MANAGEMENT OF LICENSE COST UNCERTAINTY IN SOFTWARE DEVELOPMENT: A REAL OPTIONS APPROACH

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ABSTRACT—Software development based on Commercial Off-the-Shelf products is subject to multiple sources of uncertainty. One potential source of uncertainty is the license costs of the COTS product used in the system. The management of such uncertainty requires strategies that effectively mitigate the underlying risk with minimal impact on the economic value generated. This paper presents such a strategy, and shows how it can be evaluated using a state-of-the-art financial valuation technique, namely, *real options analysis*.

1. INTRODUCTION

Software development based on *Commercial Off-The-Shelf*, or COTS, products is making inroads in the software engineering community. Advocates claim that COTS-based system development offers faster, better, and cheaper solutions, and thus is a viable alternative to the traditional way of developing software mostly through writing custom code. Skeptics, on the other hand, see it as the latest bandwagon. Others take a more neutral and cautious position: While the COTS paradigm may be a viable alternative, and even sometimes the only feasible alternative, it is neither suitable in all situations nor free of pitfalls [8, 11]. Unfortunately, the optimistic claims of the advocates lack compelling empirical evidence, and experience with large-scale use of COTS products in industrial size projects is still limited.

COTS-based software development is risky. It is subject to multiple sources of uncertainty. While some of this uncertainty is private, some is external. External uncertainty largely results from vendor behavior. One driver of this kind of uncertainty is license costs. The developer often cannot bundle a third-party product as a subsystem without compensating the product's vendor: license fees have to be paid. Thus COTS-based systems may incur substantial license costs. When both the license fees and the target market are uncertain, total license costs may exhibit a great deal of variation. Consequently, the management of the resulting risk can be a major issue.

This paper will address the management of license cost risk in COTS-based software development. The specific question under investigation is this:

Consider a system under development that will use a third-party COTS product in a future release. What is the fair price the developer should pay to the COTS product's vendor for the right to include with the future release an as yet unknown number of licenses of the COTS product at a preset single-license fee? What is the net value of the developer's decision to use the COTS product?

This problem has two sources of uncertainty: the COTS product license fee and the target market of the future release. One approach is to attack the problem with an economically sound, data-centered approach, combining the available data about the past pricing behavior of the vendor with the available data about the past behavior of the target market. As will be explained in Section 2, the target market's behavior is tracked by a custom-made stock portfolio of publicly traded companies that operate in that market. The two data sources are synthesized into an asset that represents the underlying risky variable, the *total license cost*. Then a suitable stochastic model is fitted to capture the movement of this synthetic asset.

The value of the resulting risk mitigation strategy is then determined through real options analysis [18]—a financial valuation technique devised to tackle investment decisions with one or more sources of uncertainty. Basically, to manage the license cost risk, the developer engages with the vendor in an option-like contract that fixes the single license fee. At the time of market entry, the developer incurs this fixed amount for each license of its own product sold. In return, the developer advances the vendor a premium, which represents the fair market value of the risk differential. Because this strategy resembles a financial option, the techniques that have been developed for the pricing of derivative securities are applicable. The utility of real options analysis is a natural consequence of this analogy. This type of economic analysis is likewise useful in a variety of other software development investment decisions [13, 15, 16, 21, 22]

The approach is illustrated by means of an example.

2. THE CASE OF EASYORDER

Consider the situation faced by a fictitious start-up company.

SofMore is a developer of electronic order processing software. It is working on the next major release of its flagship product EasyOrder, a web-based order processing application for small businesses. The release will include improved security features, based on a secure transaction processing COTS product, called WebKeys, from a third-party vendor. For seamless operation, SofMore will need to integrate WebKeys into the new release of EasyOrder. It estimates the present market value of the integrated release at $250K, based on the company's pricing policy and a post-development sales projection of 1500 licenses. The integrated release is expected to be ready in one year.

