Real Options and Enterprise Technology Project Selection and Deployment Strategies

Mark Jeffery
Center for Research on Technology and Innovation
Kellogg School of Management
Northwestern University
2001 Sheridan Road
Evanston IL 60208-2001
847-467-5509
mjeffery@kellogg.northwestern.edu

Sandeep Shah
Center for Research on Technology and Innovation
Kellogg School of Management
Northwestern University
2001 Sheridan Road
Evanston IL 60208-2001
847-491-2472
s-shah9@kellogg.northwestern.edu

Robert J. Sweeney
Department of Finance and Financial Services
Raj Soin College of Business
Wright State University
3640 Colonel Glenn Hwy
Dayton, OH. 45435
937-775-3488
robert.sweeney@wright.edu

Submitted to MIS Quarterly, April 2003

REAL OPTIONS AND ENTERPRISE TECHNOLOGY PROJECT SELECTION AND DEPLOYMENT STRATEGIES

Acknowledgements

We gratefully acknowledge C. Dadah at NCR Teradata, R. McDonald at the Kellogg School of Management, V. Antikarov at the Monitor Group, and H. Herath at the University of Northern British Columbia for useful discussions. This research was supported by a research grant from Teradata, a division of NCR Corporation.

Mark Jeffery: Dr. Jeffery is an Assistant Professor of Technology in the Technology Management Group at the Kellogg School of Management. His research is in technology portfolio management, real options applied to technology projects, and quantifying the business value of information technology initiatives. He has more than 30 publications in scientific and technology journals, and three book chapters including a chapter on ROI analysis for e-business projects in the 2003 Wiley Encyclopedia of the Internet. Prof. Jeffery has also developed 14 original case studies that are used in the Kellogg MBA course he teaches on Technology Portfolio and Program Management, and the Kellogg executive program he directs called Driving Strategic Results through IT Portfolio Management.

Sandeep Shah: Sandeep Shah is a Research Fellow in the Center for Research in Technology and Innovation at the Kellogg School of Management. He has more than ten years of experience in product development and management in technology, telecommunications and wireless industries. Mr. Shah worked as an associate at the Telecommunications Development Fund (TDF), a venture

capital firm focused on early-stage telecommunications and technology companies. He holds a BSEE with Honors from the University of Houston and an MBA from the Kellogg Graduate School of Management, Northwestern University.

Robert J. Sweeney: Robert J. Sweeney is a professor in the Department of Finance and Financial Services in the Raj Soin College of Business at Wright State University. A graduate of Wright State University (B.S. 1977; MBA 1979) and the University of South Carolina (Ph.D. 1985), he has taught at The Citadel in Charleston, South Carolina and at Marquette University in Milwaukee, Wisconsin. The author of numerous articles on such topics as the small firm effect, option trading strategies, and valuation, Dr. Sweeney has also been recognized as an outstanding teacher as evidenced by the 1995 Alumni Award for Teaching Excellence.

REAL OPTIONS AND ENTERPRISE TECHNOLOGY PROJECT SELECTION AND DEPLOYMENT STRATEGIES

The reality of most IT departments is that capital is limited, or rationed, so that positive net present value (NPV) projects are not always funded. In the present work we examine enterprise technology projects that have a positive traditional NPV. Incorporating real option value enables management to more objectively compare and rank projects in a capital rationed information technology portfolio management process, and decide upon the optimal deployment strategy for the project. The present work examines different phase-wise deployment strategies for large enterprise technology projects and incorporates real options into the decision making framework. We focus specifically on multi-stage options embedded in enterprise data warehousing projects (EDW). We also examine the lattice granularity necessary so that discrete time option valuation models more accurately describe large enterprise projects. Different deployment strategies with different underlying NPVs and volatilities are compared. These results show that the traditional NPV of a project combined with additional real option premiums can provide important insight into the selection and deployment strategy for a project. Our results are generalizable to a large class of IT investment decisions where managers may consider single-phase versus multi-phase deployment in the presence of project risk.

