risk. As such, this flexibility must have a value. The problem they attempt to solve in this chapter is the quantification of such value. To achieve this goal, the authors propose a real options-based framework to value IT investments, having risk in account.

INTRODUCTION

The pure Taylorism saw its end on October 24, 1929—the Black Thursday—when the Wall Street Stock Market crashed yet again, this time with violence (Henin, 1986).

Years later, in the 80’s, Michael Porter popularized the ideas of the value chain, focused on maximizing value creation and minimizing costs (Porter, 1985) which, in the end, were exactly the same goals of Taylor.

As an example, the Ford Motor Company applied Taylor’s methodology and was able to
implement a Just-In-Time production, so called “Dock to Factory Floor” since it demanded an almost inexistent warehouse stock.

Now what is wrong with Taylorism or Porter’s value chain? Nothing. The problem is not with the models, but rather on how Ford and others applied them. Among other problems, Ford failed to create a value chain starting at the customer and ending at the suppliers, culminating in a super production crisis.

Japan understood this chain issue back in the 50’s, and met an astonishing growth in the 60’s, known as the Japanese Miracle.

As an example, by the middle of the past century, the Toyota Motor Company implemented a new methodology for building cars also with smaller economic lot sizes but, more important, targeted for flexible factories capable of shifting production in a matter of days.

More recently, we have other success examples, such as Zara, which was able to create a flexible production, parameterized by its costumers’ demand, collected on a daily basis.

As odd it might seem, usually only marketing disciplines have this market or customer-oriented value chain as a basic pillar. Only with this view, a competitive advantage can be sustained.

Even odder, we are constantly assisting a dummy first mover’s dictatorship. For instance, take the example of the third generation (3G) mobile communications. As soon as the first communications operator introduced 3G services, all the others followed, investing heavily on the infrastructure. However, there is still no market demand for 3G (Hearts, 2002; 3G.co.uk., 2004).

Bottom line, companies need to be flexible to provide customers with products that meet their ever changing needs. Unfortunately, mankind doesn’t deal well with flexibility, or it wouldn’t have only started accentuating its evolution 10,000 years ago, when it got sedentary, and thus more stable, in Neolithic.

Context

In the context of the Information Technology (IT) world, we have now been creating applications for over 50 years.

In that time, we have evolved our processes and tools, creating a broad range of methodologies, nevertheless almost all of them seem to have high rates of failure.

In 1995, the Standish Group published a survey, called “The Chaos Report”, showing that, on average, only 16% of the IT projects succeeded, ending on budget, on time, and with all the requirements implemented. If we only account for large companies, this rate dropped to 9%.

One might think that from 1995 to nowadays some evolution was achieved, and it was. The Standish Group updated this report on 2001, publishing the “Extreme CHAOS Report”. This latter report showed that, on average, 28% of the projects were then succeeding. Therefore, in 6 years, with all the great advances in processes and tools, we were not even able to double the success rate of IT projects.

When compared to other engineering fields, IT won’t even qualify as a wannabe. For instance, the first documented civil engineer dates from 2550 BC and contains the schemas for the Imhotep stepped pyramid of King Zoser, located at Saqqarah, which still stands today (Penwell et al., 1995). The Unified Modeling Language (UML) development, if you like, only started in the 90’s.

This is why it is so tempting to compare IT with civil engineering and why we hear it so often. Nonetheless, is quite an erroneously comparison. Imagine that when building a bridge, the stakeholders change, on a daily basis, the number of cars the bridge must support, or even the river it must be built on. No bridge will come on budget and on time under such scenario.

However, even if the comparison with civil engineering is wrong, this is no excuse for the
ever-repeating failures of IT projects. If it is possible to have flexible automobile or cloth productions, then it must also be possible to have a flexible software production.

When an IT project starts, there is often an unclear vision of the requirements the system must support, an internal resistance to change, or even no top management support. Therefore, it might look that IT projects become mainly sociological projects, and that the barriers to their success tend to be non-technological. This awareness is also stated in the Standish Group reports in which we can see that successful projects have clear statement of requirements, high rates of user involvement, and top management support. In contrast, failing projects don’t have this microenvironment. Nevertheless, most important, the reports showed that failed projects had incomplete and constantly changing requirements.

There it is again, the inability to properly handle flexibility. If when building a bridge it would be there for several years without the need for changes, when building Information Systems (IS) this is not true. Companies are facing an ever-increasing strategic change pace. New demands, new competitors, new business models, new rising super powers, new frontiers, new regulations, new problems, new solutions… ISs are the basic tools companies have to handle their businesses, therefore such tools must keep up with the business change pace; they must be flexible both in development and in production time.

Flexibility exists to handle risk. A risky business must be flexible enough for the stakeholders to abandon it or shift in a different direction, otherwise it may become a dead end. When building ISs for companies pressured to change in some way, we must have in account it is not possible to have a clear definition of the requirements upfront. Apart from core systems, the requirements for today will most certainly not be similar in a month, and will for sure be completely different in a year.

This is one of the reasons why IT projects are risky. Technologies that ignore this fact will only be able to survive if they are used for building core systems or pre-doomed projects.

Ultimately, technologies that can handle risk by being flexible enough to deal with constant changes in already incomplete requirements have more value than others, as only this way they can provide any return on the IT investments. However, this will only be a better starting point, since most of the previously cited problems are non-technological.

Problem

As explained, nowadays software projects are high risky investments (Standish Group, 1995; Standish Group, 2001). Therefore, it becomes vital to quantify this risk in order to be able to value the investments. However, this quantification is hard to perform since it enters the futurology realms. As such, how do we handle risk in IT investments?

The answer to this question was already given: we must accept and embrace the uncertainty of the future. Rather than keep thinking in all the possible scenarios and respective needs, which ultimately only leads to an increasing delay in solving the present needs, we should try to be flexible enough to handle the upcoming scenarios while addressing yesterday’s needs.

This chapter bases itself in the dogma that flexibility is the key to handle the uncertainty and risk of the future, and therefore is also a philosophy that must be in the very foundations of IT investments, since IT is the basic foundation of so many businesses.

However, most of the traditional investment valuation models do not have risk in account, leading to erroneous choices. Most often, when comparing different technologies to implement a given project, managers have the tendency to choose the ones with smaller upfront costs. Un-
The Value of Flexibility

fortunately, these kick-off costs are just the tip of a huge iceberg. Then how do we value a risky IT investment?

This latter question is the subject of this chapter. Having the previous dogma as a basis, we state that flexibility is a vaccine against risk. Therefore, this flexibility must have a value. The quantification of this value is the problem we will address.

BACKGROUND

Traditional Valuation Models

For several reasons, the measurement of the IT investments value has been increasing dramatically in the past few years. From 2000 to 2001, the importance of this measurement increased for 80% of the organizations (Hayes, 2001).

Typically, pre implementation measurements are used to compare different alternatives (King et al., 1978) and post implementation measurements are used to cut costs and close projects (Kumar, 1990).