SofMore's decision to incorporate WebKeys into the next release of EasyOrder subjects the company to additional risk. According to available historical data, the WebKeys license fee exhibits an upward trend and significant volatility, as shown in Fig. 1. This could possibly lead to significant license costs for SofMore when its product is introduced a year from now. Therefore, SofMore would like to protect itself against possible fluctuations in license costs.

In addition the license cost risk, SofMore is also subject to market risk. Company analysts track the market risk of the integrated release through the performance of a customized, dynamic stock portfolio of public companies that include SofMore itself, its competitors, the developer of WebKeys, and other security software developers. The major assumption here is that the market capitalizations of the companies in the portfolio are positively correlated, to various degrees, with the market value of EasyOrder's integrated release. The soundness of this approach is due to a widely accepted financial model, the *Capital Asset Pricing Model*. At the heart of CAPM is the diversification principle. In a sufficiently diversified portfolio, risk that is unique to individual assets

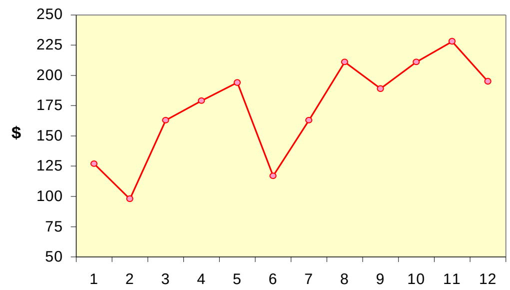

Fig. 1. Historical license fees for WebKeys.

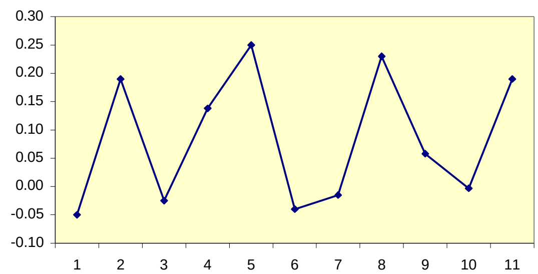

Fig. 2. Historical uncertainty of EasyOrder's target market as captured by the continuous returns of a stock portfolio.

(private risk) will be negligible. The fluctuations caused by the unique circumstances will appear to be random, and therefore, they will tend to cancel each other out. What is left is the risk that is unavoidable, or the risk that systematically applies to all the assets in the portfolio. Note that the absolute size of the tracking portfolio is not of interest since the pertinent information is embedded in its growth rate and the variation around this growth rate. A more detailed discussion of CAPM is unfortunately beyond the scope of this paper, however, an overview can be found in any introductory corporate finance text [20].

According to its performance over the last three years, the tracking portfolio exhibits an annual average (continuously compounded) growth rate of 34% (or 8.5% per quarter) and a standard deviation of 24% (or 12% per quarter) around this growth rate. Fig. 2 illustrates the fluctuations in the growth rate of this portfolio in quarterly increments.

To mitigate the license cost risk, SofMore would like to negotiate a contract with the vendor of WebKeys. The contract will give SofMore the right to bundle WebKeys with the future release of EasyOrder at a preset single-license fee. SofMore wants to determine the fair value of this contract. In other words, what is the fair amount it should pay now to the vendor of WebKeys to obtain this right? Given the value of this contract and the company's market projections, is this strategy economically feasible?

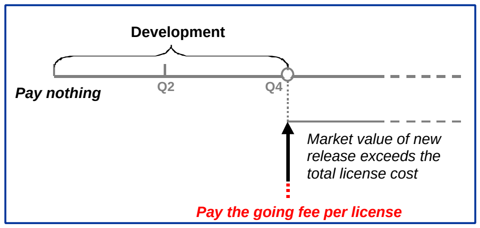

Fig. 3. Strategy A.