Keywords: Data Warehousing, Valuation, Real Options, Strategic Flexibility, Volatility, Investment Analysis, CRM, Monte Carlo

Categories: HA03 DSS, **AC0406** Decision making under risk and uncertainty, **AF0410** Priority setting, **EE0101** IS project risk management, **EF0601** IS project selection criteria, **EF07** IS INVESTMENT

REAL OPTIONS AND ENTERPRISE TECHNOLOGY PROJECT SELECTION AND DEPLOYMENT STRATEGIES

INTRODUCTION

There is a large body of research literature on real options applied to a variety of projects and investments, including information technology (IT). For example, Benaroch and Kauffman (1999) used the Black-Scholes model to analyze point-of-sale debit services in an electronic banking network. Panayi and Trigeorgis (1998) used a two-stage real options pricing model to value the IT infrastructure project for the state telecommunications authority of Cyprus. Kumar (1996 and 1999) used a real options approach to quantify the value provided by decision support systems in several decision scenarios, such as commodity trading and marketing, and Taudes and Feurstein (2000) used options theory to decide whether to continue employing SAP R/2 or to switch to SAP R/3. More recently, Herath and Park (2002) used the binomial lattice framework to model a multi-stage technology investment as a compound real option.

The present work builds upon and extends the previous body of research on real options applied to information technology investments. Real options are often discussed in the context of projects that will have a negative net present value (NPV) if option values are not considered (Panayi et al. 1998 and Tudes et al. 2000). That is, based upon purely financial metrics without options, the negative NPV project will not be funded. Since the option value adds to the traditional NPV, real options can potentially make a negative NPV project into a positive investment opportunity.

In the present work we focus on a different class of problems - projects that already have a positive NPV. We investigate the role that real options can play in management's project selection criteria and the strategy for execution in an environment where there is risk of project failure. The typical IT department is under considerable capital budgeting constraints, and hence positive NPV projects are not always funded. Given this capital rationing environment, option value can be an important consideration for justification and prioritization of positive NPV projects.

We focus on multi-stage options embedded in enterprise data warehousing (EDW) projects, and we investigate the pros and cons of different phase-wise deployment strategies. We also examine the lattice granularity necessary so that discrete time option valuation models more accurately describe real enterprise projects. The results of this analysis are generalizable to a large class of IT investment decisions where managers may consider single-phase versus multi-phase deployment in the presence of project risk.

An overwhelming number of organizations are deploying data warehousing technologies to increase their returns on information technology assets and investments. In 2001, almost all of the Fortune 1000 companies have deployed data warehouses (Watson et al. 2001). According to International Data Corp. (IDC), worldwide revenues for total data warehousing software tools was $6.4 billion in 2000 and IDC expects the market to reach $16.6 billion by 2005; this market has a compounded annual growth rate of 21.2% from 2000 to 2005 (IDC 2000). However data warehousing projects, similar to other large enterprise technology projects (Davenport 1998 and Rigby et al. 2002), are claimed to have high failure rates (Watson et al. 2001). It is estimated that one-half to two-thirds of all initial data warehousing efforts do not deliver the projected business benefits (Kelley 1997).

EDW projects, similar to other large IT investments, have considerable risk that the project will not be on time, on budget, and the expected business benefits will not be realized. Wixom and Watson (2001) studied factors that effect EDW success. Their research found that EDW projects need a high level of management support, senior executive buy-in, and significant levels of user participation—starting at the inception of the project, through its development, and into the final stages of implementation. They also found that 43% of firms implement some form of phase-wise consolidation of data marts into a full EDW (Watson et al. 2001).

Phase-wise deployment of large technology projects creates options that value the opportunity to mitigate downside loss, or risk. We analyze three distinct scenarios: (1) immediate enterprise-wide data mart consolidation into an EDW, and (2) two-phase versus (3) three-phase consolidation. We show that the risk of the project, embedded in the option value through the project volatility, can give management executives valuable information on the prioritization of projects for funding decisions and the choice of deployment strategy.

A few authors have commented upon the applicability of real options to IT infrastructure investments such as an EDW (Kumar 1996). However, to our knowledge no authors have actually applied real options in EDW investment analysis. Our analysis is based upon cash flows for data mart consolidation into an EDW. These cash flows are representative of other EDW projects, and are based upon the two case studies of Sweeney, Davis and Jeffery (2002) for an EDW investment at a major telecommunications company.

