# Quantitative Approaches for Assessing the Value of COTS-centric Development

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## Abstract

*Software development based on commercial off-the-shelf, or COTS, components is currently drawing considerable attention. This paper presents the results of two complementary quantitative valuation methods applied to the assessment of the COTS-centric software development projects. We use a standard corporate finance tool, Net Present Value, as a basis for both methods. The first method, comparative valuation, investigates the economic incentive to choose the COTS-centric strategy in a project vis à vis the alternative, the custom development strategy, through an incentive metric based on NPV. The analysis concentrates on the impact of product risk and development time on the defined metric. The second method, real options valuation, primarily deals with uncertainty. It is employed to investigate the value of strategic flexibility inherent in COTS-centric development. We provide examples of several such options and summarize qualitatively the results of their analyses. Using these two approaches, some common anecdotes of COTS-centric development can be substantiated by sound financial arguments. Through scenarios and sensitivity analyses, we show that different circumstances and assumptions give rise to different winning conditions. Some general principles are summarized at the end.*

## 1. Introduction

The push toward the widespread use of *Commercial Off-The-Shelf*, or COTS, components is causing a paradigm shift in software development. Software construction largely from such ready-made, non-proprietary parts is sometimes being advocated as the most feasible way to satisfy the demands of today's complex applications. Enabling technologies such as JavaBeans, ActiveX, and CORBA, coupled with the growing popularity of the Internet as a medium for information exchange and application distribution, make this approach both viable and attractive. As a result, government organizations and businesses alike increasingly prefer system assembly centered on COTS software products, or *COTS-centric development* in short, over the traditional *custom development* approach [5].

This paper presents the results of some novel quantitative investment analysis techniques as they were applied to the assessment of the economic value of COTS-centric software development projects. Economic value is measured by a standard corporate finance tool, *Net Present Value.* The analysis involves two complementary valuation approaches: *comparative valuation* and *real-options-based valuation*.

Comparative valuation is employed to study the economic incentive to choose the COTS-centric strategy in a project *vis à vis* the alternative, the custom development strategy. We accomplish this by defining an incentive metric based on NPV. Here the analysis concentrates on the impact of product risk and development time on the defined incentive metric.

Real options valuation primarily deals with uncertainty. This approach is employed to quantify strategic flexibility inherent in COTS-centric development. The paper provides examples of several such options.

Using these two approaches, some common anecdotes of COTS-centric development can be substantiated by sound financial arguments. Through hypothetical scenarios and sensitivity analyses, it is possible to demonstrate that different circumstances and assumptions give rise to different winning conditions. The focus of the paper is on these qualitative observations that are drawn from the quantitative analyses performed. The details of the valuation techniques used are expounded elsewhere [10, 11], and more information is available at http://wwwsel.iit.nrc.ca/~erdogmus. The last section states some general guidelines.

The ultimate goal is to apply the quantitative valuation approaches to real examples. In this paper, we have relied exclusively on hypothetical scenarios that cover a small, yet representative, subset of the possible situations.

## 2. Motivation

The main drivers for using COTS components in new software are cost savings and rapid development. However, COTS-centric development is not universally the most economical approach. The processes, technologies, and skills required differ from those of traditional development in many aspects [8, 4]. The development process includes the additional lifestyle activities of component selection, adaptation, integration, upgrade, and replacement. Unfortunately, the impact of these activities on costs and returns is not yet well understood.

As with any new solution to a long-standing problem, COTS-centric development has both advantages and disadvantages. Carney and Oberndorf [4] dispel some of the common misconceptions. Component selection and integration may be both time-consuming and costly. Maintenance costs, driven by component upgrades and replacements, are often highly uncertain (Vigder and Dean, 1998). The inability to control the functionality and quality of the COTS components may impact both the quality and the usability of the end system [22]. Licensing fees and royalties paid for the COTS components reduce net earnings. Consequently, the actual cost savings may be significantly less than originally anticipated. On the upside are some potentially valuable indirect benefits. Early market entry, achieved by a reduction in development time, is likely to improve market capture. Built-in flexibility to replace components may increase the acceptance, competitiveness, and lifetime of the end system through leverage on third party innovations and improvements. All of these interacting factors make it difficult to establish a business case for COTS-centric development, which arises the need to view them from a common, bottom-line perspective.

In a strictly business context, the governing objective of software development is wealth generation [16; 13]. Thus economic value should be a primary concern for a new software development project. The business case for the project must demonstrate in a sound manner that the proposed development strategy is likely to maximize economic value. This stipulation forces the advantages and disadvantages of the alternative strategies to be considered from a value perspective. Clemons [7] states that “evaluation of a system’s development based on potential competitive impact is fundamentally different from evaluation based on cost.” However, without a common, value perspective, this impact is very hard to assess, especially in the face of uncertainty and multiple alternatives.

## 3. A value-based approach to business case development

The business case for a new software projects is best constructed using a multi-stage, multi-disciplinary model that focuses on economic value. The model we propose consists of three stages: *planning*, *estimation*, and *analysis* (Figure 1). Planning starts with the recognition of the relevant forces that affect economic value. The project is cast as an investment opportunity with six high-level value determinants: *product risk*, *development time*, *development cost*, *asset value*, *operation cost*, and *flexibility premium*. Identification of alternative strategies and development of business scenarios also take place during planning. The scenarios take into account the flexibilities and uncertainties inherent in each strategy. These activities help define the cost, cash flow, schedule, market, and risk variables to be estimated in the next stage.

Estimation is concerned with assigning values, bounds, and distributions to these variables. Cost estimation [2, 3], forecasting, risk analysis, market research are some of the tools that can be used in this stage.