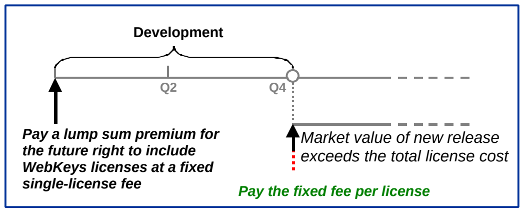

Fig. 4. Strategy B.

3. ALTERNATIVE STRATEGIES

Real options analysis can determine both the value of SofMore's decision to incorporate WebKeys as a COTS component to its own product and the value of the contract that would give it the right to fix the future license fee of WebKeys. As a first step, it is worthwhile to identify SofMore's alternative strategies more explicitly. The next section will frame each strategy as a real option.

SofMore has two alternative strategies:

Strategy A, the passive strategy, is straightforward (Fig. 3). SofMore does nothing now to alleviate the license cost risk. At the end of year one (Q4), when the EasyOrder's integrated release is ready, it makes a decision. If at that time, the expected market value of the integrated release exceeds the expected total license cost, it accepts to pay the going license fee to the vendor of WebKeys for each license of its own product sold, and releases EasyOrder bundled with WebKeys. Otherwise, it witholds the integrated release, and continues to sell EasyOrder without the improved security features. In the latter case, SofMore's extra development cost will be sunk.

Strategy B, the active strategy, takes advantage of the contract to reduce the risk of license costs exceeding the market value, and thereby, increasing the chances that EasyOrder will be released with the improved security features (Fig. 4). SofMore negotiates a set price for future licenses of WebKeys. The vendor requires a premium to allow this price, and SofMore pays this amount up-front. At the end of year one, SofMore will face the same decision as in strategy A, but this time, its total license cost will be limited by the fixed price it has negotiated with the vendor.

In both cases, SofMore has the *option* to exchange the total license cost of WebKeys for the market value of EasyOrder's upcoming release. SofMore will exercise its options only if it is profitable to do so. The value of these options determines the respective values of the two strategies relative to each other.

3. BACKGROUND: REAL OPTIONS ANALYSIS

Real options analysis [2, 12, 18] is used in the valuation of strategic investments and flexible business transactions. Its suitability depends on the presence of two properties: *one or more sources of uncertainty* and *irreversible future decisions* that depend on the uncertain outcomes. The technique is particularly appropriate in cases where classical financial valuation techniques, such as Discounted Cash Flow and static Net Present Value [20], fail to deal with the dynamic aspects of decision making under uncertainty [12].

Real options analysis techniques are increasingly applied in such sectors as natural resources (exploration and development), pharmaceutical (drug development), real estate (leasing decisions) manufacturing systems (convertible plants), aerospace (aircraft development and acquisition), and information technology (R&D, technology valuation). For examples, see Trigeorgis [23] and Amram and Kulatalika [1]. Applications to IT investments in general, and software development decisions in particular, are more recent, but are quickly gaining popularity [5, 7, 9, 14-16, 21, 22]. Here are a few example contexts:

- Flexibility projects: designing a system to easily accept COTS components [14];
- Learning projects: development of a software prototype to resolve technical or market uncertainty [21];
- Infrastructure projects: development of an application framework for a future product line [15, 16]; and
- Risk management [9]: simultaneous support of competing software standards in a product.

Central to the real options approach is the concept of an *option*. In general terms, an option refers to a projected discretionary action whose execution is contingent on the realization of certain future conditions. More specifically, an option is the opportunity, *without the obligation*, to exchange two possibly uncertain assets on or before a future date. Both of these definitions stress three fundamental characteristics: the presence of uncertainty, the presence of a future opportunity, and the discretionary nature of the action associated with the future opportunity.