As discussed in a later section, the most important parameter in any real option analysis is the volatility of the project. Following Herath and Park (2002) who demonstrated how to calculate volatility for compound options using a Monte Carlo method with 200 simulation runs, we calculate the volatility of the EDW project phases based upon 10,000 Monte Carlo simulation runs of the underlying cash flows. The distribution functions and related standard deviations of the several input variable parameters were obtained from interviews with management executives, and are representative of EDW projects.

In the following two sections we briefly review enterprise data warehousing projects, the major issues for data mart consolidation, and the basic principles of option theory as they apply to data mart consolidation for an EDW. Then, we discuss the cash flows for three different EDW scenarios, and describe in detail how real option theory is applied to the cash flows in order to calculate the multi-stage option values. For the two-stage case we use both the Black-Scholes and the one-step binomial method, and a multi-step binomial method. We show that the one-step binomial model is a gross approximation of the value of the real option embedded in the project. Finally, we discuss the analysis results and the implications for management decisions. We show that the traditional NPV of the project, combined with additional option values from phase-wide deployment, provides important insight into project selection and the optimal deployment strategy. A summary and conclusion are given in the last section.

ENTERPRISE DATA WAREHOUSE PROJECTS

A common problem within large enterprises is the proliferation of data marts. A data mart is a database that is most often associated with a specific business unit, business process, or customer segment. Often the data marts are related to the silo organizational structure within a company. For example, the customer service department may collect customer service data, the accounting enterprise resource planning (ERP) system may have purchasing financial information, the customer relation management (CRM) system may have marketing contact information, and the firm's product web site may have data on what products the customer viewed, click streams, and where they came from and went to on the web. If each interaction with a customer is in a separate database, or data mart, it is simply not possible to create a single voice and single view of the customer. A solution to this problem is to consolidate the disparate data marts into a single enterprise data warehouse.

In addition to improved information, consolidation of data marts into an EDW can have immediate business benefits. The consolidation of systems can reduce total cost of ownership since often different vendors support multiple data marts. Specifically, a consolidated system can potentially enable a better service contract negotiated on a single vendor solution, fewer personnel are required to support the system since there are some economies of scale, overhead is reduced since a single data center location is required, and employees need only be trained to use one system instead of several different vendor solutions. These hard cost containment benefits are often used to justify an initial EDW investment, since the soft benefits of improved information are extremely difficult to quantify.

For a Fortune 1000 firm, constructing an EDW through data mart consolidation can be a large technology project ranging from a few million dollars to several tens of millions. Often there can be considerable resistance within a company to dismantling individual data marts. This is because business unit executives ‘own’ the data and may be reluctant to relinquish the power over the information in the data mart. Since significant organizational change is required across multiple business units, and the project is a large complex technology project, there is considerable risk that EDW projects will not be completed on time, on budget, and will not produce the expected business benefits.

Wixom and Watson (2001) have identified several important factors important for the success of data warehousing projects: management support, resources, user participation, team skills, source systems, and development technology. Management support is the widespread sponsorship for a project by the management team, and is consistently identified as one of the most important factors for data warehousing success and for the success of any large enterprise technology project (Wixom et al. 2001, Kiel et al. 1998). The existence of a project champion does not necessarily correlate with an EDW projects success; however a project champion can be a positive influence on an EDW project. Resources include the funding, personnel, and time that are required to successfully complete the project. User participation, in terms of their involvement during the project execution, leads to a better understanding of their needs and requirements, and helps ensure that the system is implemented in accordance with their demands. The skills of the data warehousing professional services team, who develop and deploy data warehousing solutions, also have a major influence on the outcomes of the warehouse project.

On the technology side, the quality of existing databases from diverse heterogeneous data marts can also have a profound impact on data warehousing success. Development technology includes the hardware, software, process, and programs used in completing a project. The development tools that a project team uses can also influence the effectiveness of the data warehousing efforts. There are other uncertainties which also impact the success of data warehousing efforts: scalability of the solution, reliance on external IT help, changes in job skills and personnel displacement, training, organizational politics, cultural issues, lack of insight and vision, and lack of focus on overall objectives of data warehousing efforts.