The analysis stage uses these estimates and the scenarios from the planning stage to evaluate the alternative strategies. The processes involved in this stage are formulation, valuation, comparison, and sensitivity analysis. These processes combine standard corporate

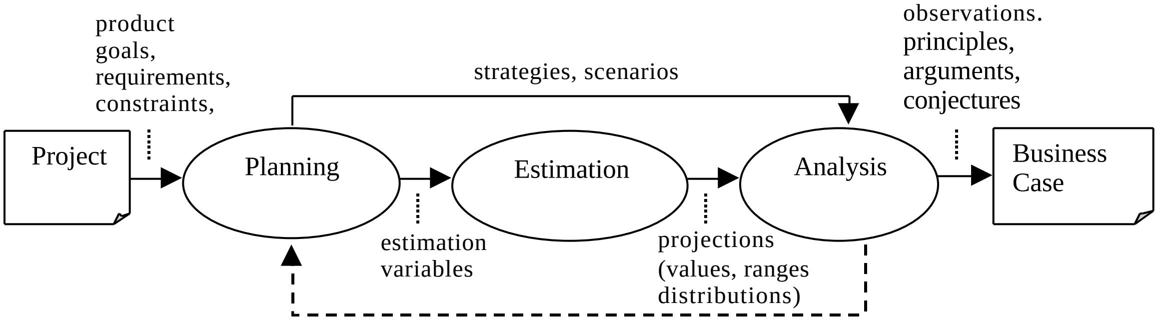


Figure 1. Process of business case development

finance, decision making, and mathematical tools with novel investment analysis techniques. Analysis results may provide further insight into the factors to be considered during estimation, hence the feedback loop.

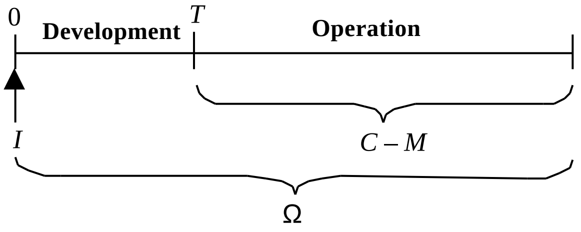
## 4. Net Present Value of a software development project

*Net Present Value* (NPV) is the most widely accepted criterion for project evaluation in corporate finance [17]. A project with a positive NPV increases the wealth of the firm, that is, the total value generated through the project's lifetime is superior to the cost of financing it. NPV is measured in today's dollars. Its computation is based on the principle of *discounting*: all projected future cash flows of the project are *discounted back* to the present time under the assumption that one dollar today is worth $(1 + d)^T$ dollars at time $T$ in the future. The cash flows represent the estimated costs, cost savings, and revenues at various points during the useful lifetime of the project. The positive quantity $d$[1] is referred to as the *discount rate*. It captures the *opportunity cost* of the underlying investment. A higher NPV is always preferable to a lower NPV, and a negative NPV represents an unacceptable investment.

The following equation defines the NPV of a software development project in terms of six high-level determinants:

$NPV = (C - M)/(1 + d)^T - I + \Omega$, where

- $I$ is the (initial) *development cost*,
- $T$ is the (initial) *development time*,
- $C$ is the *asset value*,
- $M$ is the *operation cost*,
- $\Omega$ is the *flexibility (option) premium*, and
- $d$ is the rate at which all future cash flows are to be discounted (the *discount rate*).



This model effectively separates the project into two phases, *development* and *operation*, as shown in the diagram. Athough seemingly simplistic, the model will be sufficient for an initial high-level analysis. We assume that $C - M$ is always positive.

**Product (market) risk** refers to the systematic risk inherent in the project. Since systematic risk is similar for similar types of assets, this kind of risk is not affected by the development strategy used as long as the product goals, the targeted market segment, and the requirements remain the same. Product risk does not cover unique, or private, risk associated with the choice of the development strategy [14]. This second kind of risk is assumed to be already factored into the quantities $I$, $M$, and $\Omega$. Product risk is captured by the parameter $\boldsymbol{d}$, the discount rate used.

**Development time (*T*)**, or *time to market*, is defined as the elapsed time between the commitment to invest in the project and the time of its first major positive cash flow. This period covers activities leading to the deployment of the end product. We assume that COTS-centric development is at least as fast as custom development; hence $T_{\mathrm{COTS}} \leq T_{\mathrm{custom}}$.

**Development cost (*I*)** is the total present value of all negative cash flows from the time the decision to invest is made to the time of the first major positive cash flow (time $T$). In COTS-centric development, the value of the resources committed to implement a system architecture and to evaluate, select, and integrate COTS components dominate this determinant [8]. Development cost and development time are positively correlated [2; ch. 27].

**(Future) asset value (*C*)** is the total value of the positive cash flows that the project is expected to generate during its lifetime, calculated at time $T$. Asset value mainly consists of the revenues from sales, licenses, and royalties, and direct cost savings from using the end product. It should include contributions such as cash grants and the value of resources (software, hardware, human), rights, and licenses acquired at no additional cost as a result of undertaking the project. Additionally, it should take into account *termination value* (value of the previously committed resources that are expected to be recovered at the end of the project). *Direct product costs*, which represent the expenses incurred in proportion to the revenues generated, are deducted from asset value. These may include licensing fees and royalties *paid* per product sold or per license granted, or telecommunications costs incurred per unit of revenue-generating usage. COTS components may incur substantial direct product costs.

**Operation cost (*M*)** is the total value of all negative cash flows of the operation phase, calculated at time $T$. This amount consists mainly of regular maintenance costs and pre-planned future investment outlays. Note that direct product costs (which are deducted from asset value) are not included here. In COTS-centric development, since the maintenance activity focuses on component upgrades and replacements (Vigder and Dean, 1998), operation cost is dominated by the cost of these activities.