Investment Analysis

Nowadays, the value of IT investments is mainly based on Cost-Benefit Analysis (CBA) (Dupuit, 1844; Marshall, 1920) mingled with the Time Value of Money (TVM) formula (Goetzmann, 2003) with some Weighted Discount Rate (WDR), such as the Interest Rate (IR) or the organization’s Weighted Average Cost of Capital (WACC), that feed a Net Present Value (NPV) formula. See Box 1.

However, the value of an investment means nothing by itself, since it must be relativized to the environment where it occurs. As such, companies usually value IT investments by calculating the Return on Investment (ROI), which is the ratio of the gained value compared to a given basis, such as the value of a system before the new IT investment.

\[
\text{return on investment}_{\text{arithmetic}} = \frac{\text{final value} - \text{basis value}}{\text{basis value}}
\]

\[
\text{return on investment}_{\text{logarithmic}} = \ln \left( \frac{\text{final value}}{\text{basis value}} \right)
\]

As investing in something includes the cost of not investing on something else, companies may also value the investment by comparing it with the average organization’s investment, thus obtaining the Economic Value Added (EVA) (Magretta et al., 2002). See Box 2.

Costs and Benefits

In contrast to the general CBA theory, which is based on strongly accepted principles, the elicitation of the costs and benefits and their valuation is by itself an area of research.

In 1992, DeLone and McLean produced an extensive taxonomy to measure the IT effective-

Box 1.

\[
\text{CBA value} = \sum_i \text{benefit}_i - \sum_j \text{cost}_j
\]

\[
\text{future value} = \text{present value} \cdot (1 + \text{weighted discount rate})^{\text{years}}
\]

\[
\text{net present value} = \sum_i \text{benefit present value}_i - \sum_j \text{cost present value}_j = \sum_i \frac{\text{benefit future value}_i}{(1 + \text{weighted discount rate})^{\text{years}_i}} - \sum_j \frac{\text{cost future value}_j}{(1 + \text{weighted discount rate})^{\text{years}_j}}
\]
The Value of Flexibility

Box 2.

\[
\text{economic value added} = \text{investment profits} - \left( \text{weighted discount rate} \times \text{investment costs} \right) = \sum \text{benefit}_i - \text{weighted discount rate} \sum \text{cost}_j
\]

ness, which can be used as a basis list of costs and benefits, since the effectiveness of a system comes from its benefits. DeLone and McLean’s research was later extended by Scott (1995) to even include Structural Equation Models (SEM), such as the Multiple Indicator Multiple Cause (MIMIC) model that can correlate a set of indicators and causes, e.g. costs and benefits, with one given dependent variable, e.g. the IT investment value.

Nowadays, for the purpose of eliciting all the costs and benefits of an IT investment, there are, among others, the Total Costs of Ownership (TCO) and the Total Benefits of Ownership (TBO) approaches. The TCO includes all the system costs and respective values, for instance, its licensing costs and maintenance costs (Ellram, 1993). Conversely, the TBO is a list of all the benefits and respective values of a given IT system, for instance, its adoption rate and usability.

However, the elicitation of the costs and benefits and their valuation is a large area of research, and no simple solution has yet been presented. The time dependency, the need to prove the correlation between the selected costs and benefits and the resulting IT investment value, and finally the valuation of the costs and benefits, all increase the complexity of the models. Furthermore, the gathering of data to predict the costs and benefits values is not only expensive but also time consuming. This is particularly true for the benefits, as the costs already have industry accepted average values.

Traditional Valuation Framework

There is currently a strong use of NPV, ROI and EVA models in the IT industry and, for some years, stakeholders generally agree on their CBA principles to measure the value of IT investments (Sassone, 1988).

For a limited set of benefits and costs, this framework is more than enough to measure the value of IT investments. However, when dealing with risk and flexibility, we cannot rely on these models to value IT investments, either because they become too hard to use, or because they become invalid.

Risk must be accounted for, when measuring the value of an IT investment, but it is neither a cost nor a benefit. Risk stands outside the CBA and represents a kind of global accuracy of the calculated IT investment value. Being even harder to measure, it should be used to classify the investment. However, these models only account for risk in a very rudimentary fashion, embedded in the WDR, for instance.

Also, it is not realistic nor interesting to assume organizations will hold passively to their IT investments. In most scenarios, an investment creates options and opens new paths over future decisions that managers can take advantage of. These options may add value to investments that cannot be easily calculated by this framework.

For handling these factors, we must use more advanced valuation frameworks.

Options-Based Valuation Models

The value of an IT investment is often used to support the decision of whether or not we should make that investment. However, there may exist other hidden options, as we will see.
The Value of Flexibility

Decision Trees

When you invest, you limit your future options in several ways: you lose the option to invest on something else with the same capital, you win the option of putting the investment on the market, or even to abandon it at a given time, etc.

Hence, when trying to value an investment, we must account for all the decisions we can subsequently make. This is why, when measuring the value of an investment, you must remember this value is the result of the several decisions you make over time, which increase and decrease the value of the investment.

Decision Trees are used to model this type of decisions, not only to help you visualize how the value of your investment will vary with each decision, but also to clarify the set of possible future decisions opened by each one. Many managers use these simpler models to base their decisions, since they can be mingled with dynamically and with low effort, in order to cover a wide range of scenarios (Copeland et al., 2004).

Call and Put Options

There are two types of options. A call option is a contract that gives the holder the right but not the obligation to buy the underlying asset for a certain price at a certain date. A put option is a contract that gives the holder the right but not the obligation to sell the underlying asset for a certain price at a certain date (Hull, 1992).

The price in the contract is known as exercise price or strike price, and the date is known as expiration date, exercise date or maturity.

Technically, the value of an option is called payoff and does not account for its price, it simply accounts for its exercise price and its underlying market price (Brealey et al., 2003). If we include the initial cost of buying the option, we get its profit. Also, the exercise price and the underlying asset market price are values in the future, therefore to estimate the option future profit you must estimate the future value of the present option profit. See Box 3.

Options Value

At a first glance, it is intuitively understandable that, for a fixed exercise price, the value of a call option increases with the increase of the underlying asset price.

From the option seller perspective, it also comes naturally that the option price should be similar to the underlying asset price less the exercise price. This would give origin to a zero-loss option for the seller and a zero-profit option for the buyer.

However, if the underlying asset price rises much above the exercise price, one can assume

Figure 1. A Traditional Framework for Valuing IT Investments
The Value of Flexibility

Box 3.

\[
\text{call option future profit} = \underbrace{\text{underlying asset market price} - \text{exercise price}}_{\text{call option future price}} - \underbrace{\text{call option future price}}_{\text{call option future profit}} \\
\text{put option future profit} = \underbrace{\text{exercise price} - \text{underlying asset market price}}_{\text{put option future price}} - \underbrace{\text{put option future price}}_{\text{put option future profit}}
\]

that the call option holders will exercise them. In this scenario, the holder is in fact buying on credit as he will acquire the underlying asset “for sure” but has chosen to finance part of that operation by borrowing. Therefore, for the holder, the delay of the payment to exercise the call may be very valuable if the interest rates or the option exercise date are high. This is so because we can use the amount of money needed to exercise the option to perform other investments and therefore gain more. This is also true for the option seller that can do the same with the collected option price.