Clearly, there are multiple factors important for the success of a data warehousing project. The variability in these factors among various deployment efforts introduces uncertainty in the project execution. For example, lack of team skills make it less likely and uncertain that data warehousing efforts will succeed and complete on-time and on-budget. The overall uncertainty, derived from all of the above implementation factors, influences the financial returns actually realized from data warehousing efforts.

A FRAMEWORK FOR REAL OPTIONS APPLIED TO ENTERPRISE TECHNOLOGY PROJECTS

The return on investment (ROI) of a large enterprise wide project, such as data mart consolidation (DMC) into an EDW, is often calculated prior to making an investment decision. This analysis most often uses traditional discounted cash flow (DCF) analysis and the related internal rate of return (IRR) to define the project ROI. However, the DCF approach makes many implicit assumptions that may not hold true in reality. For example, DCF makes an explicit assumption that managers will follow the proposed investment strategy to completion and they will passively allow the project to unfold in time (Trigeorgis 1996). That is, the project cash flows are assumed to be expected values that are a probability-weighted average of all possibilities, and the project once launched is assumed to be passively managed (Thomas 2001).

However, managers have flexibility to adapt their response to unexpected market developments resulting from change, uncertainty, and competitive interactions. As a project evolves in time, new information may becomes available and uncertainty about market conditions and cash flows is gradually resolved. Management may therefore have flexibility to alter its initial operating strategy in order to capitalize on favorable future opportunities, or to react so as to mitigate losses (Trigeorgis 1996). For example, managers have at their disposal the flexibility to defer, expand, contract, abandon, or alter a project contingent upon the future evolution of the business environment. Hence, managers are actively involved in the investment, contrary to the assumption of passive management for the traditional DCF approach.

Traditional valuation techniques therefore do not take into account this management flexibility, and as a result often underestimate the value of investments (Dean 1951, Hayes et al. 1980, and Hayes et al. 1982). Figure 1 is a schematic diagram showing the probability distribution of cash flows for a passively vs. actively managed project (Trigeorgis 1996). The NPV of the passively managed project is the expected value of all possibilities that are assumed to have normal probability distribution (dotted line in Figure 1). However, management will actively manage projects in such a way as to mitigate downside loss and improve the possibility of upside value (solid line in Figure 1). This flexibility to adapt depending upon the future environment introduces an asymmetry in the probability distribution of NPV. This asymmetry expands the investment's true value by improving its upside potential while limiting downside losses (Trigeorgis 1996).

Real options enable one to calculate the expected value of actively managed projects. A conceptual framework for the relationship between NPV and real options is shown in Figure 2. The NPV of the project with real options is said to be 'expanded' by the option value of management flexibility. Hence the option value is the difference between the expanded NPV and the traditional NPV calculated using DCF techniques.

A common strategy to mitigate risk in large enterprise technology projects is to divide the project into smaller components, or phases. Each phase is often executed sequentially with a stage-gate at the end of the phase. This stage-gate approach gives management the opportunity to review the project at the end of each phase – if the completed phases of the project are not demonstrating business value management may decide not to continue. Each phase therefore incorporates real option value - at the end of each phase management is actively deciding whether to continue the project, and working to leverage learning to improve results in later phases.

For a data mart consolidation project into an enterprise-wide data warehouse, management will often select a phase-wise consolidation of data marts. Five or ten data marts may be chosen for consolidation in each phase. These phases each have real option value, since at the end of a consolidation phase management has the option to fund the next phase. This funding will be contingent on the success of the previous consolidation phase.

An important management question is: 'What is the optimal phase-wise deployment strategy that balances risk and return?' We will use a real options approach to answer this question, and show that the answer depends upon the risk, or volatility, of the project and the traditional NPV of each phase. The following section discusses the calculation of option value for phase-wise deployment in the explicit context of data mart consolidation for enterprise data warehousing. However, as discussed in the introduction section, the process and conclusions are generalizable to enterprise technology projects where management is considering the optimal strategy for phase-wise deployment.