**Flexibility (option) premium** ($\Omega$) measures the contribution of the project's inherent strategic flexibility to its base NPV under uncertain conditions. For example, the ability to delay the commitment of certain resources, to change the maintenance schedule, to add and replace

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[1] Expressed here in percentage/100.

software components in order to leverage on third-party innovations, as well as growth opportunities cast as follow-on projects are all forms of flexibility that generate additional value for a project. As the underlying uncertainties resolve, management can re-adjust its position with respect to these opportunities, and will take advantage of them only if and when the conditions are favorable. Flexibility premium is highly dependent on the development strategy chosen. It can often be valued as a portfolio of *real options*. Real options in COTS-centric development include the option to replace components and the option to skip upgrades. We will discuss this variable in more detail later.

## 5. Economic incentive for COTS-centric development

One way to compare the NPV of two development strategies is to study an appropriately defined metric. We measure the economic incentive to choose the COTS-centric strategy (hereby COTS) over the custom strategy by means of such a metric called *NPV Incentive* (*NPVI*). This metric is defined as the NPV premium for choosing the COTS strategy over the custom strategy, per unit of project scale:

$$NPVI = \frac{NPV_{COTS} - NPV_{custom}}{C_{custom} - M_{custom} + I_{custom}}$$

The denominator, a measure of project scale, normalizes the difference between the two NPVs so that comparison among projects of varying scale is possible [11]. When *NPVI* is positive, the COTS strategy is more valuable. When it is negative, the custom strategy is more valuable. The positive quantity $C - M$ (difference between asset value and operation cost) in the NPV formula is referred to as the *Net Asset Value* (*NAV*). Note that since product risk is invariant across all strategies for the same project, the discount rate $d$ is the same for both COTS-centric and custom development.

An analysis of the NPV incentive metric confirms the importance of development time advantage that can be gained by choosing the COTS strategy. It also provides valuable insight into the impact of product risk on a COTS-favorable decision. The first observation we make is that product risk and rapid development work towards the COTS strategy when it has operation cost advantage, and against it when it has asset value advantage over the custom strategy. In the latter case, the benefit of a higher asset value is partially cancelled out by the product risk (as captured by the chosen discount rate.)

An interesting case to note is where the COTS strategy has marginal (at 90%) to significant (at 50%) net asset value (NAV) *disadvantage.* This situation is illustrated in Figure 2. The two graphs demonstrate the impact of product risk and development time on NPVI when the COTS strategy has marginal net asset value disadvantage (left; at 90%) and significant net asset value disadvantage (right; at 50%) over the custom strategy under identical development costs. Each curve of the graphs represents a fixed value of development time advantage of the COTS strategy over the custom strategy. This advantage is measured by the ratio $T_{custom}/T_{COTS}$. Point A represents maximum NPVI for a moderate value of development time advantage. For higher values of product risk, NPVI gradually drops for that value. With significant NAV disadvantage, increasing product risk consistently increases the incentive for the COTS strategy, faster when the COTS strategy's development time advantage is high. With marginal NAV disadvantage, the same observation holds only up to a certain product risk level. This is most noticeable when the COTS strategy has moderate development time advantage. After this critical level, product risk starts working against the COTS strategy, although NPV incentive may remain considerably high.

The impact of rapid development on *NPVI* increases under a reward model for *early market entry.* The simplest

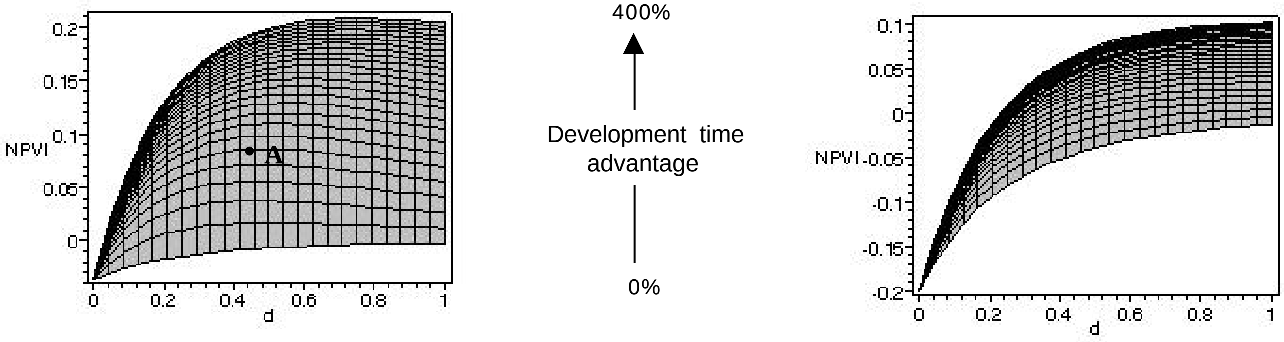

**Figure 2. Impact of product risk and development time on NPVI**

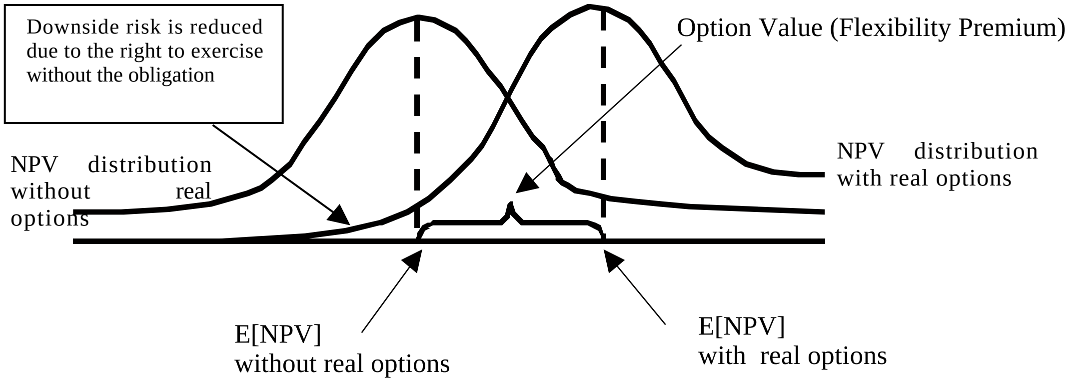

**Figure 3. Effect of real options on the distribution and expectation of NPV**

model assumes an already ripe market for the end product, and maximum reward is achieved through immediate entry. The reward may be expressed as a percentage increase in the remaining asset value, and often declines rapidly as the development time advantage of the COTS strategy over the custom strategy decreases, ultimately vanishing when this advantage reaches its minimum value [11]. Under such a model, increasing the development time advantage of the COTS strategy increases the NPV incentive at a faster rate.