Given this, it comes naturally a call option whose underlying asset price has a strong probability of increasing is more valuable than an option whose underlying asset is unlikely to change.

Additionally, if the underlying asset market price is a random walk (Kendall, 1953) then its variance increases linearly with time (Spitzer, 2001).

\[
\text{random walk variance} = \sigma^2 t
\]

Therefore, the price of the underlying asset varies more with time. Hence, an option value increases both with the variance or volatility of the underlying asset price, and with the exercise date.

Risk
Assuming the price of the underlying asset is a random walk, we were able to associate the value of its call option with the volatility and exercise date, and show that options over riskier assets are more valuable than options over safer ones.

As when you buy a call option, you are actually acquiring the underlying asset without paying for it immediately, the option is always riskier than the underlying asset. To know how much riskier the option is, we must look at its exercise price and underlying asset price. The more these values are similar, the less risky the option is. The increase of the underlying asset price increases the option value and reduces its risk. Conversely, the decrease of the underlying asset price reduces the option value and increases its risk. As the market price of the underlying asset changes on a daily basis, so does the value and risk of an option to buy that asset.

Bottom line, based on the large numbers probability and statistics theory, the more risky the option is, the more valuable it becomes (Brealey et al., 2003), contrarily to the reasoning we might have when deciding to go ahead with an IT investment over another.

The Five Variables
Table 1 summarizes the five variables that concur to the value and risk of an option, and Table 2 presents a set of rules that relate the value and risk of an option with each one of the five variables, assuming that all the other four variables are fixed.

Replicating Portfolio Technique
As can be noticed, standard discount formulas become very hard to use to value an option, namely because the price of the underlying asset follows a random walk. Fortunately for us, in 1969, Myron Scholes and Fischer Black found the trick to value an option (Black, 1987).

Imagining the price of the underlying asset can go up and down by a known amount, if instead of buying the option you bought an amount of the
underlying asset, and borrowed a certain amount of money from the bank, then you could get the exactly same payoffs.

If the payoffs of these investments are equal then both must have the same value. Therefore the value of the call option should be equal to the value of the bought underlying asset, less the repayment of the loan.

This way you have just created a homemade option by buying its underlying asset and borrowing money in such a way that you replicated the payoff of the option. This is called the replicating portfolio technique. The quantity of the underlying asset you must buy to replicate a call option, is called the hedge ratio or option delta.

See Box 4.

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**Binomial Method**

Another way to value options is using the binomial method (Cox et al., 1979). The method assumes that, for a given period, only two possible changes can occur in the underlying asset’s price of an option. That is, the underlying asset price can go up or down in a given period, with a given probability. In these formulas $t$ is the number of years per period and $\sigma$ the underlying asset’s volatility.

$$P \leftarrow uP, \text{ with probability } q$$

$$d = \frac{1}{u} = e^{-\sigma \sqrt{t}}$$

---

**Table 1. The Five Variables, Value and Risk (Brealey et al., 2003)**

<table>
<thead>
<tr>
<th>#</th>
<th>Variable</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Underlying Asset Price</td>
<td>$P$</td>
</tr>
<tr>
<td>2</td>
<td>Exercise Price</td>
<td>$EX$</td>
</tr>
<tr>
<td>3</td>
<td>Underlying Asset Volatility</td>
<td>$\sigma$</td>
</tr>
<tr>
<td>4</td>
<td>Interest Rate</td>
<td>$r_f$</td>
</tr>
<tr>
<td>5</td>
<td>Time to Expiration</td>
<td>$t$</td>
</tr>
<tr>
<td>6</td>
<td>Option Value</td>
<td>$V$</td>
</tr>
<tr>
<td>7</td>
<td>Option Risk</td>
<td>$R$</td>
</tr>
</tbody>
</table>

**Table 2. Options Value and Risk Synthesis (Based on Brealey et al. (2003) reasoning)**

<table>
<thead>
<tr>
<th>#</th>
<th>Rule</th>
<th>Value</th>
<th>Risk</th>
</tr>
</thead>
</table>
| 1 | The value of an option increases with the increasing of the underlying asset price.  
The risk of an option increases with the decrease of the underlying asset price. | $P \uparrow \rightarrow V \uparrow$ | $P \downarrow \rightarrow R \uparrow$ |
| 2 | The value of an option increases with the decrease of the exercise price.  
The risk of an option increases with the increase of the exercise price. | $EX \downarrow \rightarrow V \uparrow$ | $EX \uparrow \rightarrow R \uparrow$ |
| 3 | The value of an option increases with the increase of underlying asset price volatility.  
The risk of an option increases with the increase of the underlying asset price volatility. | $\sigma \uparrow \rightarrow V \uparrow$ | $\sigma \uparrow \rightarrow R \uparrow$ |
| 4 | The value of an option increases with increase of the interest rate.  
The risk of an option increases with the decrease of the interest rate. | $r_f \uparrow \rightarrow V \uparrow$ | $r_f \downarrow \rightarrow R \uparrow$ |
| 5 | The value of an option increases with increase of the expiration date.  
The risk of an option increases with the increase of the expiration date. | $t \uparrow \rightarrow V \uparrow$ | $t \uparrow \rightarrow R \uparrow$ |
The Value of Flexibility

Box 4.

\[
\text{option delta} = \frac{\text{possible option prices spread}}{\text{possible underlying asset prices spread}} \\
\text{call option value} = \text{option delta} \times \text{underlying asset price} - \text{bank loan}
\]

Box 5.

\[
\text{call option value} = \text{option delta} \times \text{underlying asset price} - \text{bank loan} = \\
N(d_1)P - N(d_2)PV(EX) \\
d_1 = \frac{\log \left( \frac{P}{PV(EX)} \right) + \sigma \sqrt{t}}{\sigma \sqrt{t}} \\
N(d) = \text{Cumulative normal probability density function.} \\
PV(EX) = \text{Option's exercise price discounted at the interest rate } r_f. \\
t = \text{Number of periods to exercise date or years to maturity.} \\
P = \text{Underlying's asset present price.} \\
\sigma = \text{Standard deviation of continuously compounded rate of return.}
\]

However, this model is still not practical for a real scenario, since the underlying asset price should vary several times.

**Black-Scholes-Merton Formula**

For accurate results, we would have to chop the periods on smaller and smaller slices, making the calculation of the option’s value very costly. Fortunately, Robert Merton, Myron Scholes and Fischer Black conceived a formula to solve this problem and calculate the value of any option (Black et al., 1973; Black, 1987). See Box 5.