The last characteristic is of paramount importance, and as such, deserves further elaboration. Since an option represents a discretionary action ("an opportunity without the obligation"), it should be exercised only when the net payoff of exercise is positive. This behavior, called rational exercise, has a central implication: the value of an option is always positive since a loss can be avoided by refusing to exercise the option. In addition, while losses can be avoided, no such limitation is placed on the gains. When the underlying uncertainty is high, the potential for gains is also proportionately high. Therefore the value of an option in general increases with the level of uncertainty. This intuition is one of the cornerstones of option valuation.

Financial options refer to options contracts written on financial assets, such as stocks, commodities, or exchange rates. A stock option is the best known form of a financial option. Real options refer to options that are implicit in a capital budgeting project or in an investment decision, or that are deliberately designed into a business transaction. They are defined on real assets, typically on a stream of uncertain future cash flows. They focus on the ability of management to respond to changing conditions. Real options analysis is concerned with the identification of such options, their framing as option pricing problems, their valuation, and the interpretation of the results [1].

The theory of option valuation, both financial and real, has its roots in the Nobel prize winning work of three financial economists—Black, Scholes, and Merton—on the pricing of derivative securities and corporate liabilities [6]. In their seminal work, Black and Scholes derive an analytic solution for the value of a call option. Their solution is based on no-arbitrage arguments and a certain stochastic model of the underlying risky asset value.

<u>Black-Scholes Call Option</u>

A call option is the right to acquire a risky asset (called the *underlying asset*) for a preset price (called the *exercise price*) on or before a future date (called the *maturity date*). A call option is exercised only when the payoff is positive, that is when the strike price is inferior to the value of the underlying asset at maturity. Let V represent the value of the underlying asset. V is assumed to follow a lognormal diffusion process, specified by the stochastic differential equation:

$$\frac{dV}{V} = \alpha_V dt + \sigma_V dZ_V ,$$

where α_V is the expected continuous growth rate of V, σ_V^2 is the variance of this growth rate, and dZ_V is the increment of the standard Wiener process. Roughly, this equation states that percentage changes in the asset's value over small intervals exhibit random fluctuations around a mean. Based on this model, Black and Scholes arrive at an analytic solution for the value of the call option by constructing a continuously updated portfolio that consists of a long position in the underlying asset, levered by a short position in a riskless asset (such as a short-term government bond). The portfolio is constructed and updated such that it replicates exactly the payoffs of the option at all possible states of the future. The value of the call option must then equal the value of this portfolio to avoid any arbitrage opportunities. If S is the agreed upon strike price, τ is the maturity date of the option, r is the short-term risk-free interest rate, $D_0 = S\exp(-r \cdot \tau)$ is the present value of S, V_0 is the present value of the underlying asset, and $\sigma = \sigma_v$, then the (present) value of the call option is given by the formula:

$$C(V_0, D_0, \tau, \sigma) = V_0 N(d_1(P, \tau, \sigma)) - D_0 N(d_2(P, \tau, \sigma)),\ \text{where}$$

$$P = \frac{V_0}{D_0},\ d_1(x, \tau, \sigma) = \frac{\ln x + \frac{1}{2}\sigma^2 \tau}{\sigma\sqrt{\tau}},\ d_2(x, \tau, \sigma) = d_1(x, \tau, \sigma) - \sigma\sqrt{\tau},$$

and N denotes the cumulative standardized normal distribution function. Most remarkable here is that the solution does not depend on α_V, the expected growth rate of the underlying asset. The derivation elegantly eliminates this variable, thanks to the replication and the no-arbitrage assumptions. For a simplified, alternative derivation of the Black-Scholes model, see Cox et al. [10]

The parameter σ is often referred to as the *volatility* of the underlying asset. It is a quantitative expression of the uncertainty to which the underlying asset is subject. The value of a call option increases when the value of this parameter increases.

<u>Margrabe's Exchange Option</u>

The Black-Scholes call option model has a single source of uncertainty. The exercise price of a call option is constant, and thus certain. When the exercise price is uncertain, the call option takes the more general form of an exchange option—an option to switch two (possibly uncertain) assets. The asset to acquire upon exercising the option is called the *optioned asset*. The asset to be given up to acquire the optioned asset is called the *delivery asset*. Hence a call option is simply an exchange option with a riskless delivery asset.