This comparative analysis reveals the economic basis for using the combination of rapid development, high product risk, and early market entry reward to support the business case for COTS-centric development when the net asset value comparison favors the custom strategy. Under such circumstances, underestimating the product risk is safer than overestimating it since it is likely to make the COTS strategy look less attractive than it actually is.

In this analysis we have not considered the close relationship between development time and development cost. The COCOMO cost estimation model [2, 3] has not yet defined a schedule estimation equation that explains the relationship between development time and effort for COTS-centric development; work is under way in the context of the COCOTS initiative. Once this equation is known, it can be used along with the regular COCOMO schedule estimator to account for the dependence of development time on development cost in the comparative valuation model. In general, development cost differential has the expected linear affect on *NPVI*, and therefore its analysis is straightforward. That a strategy with development time advantage is also likely to cost less to develop (or vice versa) magnifies the positive impact of rapid development on a COTS-favorable decision.

## 6. Flexibility premium: a real options approach

Standard NPV analysis falls short in measuring the value of strategic flexibility inherent in a project [9]. The concept of *real option* addresses this shortcoming by combining NPV with techniques originally developed for the pricing of financial options [24, 15]. The real options approach can also be used to value strategic flexibility in software projects under uncertain conditions [20, 19, 14].

The fundamental characteristic of an *option* is that it gives its holder (in the case of a real option, the management) the right, *without* the obligation, to *acquire* or *dispose of* a risky asset at a given *strike* price within a specified time period. If and when the conditions are favorable, the holder exercises the option, making a profit; otherwise the holder foregoes the option, limiting the losses to the *value of the option*. If the option consists of the right to acquire or buy an asset (a *call* option), there is a potential benefit associated with its exercise. If the option consists of the right to dispose of or sell an asset (a *put* option), there is a potential penalty associated with its exercise. A profit is incurred upon the exercise of the option if the benefit (penalty) is greater (less than) the strike price.

The asymmetry associated with *having the right without the obligation* effectively reduces the downside risk for the holder of an option without constraining the upside potential. Consequently options have economic value. This value increases with the uncertainty of the underlying asset (option's incremental benefit or penalty). The uncertainty is usually captured through a volatility parameter that estimates the spread of the option’s incremental benefit or penalty.

Financial options are written on financial assets, such as stocks, bonds, and foreign currencies. Real options are defined on real assets, such as the expected positive cash flows (future revenues, cost savings) or negative cash flows (future costs, expenditures, resource commitments) of a software project. The analogy between financial and real options can be taken advantage of in the valuation of strategic flexibility inherent in software investments. Figure 3 illustrates the impact of real options on the expected NPV of an investment. The difference between the two NPVs represent the flexibility, or option, premium $\Omega$.

The real options thinking is becoming increasingly widespread in corporate finance to evaluate irreversible investments in the face of uncertainty. A variety of techniques exist for valuing real options. Some stick closely to the analogy with financial options [15, 23] based on non-arbitrage arguments. Others follow methods founded on dynamic decision tree analysis and Bayesian principles [19, 21]. The choice of the valuation technique depends on the information available and the assumptions made. However, the discussion of these techniques are beyond the scope of this paper.

## 7. Real options in COTS-centric development

This section provides several examples of strategic flexibility that implicitly exists in COTS-centric development. We discuss each form of flexibility from a real options perspective within the context of a representative, hypothetical scenario. The value of each of these options contribute to the flexibility premium $\Omega$.

The analyses of this section were carried out using mathematical and spreadsheet software. Option valuations were performed through an approximate compositional technique [11] based on the Black-Scholes option pricing model [1]. For lack of space, we do not discuss the specific valuation techniques used here.

### 7.1. Technological leverage: option to replace components

Component-based development offers the ability to take advantage of future third-party innovations and improvements at a fraction of their cost. Part of the flexibility premium of the COTS-centric approach is attributed to this theoretically unlimited potential to leverage on new technological developments through voluntary replacement of COTS components. In a competitive market, the flexibility to replace components also allows falling prices of COTS products to generate future opportunities for reducing direct product costs [6].

It is possible to illustrate this idea through a scenario. A developer is considering a large scale COTS component to implement the database subsystem of a new application. None of the currently available products support an emerging database connectivity standard that is expected to become important in the future. A vendor is working on a new COTS product that supports this standard; unfortunately, the product will be on the market only some time after the application has been deployed. Thus the application initially will have to use one of the components currently available on the market, with the option to replace that component when the new product becomes available. The opportunity to replace will exist only during the first few release cycles of the new application. Replacement will incur an additional cost due to architectural rework and reintegration. In return, the new COTS product promises a potential, but uncertain, increase in the remaining asset value of the project. This increase is attributed to the impact of using the new technology on the future revenues, as well as to the expectation that the new COTS product will be competitively priced. The benefit of the replacement option is risky due to the uncertainty surrounding the market uptake of the new standard and the price of the new COTS product. This risk is captured as the volatility, or spread, of the growth of the option's expected benefit in time, and is estimated using both market and private data. The risk, or volatility, decreases as one approaches to the expiration time of the option.