**Real Options**

After embracing a given investment, organizations are in most scenarios also acquiring options over future decisions, which can be used to increase the value of the investment or minimize losses. Moreover, these options add more value to risky investments whose outcomes are more uncertain in the present.

The Real Options Theory applies the previously presented financial option models to real assets. It covers the scenarios in which an organization invests money now to create expansion opportunities in the future (Copeland et al., 2004).

After having calculated the value of a real option, that is, the value of the option a particular investment creates, we can then calculate the Adjusted Net Present Value or just Adjusted Present Value (APV) of that investment. The APV, simply extends the basic NPV to account for related investments that have impact on the organization’s capital structure. Recently, it was proposed that this value is more accurate than the one given by WACC (Cigola et al., 2005). See Box 6.

The APV, gives us a future vision of the investment value, eventually turning an investment that seems unprofitable at first, actually profitable if we account for the options it creates in the future.
Real Options Valuation Framework

In Figure 2 we extend the traditional investment valuation framework to have risk and future options in account.

This framework includes two advanced modeling approaches that should be used according with the objective of the valuation. The discrete approach uses the Binomial Method and Decision Trees that, although they give approximate results, are a lot more tunable and usable when dealing with compound options, therefore providing more power and understandability to managers (Copeland et al., 2004). The continuum approach uses the Black-Scholes-Merton formula and is more appropriate for single decisions where it’s harder to get accurate estimates, namely for the value of the underlying asset.

This framework includes risk as one of its basic assumptions. Moreover, it assumes that organizations do not hold passively to their investments but, instead, rely heavily, even if not quantitatively supported, on options reasoning, always increasing their investments and aiming for future growth opportunities.

When engaging in a new investment we must account for future related investments. Traditional valuation models are not applicable to these scenarios and eventually cause managers to avoid negative NPV projects, although they could open doors for future investments, which would give a positive APV.
FLEXIBILITY VALUATION

Our goal is to value the flexibility introduced and created by investments on software development. We explained why traditional investment valuation models are insufficient for this purpose, and introduced the advantages of real options models. We are now ready to propose a model to calculate the value of flexibility.

What is Flexibility

The flexibility of software is intuitively expressed as the easiness to adapt it to new requirements. This easiness has multiple metrics, like the time needed to perform changes or the number of changes per unit of time. Usually, the more complex the software is, the less flexible it becomes. Flexibility can then be defined as the changes introduced in a software application over a given time period, as measured by its complexity. Hence, this complexity must be quantified.

As we will see, some of the metrics for software complexity were developed to measure the programmers’ productivity, but all of these models can be straightforwardly applied as Software Complexity Metrics (SCM).

In 1974, Wolverton proposed a metric based on the number of code lines. As there were many criticisms to its plainness, other metrics were proposed. For instance, McCabe (1976) argued the complexity of a program could be obtained by the minimum number of paths it defined when seen as a graph.

Other researchers, such as Halstead et al. (1976), proposed easier but still acceptable metrics, such as the number of operators, operands, usage, and similars. As software programs follow the pattern expressed by the Zipf’s law (1949) which states that in the natural language a few words occur very often while many others occur rarely, these findings were extended to programming languages and its operators, operands, and to the combinations of them, thus validating Halstead’s model (1977).

Only in 1979, Albrecht introduced the now widely used Function Points Analysis (FPA) to measure the size and complexity of IT systems. This analysis is based on Function Points (FP) which are a measure of the size and complexity of computer applications, obtained from a functional perspective by objectively measuring functional requirements. This proposal is therefore independent of the programming language or technology used.

By the late 80’s, models to measure the complexity of IT systems using Object-Oriented (OO) languages were also proposed. Some researchers argue that FPA is not applicable to OO languages, and proposed other models to measure the complexity of objects, such as the Object Workload Analysis Gauge (O-WAG) (Rains, 1991), which is somewhat similar to the Halstead’s model, since instead of focusing on the object function to measure its complexity, it accounts for its attributes, operations, exceptions, and the like. Nevertheless, there are other models that still use or extend FPA to measure the complexity of OO based IT systems (Antoniol et al, 1999).

Proposed Valuation Model

As we will see, for software applications that have a well defined metric of complexity we can apply the Real Options Theory to value the option of changing or adding one of these Software Complexity Units (SCUs). Hence, we can build a model applicable to any software technology to calculate the value of flexibility, defined as the option to change or add one of its SCU.

The Option to Change

Let us give some examples to explain our approach. On September 2005, Quark unveiled its new corporate identity. The words of Glen Turpin (Quark’s director of corporate communications) about this change were (Dalrymple, 2005): “We have changed so much that we felt it was time to
send a signal to the world [...] It’s not about just changing the look, it’s about reflecting externally what has been happening internally and laying the path for everything we are going to do.”

Some time ago, Quark created its official Web site on top of some technology. Along with the selection of the technology to use, Quark also implicitly bought the option to change its Web site in September 2005. Assuming the first Quark’s Web site was the result of a single project with a given cost, we can say the value of this investment is floored by the cost of the project itself, otherwise the investment would never have been made. Years later, Quark completely changed the face of its original Web site without increasing its software complexity, thus, exercising the option bought before.

Using a SCM for the technology used to build Quark’s Web site, we can say that the first Quark’s Web site had a given number of SCUs. As there were no changes in complexity, the current Web site also has the same number of SCUs, being therefore the result of changing some of those SCUs.

We have then a first project with a given cost that originated a custom application with some SCUs, and a second project with another cost that changed the SCUs of the first project.

As such, we are in the presence of an option to change Quark’s Web site. The exercise price of this option is simply the cost of the project that changed Quark’s Web site. The underlying asset in this example is the Web site itself, so its price is at least the cost of the project that originally created it. For simplicity, this assumes, without any value judgment, that Quark’s site value equals at least its cost.

From a post implementation perspective, we can calculate the value of the option that Quark received when they first created the initial Web site. As we have seen before, the elicitation of costs and benefits of a given investment is hard to perform and often involves several assumptions and value judgments. However, if we look at the previous Quark’s investments on its Web site from a strictly technological perspective, we can value the option of changing the SCUs of this Web site without any of these problems, relying only in a SCM.

Generalizing this example, we are calculating the option to change a given number of SCUs of a technology. Empirically, we can, for any technology, define a SCM and then gather data from several projects. With that data we can calculate the value of the options at stake in all these projects and correlate their values to obtain the value of the option to change one SCU of that technology, from a strictly technological perspective.

Note this valuation is strictly technological because with this model we can only value the option of changing a SCU of a given technology, and nothing more. We are not arguing that this option adds value to the business. Most important, we are not arguing that technologies with greater values for the option of changing one of its SCUs are better than others, because we made no assumptions on the relation between requirements or benefits and their implementation SCUs, and we established no relation between the SCMs of each technology.

Therefore, we are simply presenting a model that, for a given SCM, can provide managers with a value for the option to change one of its SCUs. The decision on how to interpret this value, e.g. to relate it with the value of other technologies, must be done carefully.