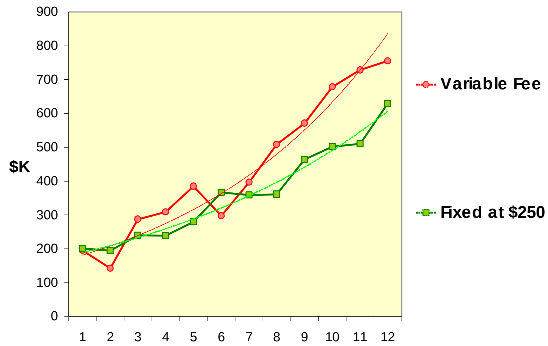

Fig. 5. Total cost of WebKeys licenses for the the integrated release of EasyOrder based on synthetic data.

Margrabe [19] generalized the Black-Scholes call option model to value an exchange option, where the delivery asset D is similarly assumed to follow a lognormal diffusion process with a instantaneous growth rate variance of σ_D^2:

$$\frac{dD}{D} = \alpha_D dt + \sigma_D dZ_D .$$

Margrabe's model must, however, account for a possible correlation between the two underlying assets. If D_0 is the present value of the delivery asset, ρ is the correlation coefficient between the growth rates of the optioned asset V and the delivery asset D, then the present value of the option to exchange D for V is given by $E(V_0, D_0, \tau, \sigma) = C(V_0, D_0, \tau, \sigma)$ with $\sigma = \sqrt{\sigma_V^2 + \sigma_D^2 - 2\rho\sigma_V\sigma_D}$ now denoting the effective combined volatility of the two assets.

Table 1 illustrates the sensitivity of an exchange option with respect to its four parameters. Note that the value of an exchange option increases with the combined volatility. Thus when the two assets are positively correlated, an increase in the volatility of just one of the assets may actually decrease the option value [17].

	V_0	D_0	τ	σ
$E(V_0, D_0, \tau, \sigma)$	$\uparrow$	$\downarrow$	$\uparrow$	$\uparrow$

Table 1. The effect of an increase in each parameter on the value of an exchange option.

4. FRAMING

Softmore's decision to integrate EasyOrder with WebKeys is akin to an exchange option to acquire the market value of the integrated product. To exercise the option, SofMore must incur, or *deliver*, the associated license costs. The value of this option gives the value of strategy A when the cost of a single license of WebKeys is uncertain, and thus variable. It gives the gross value of strategy B when the single-license fee is fixed by a contract. However, this gross value does not account for the value of the contract itself.

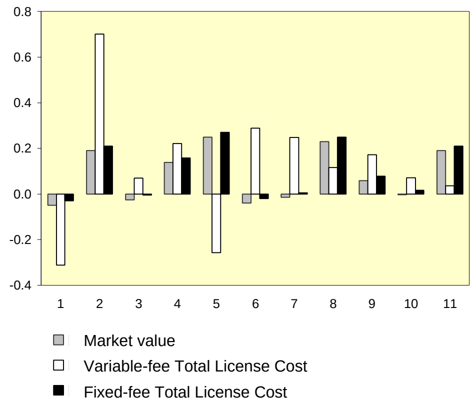

Fig. 6. Quarterly continuous growth rates of the underlying assets.

The contract that fixes the license fee is also akin to an option, but in a more limited sense. It allows SofMore to substitute the variable license fee with a fixed fee. Given the upward trend and the volatility of WebKeys' license fees, such a contract could lead to cost savings. As such, SofMore can mitigate part of the underlying risk. To obtain the net value of strategy B, the value of the contract must be deducted from the gross value of strategy B.