The application of standard NPV analysis to this scenario requires an unreasonable assumption: that the decision to replace is made at time 0. Accordingly, the NPV is computed as an ordinary expectation, considering replacement as a static alternative, not as a dynamic option whose benefit is subject to uncertainty that can only be resolved through passage of time and that is at least partially influenced by the movement of the market. In reality, the developer is not obliged to make this decision before the uncertainty surrounding the benefits of the new technology and the price of the COTS product has been resolved. For this reason, standard NPV analysis falls short here: the static NPV underestimates the value of flexibility. When the time comes (after the new product becomes available) and if the market conditions are favorable, replacement will proceed. Otherwise, the developer may decide to delay the decision until further information becomes available within the window of opportunity; or forfeit the replacement idea altogether, thereby letting the option expire without exercise.

Thus the flexibility to replace in this scenario is more akin to a *call option*, or the right, without the obligation, to acquire a risky asset at a given strike price on or before some future date. The underlying risky real asset here is the incremental benefit of the replacement and the price to pay to exercise the option before it expires, the strike price, is the expected cost of replacement. With this analogy, the flexibility to replace can more appropriately be valued as a call option using option pricing techniques. The value of this option is added to the base case NPV as an extra premium.

A simple numerical example will help make this scenario more concrete. Suppose the expected NPV of the

COTS project — i.e., the base case NPV ignoring the replacement option — is –35,000. Assume that this amount represents a significant net loss for the company. The new component is expected to be available in the market in 6 months, or two release cycles from now. Let us calculate the option value of replacement three cycles downstream, or at 9 months = .75 years from now. Replacement is estimated to cost 70,000. The expected net payoff of the replacement in today's dollars is calculated as 100,000. We assume that this uncertain amount is subject only to market risk. The ongoing short-term risk-free interest rate is 5% per annum, compounded continuously.

First suppose that replacement will take place unconditionally. If the replacement cost is fairly certain, its present value is calculated by discounting it at the continuously compounded risk-free rate of 0.05. The NPV can then be adjusted to:

$$\begin{aligned} NPV' &= -35{,}000 + (100{,}000 - 70{,}000 \times e^{-(0.05)(.75)}) \\ &\approx -2{,}400 \end{aligned}$$

This adjusted NPV still does not make the project look very attractive.

Now let us take into account the market risk of the payoff from replacement. Suppose it is estimated that the payoff will grow at a rate subject to a standard deviation of 40% per annum. Company analysts may have arrived at

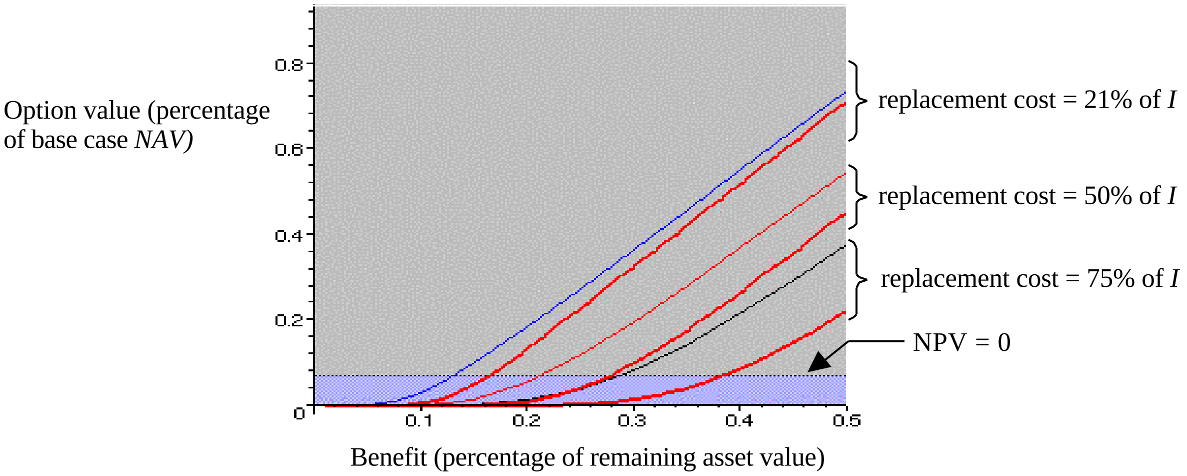

**Figure 4. Option to replace for a multi-period project**

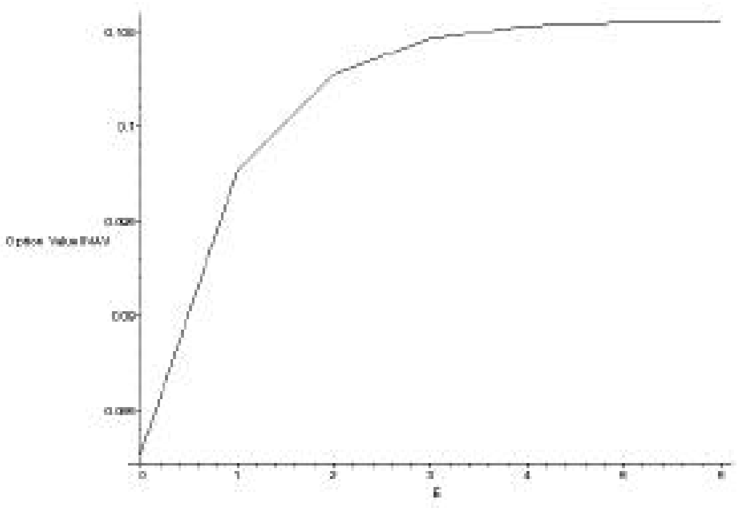

**Figure 5. Effect of multiple exercise points of replacement option on the option value**

this figure using historical stock prices of small- and medium-size publicly traded companies whose main line of business is to develop products comparable to the new component. This figure gives the volatility of the benefit, or the underlying asset, of the option.