Having said that, this issue could be solved if we used a normalized and inter-technology comparable SCM for all technologies, such as FPs.

The Option to Extend

In most scenarios, applications tend to be extended in functionality, therefore increasing their complexity and their number of SCUs.

As an example, let’s look at Amazon. Jeff Bezos started Amazon back in 1995 and, at that time, the site only sold books. Again, along with
the selection of the technology, Jeff Bezos also bought the option to change and extend the site. When in 2000 Amazon began selling products from other retailers like eBay, Amazon managers were actually exercising an option Jeff Bezos had bought five years before, back in 1995: the option to extend the site with new services.

In this scenario we have then the initial project with a given cost that originated Amazon’s first site, and a second project that extended that site, therefore increasing its number of SCUs. In this case, if we assume the original site functionalities remained unchanged, then so their corresponding SCUs remained unchanged.

The option in this example is similar to the Quark’s example, except for the fact that Amazon added new SCUs, while maintaining the existing SCUs intact. The exercise price of this option was once again the cost of the project that implemented the new functionalities and the underlying asset is the application itself, so its price is at least also the cost of the project that originally created it.

**Flexibility Valuation Model**

Figure 3 generalizes three possible scenarios for a given application regarding its evolution. We have an initial project that costs $P$ and creates an application with $N$ SCUs. Then we have the option to change or extend the initial application, resulting in an application with $M$ SCUs. This option’s exercise price is the cost of the project that will perform that change or extension over the initial application. The first alternative is to change the initial application without increasing its SCUs. The second alternative is to extend the initial application with more SCUs, without changing the original ones. Finally, the third and more realistic alternative is to both change and extend the initial application.

With this modulation, we created scenarios to value the several evolution options of an application without the need to make any assumption or value judgment about the benefits of the application. This way, we can apply the model to different

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*Figure 3. Evolution of software complexity units*
technologies and SCMs to obtain the value of the options to change or add one of its SCUs, from a strictly technological perspective.

Moreover, if we use a normalized and inter-technology comparable SCM, we can provide managers with change and extension option values for different technologies and therefore help on the selection of the technology to choose for implementing a new application.

This model can be applied to any technology as a black-box for each one of the scenarios described in Figure 3. As it will surely happen with most technologies, the option’s exercise price will not be linear with the number of SCUs being changed or added. Most probably, when the application starts to grow in complexity, it will become harder to change or extend, and therefore the value of the option to perform that change or extension will decrease.

In order to obtain the value of the option to change or add a single SCU of an application implemented with a given technology, we will need to linearize those values over the number of SCUs. Also, a valid and applicable linearization model should be chosen for each technology on analysis, since it will depend on how the technology scales with complexity.

**Case Study**

As a proof of concept, we applied the proposed model to the OutSystems technology in order to calculate the value of the options to change or add one of its SCU.
The Value of Flexibility

Each row in Table 4 represents a specific Custom Enterprise Application (CEA) developed for a particular customer. As explained, \( P \) is the cost of the initial project that originated the first version of the application with a given complexity of \( N \) SCUs. After \( t \) months, this application was changed, being its complexity increased to \( M \) SCUs. The project that introduced those changes represents an investment of \( EX \). Note the costs below only account for the required one year term licenses and the services that delivered the project.

In the first scenario, the changes introduced in the applications were merely visual updates or business logic changes that did not cause the resulting application to be more complex since no new functionality was added. Therefore, the resulting \( M \) SCUs are the same initial \( N \) SCUs, which in the presented examples were changed in some way.

In the second scenario, only new features were added to the application, while the existing ones remained equal and untouched, causing the application to increase its complexity. Hence, the final application has a complexity of \( M \) SCUs, higher than the initial \( N \) SCUs.

With this data we can apply the model with different volatility percentages to obtain the option values of the two scenarios under evaluation, dividing the value of the second project option by the number of changed or added SCUs.

Valuation Model Output

The explained reasoning can be applied to the CEAs listed in Table 4, with different volatilities, as presented in Table 5.

The different volatilities are a measure of the CEA's stability. If you are handling a core application, it is expected it won’t change that often, having therefore a low volatility. Conversely, if you are handling a non-core application to support fuzzy business process, ad-hoc activities, and so on, it is expected this application to require a lot more changes as time passes, having therefore a high volatility.

Managers should pick what they feel is an appropriated volatility for a given application, to valuate its flexibility in a particular technology.

From these calculations, we can extract both the value of the option to change one SCU and

Table 4. Projects data

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CEA</th>
<th>( P )</th>
<th>( EX )</th>
<th>( t ) (months)</th>
<th>( N )</th>
<th>( M )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1</td>
<td>$7,400</td>
<td>$3,200</td>
<td>1.23</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.2</td>
<td>$33,500</td>
<td>$9,600</td>
<td>1.68</td>
<td>25,000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.3</td>
<td>$59,400</td>
<td>$25,600</td>
<td>0.91</td>
<td>30,000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.4</td>
<td>$96,700</td>
<td>$44,800</td>
<td>1.59</td>
<td>65,000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.5</td>
<td>$171,200</td>
<td>$38,400</td>
<td>2.91</td>
<td>80,000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.6</td>
<td>$218,400</td>
<td>$134,400</td>
<td>3.18</td>
<td>120,000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.7</td>
<td>$352,800</td>
<td>$134,400</td>
<td>6.18</td>
<td>120,000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.1</td>
<td>$52,400</td>
<td>$28,800</td>
<td>0.68</td>
<td>20,000</td>
<td>35,000</td>
</tr>
<tr>
<td>2</td>
<td>2.2</td>
<td>$52,400</td>
<td>$36,100</td>
<td>2.91</td>
<td>20,000</td>
<td>35,000</td>
</tr>
<tr>
<td>2</td>
<td>2.3</td>
<td>$70,320</td>
<td>$56,320</td>
<td>4.00</td>
<td>20,000</td>
<td>35,000</td>
</tr>
<tr>
<td>2</td>
<td>2.4</td>
<td>$52,400</td>
<td>$38,400</td>
<td>0.91</td>
<td>20,000</td>
<td>45,000</td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>$85,000</td>
<td>$68,700</td>
<td>2.73</td>
<td>30,000</td>
<td>55,000</td>
</tr>
<tr>
<td>2</td>
<td>2.6</td>
<td>$248,000</td>
<td>$127,500</td>
<td>3.41</td>
<td>80,000</td>
<td>125,000</td>
</tr>
<tr>
<td>2</td>
<td>2.7</td>
<td>$712,500</td>
<td>$384,000</td>
<td>9.09</td>
<td>195,000</td>
<td>280,000</td>
</tr>
</tbody>
</table>
The Value of Flexibility