The three options underlying A and B together involve two sources of uncertainty and three correlated assets. They are the market value of EasyOrder's integrated release and the total license cost to be incurred under the two scenarios. The *Total License Cost* (TLC) is given by the product of the number of EasyOrder licenses sold and the single-license fee of WebKeys:

$$TLC = (\text{Number of EasyOrder Licenses Sold}) \times (\text{Single License Fee of WebKeys})$$

Assume that the number of licenses sold is a constant fraction of the market value, based on a fixed pricing policy for EasyOrder. Then TLC can be though of as a synthetic asset that is partially correlated with the market value.

For the variable-fee scenario, the historical behavior of this synthetic asset can be constructed by combining the available data on WebKeys' past license fees (Fig. 1) with the historical returns (growth rates) of the portfolio that tracks the market value (Fig. 2). The quarterly returns of the portfolio are first cumulatively applied to the matching license fees. This process yields a time series that emulates the hypothetical past movement of the synthetic asset. Then the continuous growth rates of this series are obtained through a log transformation, followed by first-order differencing. The standard deviation of the resulting series gives an estimate of the quarterly volatility of the synthetic asset. The single-period volatility can be converted to a multi-period volatility by multiplying it with the square root of the required number of periods.[1]

For the fixed-fee scenario, the historical returns of the market portfolio are first upward adjusted by a constant risk-free rate. The resulting time series represents the historical continuous growth rates of the underlying synthetic asset. The volatility estimate is obtained exactly as in the variable-fee

[1] If the asset follows a lognormal diffusion process, the variance of its continuous returns over multiple periods equals the number of periods times the variance of the asset's returns for a single period.

case. The constant upward adjustment accounts for a steady, predictable increase in the license fees over time.

Fig. 5 illustrates total license costs under the two scenarios, based on a sales estimate of 1000 licenses and a fixed license fee of $250. The standard deviation of the continuous growth rate for the variable-free case is 27% quarterly, or 54% annually. The standard deviation of the continuous growth rate for the fixed-fee case is 12% quarterly, or 24% annually. Note that these estimates of standard deviation are independent of the arbitrarily chosen initial conditions of 1000 licenses and $250.

Under the given assumptions, the fixed-fee TLC rates are perfectly correlated with the market value returns (implying a correlation coefficient of 1). However, the market value returns and the variable-fee TLC rates have only a slightly positive correlation coefficient of 0.09. Fig. 6. shows the quarterly growth rates for each of the three assets in relation to one another.

5. VALUATION

Having identified all the required assets, their volatility estimates, and the correlations between them, option pricing techniques can now be applied to value each strategy. Recall that the estimated present market value of the integrated release is $250K based on a sales projection of 1500 licenses.

Strategy A

The value of strategy A is given by the value of the option to exchange the variable-fee TLC for the market value of EasyOrder's integrated release. Here the delivery asset is the variable-fee TLC and the optioned asset is the market value. The present value of the delivery asset is estimated by multiplying the current license fee of WebKeys (the last observation of the historical data in Fig. 1) with the present value of the end-of-development sales projection of 1500 licenses. To calculate the present value of the sales projection, discount the projected figure using the mean growth rate of the market portfolio as a discount rate. At a continuously compounded quarterly discount rate of 8.5%, this yields, over a year, a present value of $1500 \times \exp(-0.085 \times 4) \approx 1000$ licenses. The present value of the variable-fee TLC then equals (1000 licenses)$\times$($195/license) = $195K. The volatility of the delivery asset is estimated at 27% per quarter as described above. The volatility of the optioned asset is estimated at 12% per quarter from the market portfolio data. With a correlation coefficient of 0.09, the combined effective quarterly volatility is approximately 29%. The maturity date of the option is 4 quarters, or 1 year. With these inputs, the value of the exchange option is:

$$A = E(V_0, D_0, t, s) = E(250000, 195000, 4, 0.29) = \$82K .$$

Strategy B

The valuation of strategy B is decomposed into two parts: (B1) the value of option to exchange the fixed-fee TLC for the market value, and (B2) the value of the contract that gives SofMore this right. Since both depend on the negotiated single-license fee, we will treat this predetermined amount as a sensitivity variable, and denote it by F .