The Black-Scholes formula [1] gives the value of a call option as:

$$\Omega_{call}(U, S, T, r, \sigma) = U \; N(d) - S \; e^{-rT} \; N(d - \sigma\sqrt{T}),$$

$$\text{where} \quad d = \frac{\ln\left(U \big/ S \; e^{-rT}\right)}{\sigma\sqrt{T}} + \frac{1}{2}\sigma\sqrt{T},$$

- $U$ is the present value of the underlying asset,
- $S$ is the strike price,
- $r$ is the risk-free interest rate,
- $T$ is number of periods to expiration,
- $\sigma$ is the per-period volatility of the underlying asset, and
- $N(.)$ is the cumulative standardized normal distribution function.

This formula is derived assuming that the payoffs of the option can be replicated, without giving rise to any opportunities for sure profit, through a continuously updated portfolio of two assets: a twin security that behaves just like the underlying asset and a risk-free security such as a short-term bond. Plugging in the appropriate values, we obtain an option value of

$$\Omega_{call}(100\text{K}, 70\text{K}, 0.75, 0.05, 0.4) \approx 34{,}400$$

for the replacement scenario.

The expanded NPV with the option value becomes:

$$NPV' = -35{,}000 + 34{,}400 = -600$$

This NPV is higher than the previous adjusted NPV of –2,500, but still not positive. With luck, the project may just break even!

Now let's assume the volatility of the payoff is 70% per annum, representing a highly risky return, instead of the original 40%. This new volatility yields an option value of 42,300, with the expanded NPV equal to:

$$NPV' = -35{,}000 + 42{,}300 = 7{,}300$$

The NPV is now positive and the COTS project looks much more attractive although the present value of the expected payoff remained the same at 100,000. The reason that an increase in the risk of the underlying asset increases the option value again stems from an option's asymmetric nature: the downside potential of risk can always be avoided by refusing to exercise the option, while the upside potential of risk remains unrestricted.

The value of the replacement option increases as the underlying flexibility increases. Thus the option to replace only at a specific point in the future is less valuable than the option to replace at multiple points. Figure 4 illustrates the impact of the replacement cost (strike price of the underlying option) and multiple exercise times on the value of the option to replace. The plots are derived from a hypothetical 7-period project. For each replacement cost, the bottom curve represents the value of the option in which exercise is possible at a single point at time 2 (the less flexible scenario). The top curve represents the value of the option where exercise is possible any time between period 2 and 7 (the more flexible scenario). The difference between the two option values decreases as the cost of replacement (strike price of the replacement option) decreases. Figure 5 shows the effect of the width of the exercise window (E) on the *relative* option value for a similarly structured project. The relative option value is given by the option premium per unit of base case net asset value (NAV). As the window width increases, the relative option value increases, rapidly converging to an upper bound. In this example 1 period = 1 year and the useful foreseeable lifetime of the project is 10 years.

### 7.2. Maintenance schedule flexibility: option to skip or delay upgrades

Upgrade, or refresh, refers to the activity of replacing one or more COTS components by their new releases. We distinguish upgrade from component replacement in the following sense: upgrade is a periodic activity and incurs a relatively smaller cost, whereas replacement is a sporadic activity and incurs a relatively larger cost. Maintenance in a COTS-centric system focuses on upgrades, where cost uncertainty is a major problem [25]:

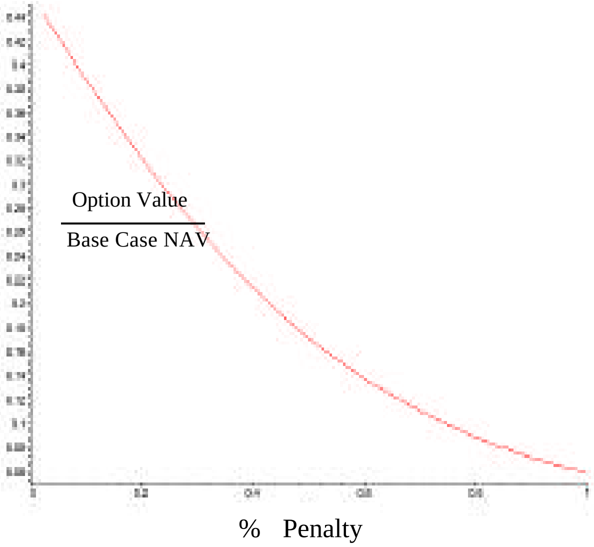

**Figure 6. Value of option to skip upgrades**

upgrade costs may vary significantly from one release to another.

From a value perspective, the situation is not as bad as it seems at first. While upgrade uncertainty increases the total risk, paradoxically, it may also increase the value of a project if it can be factored in properly. The reason, again, is inherent flexibility. Although upgrades are driven by COTS product vendors, the developer still has some control over the maintenance schedule. Since maintenance is not likely to revolve around critical bug fixes and essential functional improvements in a COTS-centric system, the developer may always choose to delay or skip an upgrade cycle if the associated cost is likely to be higher than the expected benefit of the upgrade. Of course, this decision must have a penalty. This penalty, which may itself be uncertain, can be expressed in terms of a temporary or permanent drop in the remaining asset value (due to a reduction in the future positive cash flows or cost savings).

It is possible to envision several scenarios. One way of modeling upgrade uncertainty is through conditional probabilities of minor and major upgrades. This binomial model assumes that the likelihood of a future upgrade being major (high cost) or minor (low cost) is conditional on the status of the upgrades in previous periods. For example, following a minor upgrade period, the likelihood of a major upgrade in the next period would be relatively high, while following a major upgrade period, the likelihood of another major upgrade in the next period would be relatively low. Given these probabilities, the expected cost of an upgrade can be determined for any period of the project. The developer will choose to delay an upgrade for a given period if the penalty for the delay is likely to be less than the expected cost of the upgrade for that period. If the penalty rises for each consecutive no-upgrade period due to increasing product obsolescence, it would not be economical for the developer to delay upgrades indefinitely. Otherwise, the penalty would eventually exceed the cost savings to be achieved by delaying the upgrade activity. The other alternative is to impose a fixed upper limit on the number of no-upgrade periods, thus assuring that exercising the delay option repeatedly will eventually kill the option temporarily. Following an upgrade period, the option to delay is effectively reinstated.