Table 5. CEAs’ Flexibility Option Values for a WDR of 10%

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CEA</th>
<th>N</th>
<th>M</th>
<th>( V, \sigma = 10% )</th>
<th>( V, \sigma = 20% )</th>
<th>( V, \sigma = 40% )</th>
<th>( V, \sigma = 60% )</th>
<th>( V, \sigma = 80% )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1</td>
<td>10,000</td>
<td></td>
<td>$0.4231</td>
<td>$0.4231</td>
<td>$0.4231</td>
<td>$0.4231</td>
<td>$0.4231</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>25,000</td>
<td></td>
<td>$0.9611</td>
<td>$0.9611</td>
<td>$0.9611</td>
<td>$0.9611</td>
<td>$0.9611</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>30,000</td>
<td></td>
<td>$1.1328</td>
<td>$1.1328</td>
<td>$1.1328</td>
<td>$1.1328</td>
<td>$1.1328</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>65,000</td>
<td></td>
<td>$0.8071</td>
<td>$0.8071</td>
<td>$0.8071</td>
<td>$0.8071</td>
<td>$0.8071</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>80,000</td>
<td></td>
<td>$1.6710</td>
<td>$1.6710</td>
<td>$1.6710</td>
<td>$1.6710</td>
<td>$1.6710</td>
</tr>
<tr>
<td></td>
<td>1.6</td>
<td>120,000</td>
<td></td>
<td>$0.7279</td>
<td>$0.7279</td>
<td>$0.7286</td>
<td>$0.7368</td>
<td>$0.7575</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>120,000</td>
<td></td>
<td>$1.8737</td>
<td>$1.8737</td>
<td>$1.8737</td>
<td>$1.8760</td>
<td>$1.8890</td>
</tr>
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<td>20,000</td>
<td>35,000</td>
<td>$1.5837</td>
<td>$1.5837</td>
<td>$1.5837</td>
<td>$1.5837</td>
<td>$1.5838</td>
</tr>
<tr>
<td></td>
<td>2.2</td>
<td>20,000</td>
<td>35,000</td>
<td>$1.1416</td>
<td>$1.1416</td>
<td>$1.1463</td>
<td>$1.1768</td>
<td>$1.2337</td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>20,000</td>
<td>35,000</td>
<td>$1.0507</td>
<td>$1.0531</td>
<td>$1.1160</td>
<td>$1.2424</td>
<td>$1.3949</td>
</tr>
<tr>
<td></td>
<td>2.4</td>
<td>20,000</td>
<td>45,000</td>
<td>$0.5711</td>
<td>$0.5711</td>
<td>$0.5712</td>
<td>$0.5741</td>
<td>$0.5841</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>30,000</td>
<td>55,000</td>
<td>$0.7109</td>
<td>$0.7115</td>
<td>$0.7412</td>
<td>$0.8106</td>
<td>$0.8988</td>
</tr>
<tr>
<td></td>
<td>2.6</td>
<td>80,000</td>
<td>125,000</td>
<td>$2.7535</td>
<td>$2.7535</td>
<td>$2.7536</td>
<td>$2.7601</td>
<td>$2.7894</td>
</tr>
<tr>
<td></td>
<td>2.7</td>
<td>195,000</td>
<td>280,000</td>
<td>$4.1794</td>
<td>$4.1794</td>
<td>$4.1976</td>
<td>$4.3109</td>
<td>$4.5163</td>
</tr>
</tbody>
</table>

If that was possible, the stock market would collapse. However, there is in fact a relation between risk, flexibility, and complexity, but it varies from IT project to IT project, as the stock options values vary from stock to stock. That relation can be quantified and predicted using the Options Theory.

Also, the gathered data is relative to very different projects, from different industries, and with different purposes. Hence, it was expected the options values to be highly scattered.

Nonetheless, for a particular industry and vertical CEAs we feel the constructed model can be used to calculate the applications’ price volatility, the same way financial engineers calculate the volatility of stocks in order to value their options, because in this situation the underlying asset would be the same or similar, although its price could and should vary.

This feeling is supported by the evidence shown in Figure 5, which makes visually clear there is, for each CEA, a strong relation between its initial price, its initial SCUs, the price of the second project which introduces the changes or

the value of the option to add one SCU to a CEA built with our selected technology.

Table 6 shows those values for several volatilities. Note that no advanced linearization process was used to reach these results, which are the simple average and deviation.

Seeming there is absolutely no relation with the number of changed or added SCUs and their value, what can we conclude from this gathered data? Simply that the model applies. Why? Well, we hoped that it would be possible to generally obtain the values for the options to change or add one SCU. However, for this to be possible, it would mean that the prices of the underlying asset, in our case the CEAs, wouldn’t follow a random walk. Moreover, if this was the case, the Options Theory couldn’t be applied. The results show the values of the options vary a lot from project to project. These findings further enforce our initial idea that IT investments are risky and empirically prove the Options Theory can be applied to value IT investments.

As you could have noticed, we were trying to obtain the value of a call option over any stock!
The Value of Flexibility

Table 6. General Flexibility Option Values for a WDR of 10%

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Option</th>
<th>$V, σ = 10%$</th>
<th>$V, σ = 20%$</th>
<th>$V, σ = 40%$</th>
<th>$V, σ = 60%$</th>
<th>$V, σ = 80%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Change one SCU</td>
<td>$1.085$</td>
<td>$1.085$</td>
<td>$1.085$</td>
<td>$1.087$</td>
<td>$1.092$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+/- 52.1%</td>
<td>+/- 52.1%</td>
<td>+/- 52.0%</td>
<td>+/- 52.0%</td>
<td>+/- 52.1%</td>
</tr>
<tr>
<td>2</td>
<td>Add one SCU</td>
<td>$1.713$</td>
<td>$1.713$</td>
<td>$1.730$</td>
<td>$1.780$</td>
<td>$1.857$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+/- 130.7%</td>
<td>+/- 130.7%</td>
<td>+/- 130.4%</td>
<td>+/- 132.0%</td>
<td>+/- 136.4%</td>
</tr>
</tbody>
</table>

Figure 5. CEA's Variables Correlation for a Volatility of 20% and a WDR of 10%

additions, the time between the two projects, and the value of the option to change or add one SCU. In fact, all these variables grow together in both scenarios. Therefore, for a particular type of CEA, in the scope of a given industry and concrete objectives, it should be possible to apply the created model, since these correlations exist, as evidenced.

Given all the above, instead of trying to obtain the value of any stock option, we can instead try to obtain the value of flexibility as a percentage of the initial project, thus relativizing it uniquely to the project and removing the need for external variables.

Output Analysis

Working with the samples of our case study, we can reach some interesting conclusions about the technology being evaluated.

First, we can say the selected technology handles risk quite well, possibly due to its intrinsic capabilities or the methodology it enforces. If we look at Table 5 we can see that for each CEA, the values of the options don’t change much across different volatilities. We mapped this volatility with the volatility of the CEA’s needed changes and extensions because the underlying price of the CEA varies with these two variables. The more changes and extensions are needed, the more costly the CEA will be, and therefore the volatility of such changes and extensions are a measure of the CEA’s price volatility.