B1 is easier to compute than the exchange option of strategy A since the delivery and the optioned assets are perfectly correlated and have exactly the same volatility. This results in a combined effective volatility of zero. To obtain the present value of the delivery asset—the fixed-fee TLC—multiply the present value of the sales projection with the present value of the preset fee F . The latter present value is computed by discounting this amount back using the risk-free rate. Assume a continuously compounded risk-free rate of 2% quarterly, or 8% annually. This yields a present

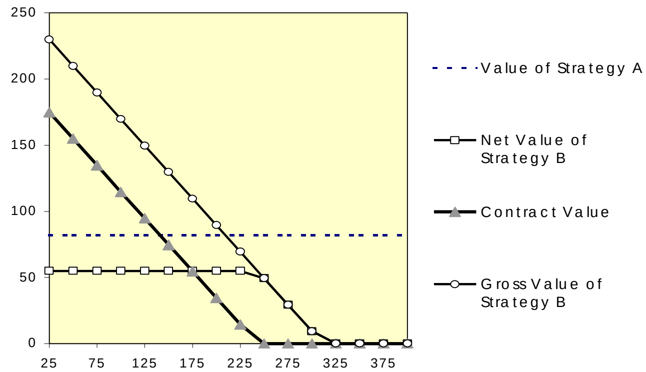

Fig. 7. Analysis of SofMore's risk mitigation strategy.

value of $1000 \times F \exp(-0.02 \times 4)$ for the delivery asset. The value of the exchange option, the gross value of strategy B, is then given by:

$$B1 = E(V_0, D_0, t, s) = E(250000, 1000 \times F \exp(-0.02 \times 4), 4, 0)$$
$$= \max(0, 250000 - 1000 \times F \exp(-0.02 \times 4))$$

The value of the contract itself is based on the present value of the expected cost savings for SofMore, or conversely, the present value of the expected losses for the vendor of WebKeys. The contract is meaningless when this amount is negative, thus its value is simply given by:

$$B2 = \max(0, 195000 - 1000 \times F \exp(-0.02 \times 4))$$

On the one hand, the contract is option-like since it does not pre-commit SofMore to buying any licenses of WebKeys. On the other hand, neither does it give SofMore the flexibility of incurring the variable-fee cost should the license fee fall below the preset fee. For these reasons, the use of exchange option formula is not suitable in this case.

Finally, to obtain the net value of strategy B, the amount $B2$ is deducted from the amount $B1$; therefore, $B = B1 - B2$.

6. ANALYSIS

Fig. 7 illustrates the value of the two strategies as a function of the single-license fee set by the contract. The value of strategy A is constant because it does not use the contract. Both the value of the contract and the gross value of strategy B decrease linearly as the license fee increases, and levels off when they reach zero. Since the linear segments are parallel, the net value of strategy B remains constant below a threshold. At a license fee of approximately $225, the net value starts decreasing until it also reaches a minimum value of zero. The option-like nature of the two strategies and of the contract assures that the curves remain above the horizontal axis.

Remarkably, the active strategy, A, is always less valuable than the passive strategy B. Strategy B, due to the contract, allows SofMore to partially mitigate license cost risk. The less risky alternative is more expensive because of the additional up-front cost. This result appeals to the general intuition that reducing risk often has a price.

Up to the threshold value of $225, the difference between the two strategies remains constant at about $27K. It then increases linearly until it equals the full value of strategy A. The first implication of this observation is that SofMore should always negotiate a license fee lower than the threshold value of $225. Second, it should try to keep this amount as low as possible to simultaneously maximize the value of the strategy and minimize the project's exposure to risk. The lower the license fee, the lower the company's exposure to the uncertainty of the total license cost. Since increasing the license fee increases this exposure with no improvement in the value generated, SofMore—if it chooses to pursue strategy B—should prefer to trade a higher contract premium for a lower license fee.