The flexibility to skip an upgrade (or delay it by one period) at a given time is thus akin to a *put* option. A put option gives its holder the right, without the obligation, to sell a risky asset at a given price at some future date. Using this analogy, an upgrade scenario can be formulated and valued as a series of such options on the amount of the penalty to be incurred by skipping or delaying an upgrade cycle. The strike price of each *suboption* in the series is given by the expected cost of upgrade for the associated period. The fact that both the penalty and the strike price may be uncertain can be accounted for during the valuation of these options. Figure 6 illustrates how the option value of such a scenario changes as a function of the delay penalty for a hypothetical COTS-based development project with a finite time horizon. Option value here again is relative, measured as a percentage of the base case NAV. The value of the option decreases as the exercise penalty (x) increases. The exercise penalty is measured as percent reduction in the remaining asset value of the project. The upgrade scenario differentiates between major and minor upgrades by attaching fixed probabilities to their occurrence, conditional on the type of the previous upgrade cycle. In this example, upgrades cannot be delayed beyond two consecutive cycles.

## 7.3. Value of potential reuse: option to abandon

When a project unwinds, sometimes a portion of the previously committed resources may be reclaimed. The total value of the salvaged resources, called *termination value*, contributes positively to the NPV. It is also conceivable for salvage to occur before the pre-planned lifetime of a project should conditions turn sour enough.

In a COTS-centric system, the flexibility to abandon a project midstream may generate a premium if the acquired COTS products can be reused later for another project. In this case, the underlying option is a put option, with the strike price, or the value of the asset to be disposed of, being the depreciated and properly discounted value of the COTS components that can be salvaged for future reuse. The penalty of exercise equals the remaining asset value of the project at the time the option is exercised. The option value increases as the uncertainty of the penalty increases. As usual, the option is exercised only if the benefit of abandonment exceeds the associated penalty.

## 7.4. Taking advantage of the best of the two worlds: migration option

COTS-centric systems make it difficult to control the functionality and quality of the end product. The extra cost of adding missing functionality and removing unwanted functionality of a COTS component may be prohibitive. Additionally, the reliability, performance, and usability of the end system is only as satisfactory as the COTS components that are used to implement it. If the COTS components do not interface well with each other or fail to meet the requirements, product acceptance may suffer significantly, ultimately reducing its asset value due to a drop in future positive cash flows.

An alternative is to use a COTS-centric system initially as a prototype, both to get more information about the system (Chalasani et al., 1997) and to achieve early market presence through rapid development. The resulting system can then be migrated into a custom system by gradually replacing the unsatisfactory COTS components by their proprietary counterparts. The component-based organization of such a system is inherently conducive for the migration to take place in multiple phases. This strategy permits reclaiming the *quality and functionality disadvantage* [11] of the COTS components while sustaining an acceptable level of market presence. In addition, highly unpredictable upgrade costs can incrementally be replaced by more predictable traditional maintenance costs.

The migration strategy need not be a time-zero decision. Migration proceeds only as long as the market remains receptive to the product, revenues are likely to increase by using further proprietary components, and the cost of migration (development of the proprietary components) remains inferior to its expected benefit. The decision to execute, delay, or forego the next migration phase is taken one step at a time. Thus executing a migration phase creates a further opportunity to execute a subsequent phase. This scenario can be formulated and valued as a portfolio of *nested* call options, where each option in the portfolio is similar to a single-point replacement option.

The value of the phased migration option can be significant since it promises to combine the most advantageous aspect of COTS-centric development, early market entry, with the future opportunity to eliminate its disadvantages. The option value may increase or decrease as the number of phases increases, depending on the product risk and the distribution of the total cost and incremental benefit of the migration among the individual phases. As the quality/functionality disadvantage (QFD) of COTS-centric development over custom development increases, the value of the migration option increases relative to the value of the pure COTS-centric development. Figure 7 illustrates how the expanded NPV (NPV + migration option value) varies with the extent of this disadvantage when both the cost and the incremental benefit of the migration is distributed equally among the individual migration phases. For this particular case, the single-phase migration (k = 1) turns out to be the most valuable strategy. The QFD metric (expressed in the figure in percent/100) is a measure of the negative contribution of the quality/functionality disadvantage of the pure COTS strategy to the ratio between the pure COTS strategy's and the pure custom strategy's net asset value [11]. NPV[COTS] and NPV[cust] are the NPV of the pure COTS-based and pure custom development strategy, respectively. Note that about QFD = 110%, the value of the migration strategy where migration takes place at a single phase (k = 1) becomes superior to all the other strategies. At about QFD = 80%, the value of the migration option for k = 1 starts increasing faster than the rate of decrease of the base case NPV, NPV[COTS].

Unlike that of Section 5, this analysis factors in the relationship between development time and development effort/cost as specified by the COCOMO 2 schedule estimator equation [3], with the value of project scale factors sum *B* set to 1.11 for the pure custom strategy and .96 for the pure COTS strategy. Note that these figures are somewhat arbitrary. They are not necessarily realistic estimates, as a more appropriate schedule estimator equation and its parameters are yet to be discovered for COTS-centric development.