In Table 7 we present the averages and deviations of the options values for the several presented volatilities. As you can see, the deviations of the values of the option to change one SCU of a specific CEA are all lower than 1.3\% and the deviations of values of the option to add one SCU to a specific CEA are all lower than 14.7\%.
Table 7. CEAs’ Flexibility Option Values Averages and Deviations

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CEA</th>
<th>N</th>
<th>M</th>
<th>( V_{\text{Average}} ) for ( \sigma = {10%, 20%, 40%, 60%, 80%} )</th>
<th>( V_{\text{Deviation}} ) for ( \sigma = {10%, 20%, 40%, 60%, 80%} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1</td>
<td>10,000</td>
<td></td>
<td>$0.4231$</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>25,000</td>
<td></td>
<td>$0.9611$</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>30,000</td>
<td></td>
<td>$1.1328$</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>65,000</td>
<td></td>
<td>$0.8072$</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>80,000</td>
<td></td>
<td>$1.6710$</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>1.6</td>
<td>120,000</td>
<td></td>
<td>$0.7357$</td>
<td>1.3%</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>120,000</td>
<td></td>
<td>$1.8772$</td>
<td>0.7%</td>
</tr>
<tr>
<td>2</td>
<td>2.1</td>
<td>20,000</td>
<td>35,000</td>
<td>$1.5837$</td>
<td>0.0%</td>
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<tr>
<td></td>
<td>2.2</td>
<td>20,000</td>
<td>35,000</td>
<td>$1.1680$</td>
<td>4.0%</td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>20,000</td>
<td>35,000</td>
<td>$1.1714$</td>
<td>14.7%</td>
</tr>
<tr>
<td></td>
<td>2.4</td>
<td>20,000</td>
<td>45,000</td>
<td>$0.5743$</td>
<td>0.6%</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>30,000</td>
<td>55,000</td>
<td>$0.7746$</td>
<td>8.0%</td>
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<tr>
<td></td>
<td>2.6</td>
<td>80,000</td>
<td>125,000</td>
<td>$2.7620$</td>
<td>1.6%</td>
</tr>
<tr>
<td></td>
<td>2.7</td>
<td>195,000</td>
<td>280,000</td>
<td>$4.2767$</td>
<td>14.5%</td>
</tr>
</tbody>
</table>

This is a highly important remark because it means that for this selected technology, no matter how much volatile the requirements of a project are, or in other words, no matter how much risky the project is, the values of the options to change or add one SCU remain almost the same. This justifies the prior conclusion of this technology handling risk very well.

Albeit the gathered data for this case study is relative to very different projects in their nature, making somehow their comparison non significant, in fact, they all rest within the realms of a specific technology. Therefore, for this technology, and assuming the gathered data is significant for the universe of projects done with it, the mentioned intervals are relevant.

Also worth noticing is the higher 14.7% deviation, which indicates the scenarios where new functionality is added to the CEA are riskier. This is intuitively expected, since these scenarios increase the complexity of the CEA.

Given the prior conclusion that the selected technology is almost immune to volatility, that is, to risk, the average options values of Table 7 can be used to extrapolate significant intervals for the values of the options to change or add one SCU, that is, the value of flexibility.

Hence, for the selected technology in case study, the value of the option to change one SCU of a specific CEA is within the interval \([$0.4231; \$1.8772]\) and the value of the option to add one SCU to a specific CEA is within the interval \([$0.5743; \$4.2767]\).

With these intervals, we can obtain the value of flexibility as a percentage of the initial project, that is, we can obtain the values of the options to change or add one SCU as a percentage of the price per SCU of a given CEA.

In Table 8 we present the price per SCU of each CEA, by dividing \( P \) (the price of the underlying asset) by \( N \) (its number of SCUs).

Comparing these prices per SCU with the average option values presented in Table 7, we obtain the value of the options as a percentage of the CEA’s initial price per SCU.
The Value of Flexibility

Table 8. CEAs’ Flexibility Option Values as Percentage of Initial Price per SCU

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CEA</th>
<th>( P )</th>
<th>( N )</th>
<th>Price per SCU</th>
<th>( V ) Average</th>
<th>( V / ) Price per SCU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1</td>
<td>$7,400</td>
<td>10,000</td>
<td>$0.740</td>
<td>$0.4231</td>
<td>57.2%</td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td>$33,500</td>
<td>25,000</td>
<td>$1.340</td>
<td>$0.9611</td>
<td>71.7%</td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td>$59,400</td>
<td>30,000</td>
<td>$1.980</td>
<td>$1.1328</td>
<td>57.2%</td>
</tr>
<tr>
<td>1.4</td>
<td></td>
<td>$96,700</td>
<td>65,000</td>
<td>$1.488</td>
<td>$0.8072</td>
<td>54.3%</td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td>$171,200</td>
<td>80,000</td>
<td>$2.140</td>
<td>$1.6710</td>
<td>78.1%</td>
</tr>
<tr>
<td>1.6</td>
<td></td>
<td>$218,400</td>
<td>120,000</td>
<td>$1.820</td>
<td>$0.7357</td>
<td>40.4%</td>
</tr>
<tr>
<td>1.7</td>
<td></td>
<td>$352,800</td>
<td>120,000</td>
<td>$2.940</td>
<td>$1.8772</td>
<td>63.9%</td>
</tr>
<tr>
<td>2</td>
<td>2.1</td>
<td>$52,400</td>
<td>20,000</td>
<td>$2.620</td>
<td>$1.5837</td>
<td>60.4%</td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td>$52,400</td>
<td>20,000</td>
<td>$2.620</td>
<td>$1.1680</td>
<td>44.6%</td>
</tr>
<tr>
<td>2.3</td>
<td></td>
<td>$70,320</td>
<td>20,000</td>
<td>$3.516</td>
<td>$1.7174</td>
<td>33.3%</td>
</tr>
<tr>
<td>2.4</td>
<td></td>
<td>$52,400</td>
<td>20,000</td>
<td>$2.620</td>
<td>$0.5743</td>
<td>21.9%</td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td>$85,000</td>
<td>30,000</td>
<td>$2.833</td>
<td>$0.7746</td>
<td>27.3%</td>
</tr>
<tr>
<td>2.6</td>
<td></td>
<td>$248,000</td>
<td>80,000</td>
<td>$3.100</td>
<td>$2.7620</td>
<td>89.1%</td>
</tr>
<tr>
<td>2.7</td>
<td></td>
<td>$712,500</td>
<td>195,000</td>
<td>$3.654</td>
<td>$4.2767</td>
<td>117.0%</td>
</tr>
</tbody>
</table>

Therefore, we conclude that for this technology, the option to change one SCU of a particular CEA is worth between 40.4% and 78.1% the price of that CEA’s SCUs and the option to add one SCU to a particular CEA is worth between 21.9% and 117.0% the price of that CEA’s SCUs.