7. CONCLUSION

This paper presented an options-oriented framework for evaluating license cost management strategies in software development with COTS products. It showed how an emerging financial valuation technique, real options analysis, can be applied to compare strategies that limit a development project's exposure to volatile license costs. The example presented considered a strategy in which the license cost risk of a commercial component that is being integrated to a new release of an existing product is mitigated through a contract negotiated with the component's vendor. The contract in advance fixes the license cost of the component without obliging the developer to commit to buying a predetermined number of licenses.

One deficiency of this strategy is that the contract does not provide the developer with the flexibility to pay the going price for the component's licenses should that amount fall below the fixed fee. A better and more realistic strategy thus would be to have the contract *cap* the license fee rather than *fix* it, thereby providing the developer with the option to incur the variable cost when it is below the cap. This improvement makes the synthetic delivery asset of the strategy B dependent on the constant cap, but gives the contract the flavor of a true exchange option. So far, we have relied on the concept of an exchange option as a primitive tool to value complex strategies. Alternatively, the improved strategy, as a unit, can be treated as an exotic option, similar to a *chooser* option, but instead of choosing between a put and a call on the same underlying asset, the option holder chooses the lesser of two, possibly correlated delivery assets at the time of exercise.

Indeed, both the contract and the net value of the resulting strategy, depending on the specific characteristics of the contract and the perspective taken by its stakeholders, can be valued in many different ways. Figure 8 depicts some of the available alternatives for valuing the contract alone. For each alternative, the first letter indicates whether the license fee set by the contract represents a fixed fee (F) or a cap (M, for minimum fee). The letters within the parentheses indicate the agreed upon perspective. ES means that the valuation is based on traditional expected cost savings or losses. CX means that the valuation is based on cost exchange, which can be modeled by an exchange option. Finally, BM means that the valuation is based on a benchmark: the strategy under consideration is first valued as a unit (including the contract), and any value created in excess of a benchmark strategy that excludes the contract (in this case, Strategy A) is assumed to represent the value of the contact.

Fueled by the advent of component technologies and delivery mechanisms such as Application Server Providers [3], software is acquiring the features of a genuine capital good [4]. In such an environment, pricing will be of central importance. Moreover, the proliferation of software-based market securities—typically, publicly traded stocks of software and internet companies—is increasingly allowing the underlying risks to be estimated using objective market data. These factors are closing the gap between software development decisions and financial analysis, making the real options framework exceedingly relevant.

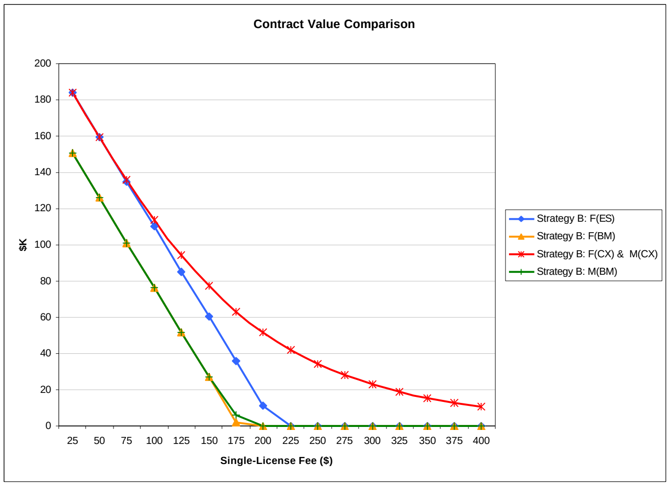

Fig. 8. Comparison of different strategies in combination with different valuation methods.

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