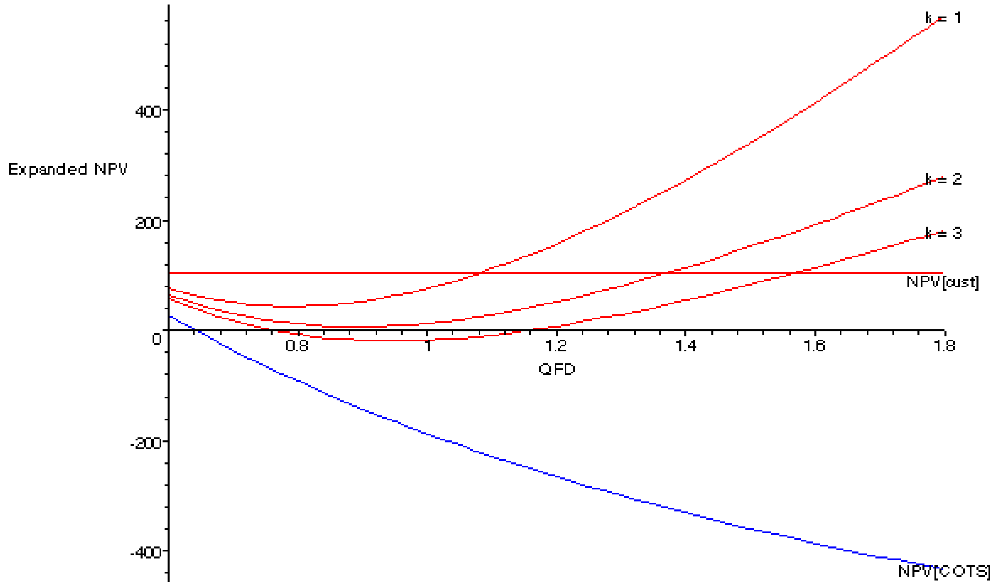

**Figure 7. Expanded NPV of the migration scenario as a function of the QFD metric**

### 7.5. Development versus operation costs: the impact of architecture on flexibility premium

Carney [5] points out that use of COTS products does not absolve the developers from engineering systems well. “Design for maintainability” is an equally valid principle for COTS-centric systems as it is for custom systems. Investing in a well thought, flexible system architecture positioned to accept a variety of COTS components in effect will reduce upgrade and replacement costs at an additional up-front development expense [6]. Most option pricing techniques value an option approximately linearly in relation to its strike price. This implies that the value of the replacement, delay-upgrade, and migration options are likely to increase simultaneously with the level of up-front investment on architecture, provided that the impact of this additional investment does not impact development time too severely. Consequently, a flexible system architecture may have a substantial cascade effect on the flexibility premium, and ultimately on the expanded project NPV.

## 8. The bottom line

As any other investment decision, the business case for the large-scale use of COTS components in a software development project must be supported by sound economic arguments. An approach firmly grounded in quantitative techniques and well recognized principles helps achieve this goal. Here are some guidelines to consider in assessing the value of a COTS-centric development project:

*The most objective way to assess the economic feasibility of a project is through Net Present Value.* Prefer this method over other investment analysis measures such as return on investment, internal rate of return, or profitability index [13, 26].

*Conduct comparative evaluation.* [7]. Study how COTS-centric development fairs relative to custom development in the context of the given project. Comparative analysis can be used to evaluate the economic incentive to choose one strategy over the other based on NPV.

*Identify several scenarios that represent the possible states of the future* [18]. Customize each scenario for both development strategies. Focus on scenarios that appear both technologically and logistically feasible.

*Do not neglect the flexibility premium.* To determine the flexibility premium, identify those scenarios that involve an embedded strategic flexibility. Also identify the underlying uncertainties that give rise to such flexibility. These scenarios should be formulated as a portfolio of real options on a base case and valued using option pricing techniques. The real options approach is highly preferred over static NPV analysis. NPV alone ignores the incremental value of flexibility, and thus may make a project look less attractive than it actually is.

*Focus estimation on variables that can be predicted relatively reliably.* In particular, experience with cost estimation for COTS-centric development is currently very limited, and COCOMO 2 [3] still does not yet address this mode of software development very well — a specialized suite called COCOTS is under development for this purpose. For those variables that cannot be estimated with reasonable confidence due to lack of information, rely on expert insight, and provide liberal ranges. These variables can later be subjected to sensitivity analysis.

*Consider market variables and business context during estimation and analysis*. For example, the chosen discount rate must reflect the systematic risk inherent in the end product. In choosing the discount rate, consider the historical returns of other similar products rather than relying on a constant weighted average cost of capital, or the standard hurdle rate of the company. In estimating the cash flow or cost uncertainty associated with the benefit or penalty of an option, consider examining the historical volatility of the returns of traded securities that invest in similar projects, as well as private data from past projects. You must account for a relatively higher degree of cash flow volatility in COTS-centric development than in custom development due to the higher private risk involved. Avoid using an unjustifiably high estimate for the discount rate (or product risk) as a surrogate for dealing with uncertainty [7; 14].

*Consider the potential impact of early market entry*. If possible, develop a reward model, and identify the parameters to be estimated to support the model. Such a model will allow you to factor in competitive advantage to your valuation. An example is provided in a related paper [11].

*Keep in mind the importance of rapid development, product risk, and reward for early market entry during analysis*. Look at the impact of underestimating or overestimating these variables. For example, the initial results may favor the custom development strategy due to its moderate net asset value advantage. If any of these variables were underestimated, a slight upward adjustment of their values may easily turn the tide in favor of the COTS-centric strategy. Conversely, if the COTS-centric strategy looks favorable due to a moderate net asset value and development time advantage, an upward adjustment of product risk may cancel out a substantial portion of its incremental value. This latter situation requires particular attention.

Finally, *focus on sensitivity and what-if analyses rather than single-value data*. Think of economic valuation as an intellectual tool. Emphasize the qualitative aspect as much as the quantitative aspect. The main goal of the assessment exercise is to discover the winning conditions that make COTS-centric development a viable alternative to custom development, rather than to produce a binary answer based on precise figures. As Clemons [7] points out, concentrating on hard values is likely to hinder rather than support decision making.

## Supplementary Documents

Supplementary documents in various formats detailing the models used, examples discussed, and the analyses performed are available at:

http://wwwsel.iit.nrc.ca/~erdogmus

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