The interest of this particular conclusion is that we can now estimate intervals for the values of the options to change or extend a given CEA in this technology, knowing only the CEA’s initial price and number of SCUs.

Imagine you have an application that cost $8,500 and has a complexity of 20,000 SCUs. In the worst scenario, the option to change your application is worth 40.4% $8,500 = $3,434, and in the best scenario 78.1% $8,500 = $6,639. Hence, the option to change your application is in the interval [$3,434; $6,639]. This means that, accounting with the option values, your application’s APV is in the interval [-$5,066; -$1,861], instead of its initial NPV of -$8,500.

As for the option to extend your application, in the worst scenario it is worth 21.9% $8,500 = $1,862 and in the best scenario 117.0% $8,500 = $9,945. Therefore, the option to extend your application is in the interval [$1,862; $9,945]. This means the APV of your investment is in the interval [-$6,638; $1,445], having some probability to be positive by itself!

FUTURE TRENDS

The main problem with the proposed model is that it requires a lot of input data. Even for vertical solutions it would be needed an effort from vendors to obtain significant statistical data to properly value the flexibility of their technologies.

A bigger obstacle to implement industry wide this or a similar model is related with the market itself. Each technology has its own advantages and disadvantages, and vendors often see no value in being compared numerically, as they would lose the option to exalt their advantages and hinder their disadvantages. As such, the quest for an inter-technology normalized Software Complexity Metric (SCM) is far from being obtained, though academic studies on this area will surely
The Value of Flexibility

continue. Nevertheless, Function Points (FPs) are quite widely accepted.

The linearization issue of the proposed model should be further investigated, since the value of the options to change or add one Software Complexity Unit (SCU) does not scale equally from technology to technology, nor even inside the same technology with the complexity of the Custom Enterprise Application (CEA).

The third CEA evolution scenario, not addressed in the case study, where the application is both changed and extended is the most real one, but the most difficult to model. With proper data it could be sliced in two compound options of changing one SCU and adding one SCU. However, more advanced models must be built for this research to handle such scenario properly and be useful, since such data is never available.

A topic not addressed in this research but worth mentioning is how metrics related with the changes performed over a CEA can be converted into risk evaluation. To answer this question a taxonomy of changes would have to be created, using, for instance, flexi-points (Rymer et al., 2007). After categorization, such change metrics could be converted into risk evaluation, thus providing a matrix to evaluate the risk of IT investments. However, such taxonomy could also make the proposed model more expensive to apply, since all the foreseen changes would need to be elicited upfront.

Finally, but not less important, a taxonomy to classify CEAs must be built to properly be able to catalog them by similarity and therefore compare what is comparable. When this is done, IT managers will be able to have real numbers to make informed decisions over what technologies to choose for what projects.

CONCLUSION

This chapter intended to value the flexibility in custom software development. The premises to prove were that IT investments are risky, and that flexibility is a tool to handle that risk.

We hope to have proven that IT investments are intrinsically risky and that the Real Options Theory is applicable to value these investments. Also, we expect to have made clear that flexibility is an appropriate way to handle risk in IT.

Several traditional investment valuation models were presented and their inability to handle risk was properly evidenced. We described the Options Theory, particularly, the Real Options Theory, and disserted on how it can be used to value investments having risk in account.

A model was iteratively developed based on the premise there is a strong relation between the costs of a Custom Enterprise Application (CEA) and its complexity. This model outputs the value of the options to change or add one unit of complexity of or to a CEA, and can be used to value the flexibility of any technology.

One of our empirical proofs is that the base premise of the model is correct but that this relation is not linear, as it should depend on several factors particular to the microenvironment were the application exists, namely, the industry, its purpose, the need for specific integrations, and so on. This finding by itself supports the idea that IT investments are risky. Moreover, it empirically proves that the Options Theory can be applied to value these investments, and therefore that the model is valid for an appropriated universe.

The acceptance of risk in IT investments, rather than pretending it doesn’t exist, must still be done while the IT industry fails to minimize it. The main tool to handle that recurring risk is flexibility, which therefore has a commensurable value in IT. Using the theory we presented and the model we proposed, managers can quantify and predict risk, and value the flexibility of a given technology before choosing it to implement a CEA.

In the lack of data to feed the model, we expect at least to have contributed to provide IT managers with an options-based reasoning, encouraging
The Value of Flexibility

them to look further ahead and use flexibility to deal with risk, which is an unavoidable reality of IT investments.

As a proof of concept, we validated the proposed model with real data against the OutSystems technology. The model allowed us, for this specific technology, to reach four important conclusions.

Firstly, we concluded the selected technology is almost immune to risk. Secondly, that the scenarios where new functionality is added with this technology are riskier than the ones where existing functionality is changed. Thirdly, we concluded the value of the option to change one Software Complexity Unit (SCU) within this technology is in the interval [0.4231; 1.8772], and the value of the option to add one SCU within the interval [0.5743; 4.2767]. Fourthly, and finally, we were able to obtain intervals for the values of the above options, knowing only the initial status of a CEA. We concluded that the value of the option to change a CEA built with the case study technology is within [40.4%; 78.1%] its initial price, and the value of the option to extend a CEA within [21.9%; 117.0%], having a wider range since it is a riskier investment.

For this selected technology, we can now use these findings to adjust the Net Present Value (NPV) of a project, accounting with the value of the options that project creates in the future.

REFERENCES


Dupuit, J. (1844). De la mesure de l’utilité des travaux publics. Annales de Ponts et Chaussées, 8(2).


**KEY TERMS AND DEFINITIONS**

**Adjusted Present Value (APV):** The APV extends the basic NPV to account for related investments that have impact on the organization’s capital structure. Is usually calculated adding the basic NPV of the investment and the related investments NPV.

**Custom Software Development:** The process by which an information system is developed, not recurring to any pre-existing package or solution sold as a product. Used when the required information system is too specific for any pre-existing product to be applicable, or when the information system needs to be flexible to cope with change or fuzzy requirements.

**Flexibility:** The ability to adapt to expected and unexpected changes in the environment. In the context of this chapter, flexibility is quantifiable by the amount of changes introduced in a custom enterprise application over a given time period, as measured by its complexity.

**Net Present Value (NPV):** Is the present value of an investment in the future, usually calculated by the difference between the present monetary values of the costs and the benefits of the investment.

**Option:** Is a contract that gives the holder the right but not the obligation to buy or sell the underlying asset for a certain price at a certain date.

**Real Option:** An opportunity that becomes available after a particular investment is made. The opportunity can be exercised or not, thus leading to impacts on the investment value or not.

**Risk:** Denotes the potential impact on an attribute of value that a future event may cause. In finances, represents the variability of returns a given investment may have. In the context of this chapter, risk is reflected, among other variables, in the uncertainty of the requirements a custom enterprise application may need to fulfill in the future.

**Volatility:** A measure of the variation a given asset may have on its price over a given time period. In the context of this chapter, volatility is the percentage of needed changes or extensions a custom enterprise application may need, when compared with its initial state.