REAL OPTIONS AND EDW PROJECTS

The objective of the enterprise technology project considered in the present work is to consolidate disparate data marts in a firm into an enterprise data warehouse. An EDW offers three main advantages: (1) EDW is more efficient to operate so that the amount of money spent on information management and human resources is reduced; (2) EDW removes data and system redundancies reducing IT expenses and provides higher quality of data for further analysis, and (3) CRM analytic applications can be more efficiently run on a fully consolidated EDW. The reader should note that the present work focuses only on the phase-wide data mart consolidation cost-containment aspects of (1) and (2) for an EDW project. We do not attempt to value the improved information that the EDW provides, and compound options from possible future revenue generation projects such as analytic CRM are discussed elsewhere.

The present research builds on the case studies completed in collaboration with the Teradata Business Impact Modeling team (Sweeney, Davis, and Jeffery 2002). Figure 3 shows a schematic of the possible deployment strategies that we consider. We assume a 15 data mart consolidation project into an EDW. Management has the choice to consolidate all the data marts at once, or to execute phase-wise deployment. A large Fortune 1000 firm may ultimately consolidate 30 to 60 data marts into a full EDW. However, we chose 15 data marts consolidated over a 3 year period since this is representative of an initial EDW project undertaken by the average Fortune 1000 Teradata customer. The option of 5 or 10 data marts in a single phase is also representative for an average initial consolidation project.

Figure 3 (a) is the project assuming all data marts are consolidated in a single-phase 15 data mart project. Figure 3 (b) and (c) are two different phase-wise deployment strategies. Figure 3 (b) is a 5 data mart consolidation 'pilot' project followed by the option to proceed on all 10 remaining data marts: this is a 5-10 data mart consolidation strategy. The last strategy, Figure 3 (c), is a 5-5-5 data mart consolidation project with a stage-gate review, and the option to proceed or kill the project at the end of each 5 data mart consolidation phase. The corresponding event trees for the two-phase and three-phase deployment strategies are shown in Figure 4. At the end of each phase management will review the project and judge success or failure. If the phase is a success management can either chose to stop the consolidation and not move forward, or they can chose to continue and consolidate the next phase. For an unsuccessful consolidation phase, management will chose to not continue with additional consolidation. However, an unsuccessful new system will most likely not be completely abandoned - rather, it will become a new independent data mart.

Note that for data mart consolidation the project is rarely a failure so that the consolidated data marts must be completely 'abandoned'. If the business benefits fail to be realized in a phase, management will keep the consolidated system as a data mart and will chose not to continue with the consolidation into a full EDW.

The event trees shown in Figure 4 schematically show the options embedded in the two-phase and three-phase deployment strategies. As our results will show, additional phases increase the option value of the project due to management flexibility at the beginning of each phase to either continue or kill the project. Note that the deployment strategy Figure 3 (a), consolidation of all 15 data marts in one phase, does not have any options. Hence the valuation of this strategy can be accomplished using the traditional DCF approach.

Cash flows for the underlying asset

The cash flows for each possible phase were constructed using standard methods. Since data mart consolidation is primarily a cost containment strategy, the cash flows focus on the major costs of the project. Figure 5 shows the NPV and IRR analysis for one 5 data mart consolidation phase. The base case Figure 5 (a) is the pro-forma costs assuming that there is no consolidation. These costs in personnel, maintenance and support, and overhead are representative of costs for 5 disparate data marts. Personnel costs include the number of DB analysts, ETL programmers, query programmers and support staff required for each data mart. Costs are assumed inflated each year by 4% and the existing systems are assumed to be fully depreciated.

The cash flows are calculated for a 5 data mart consolidated system in Figure 5 (b). Consolidation requires an upfront capital investment, user training, and professional services support. However, there is a significant cost reduction in the number of personnel required to support the system, and the maintenance costs are lower, see Table 1 for staff averages. In addition, the new system can be depreciated, and will result in a depreciation tax shield. We assume MACRS depreciation over 5 years. The detailed aspects of the base case and consolidated system costs are discussed in the case study on Teradata data mart consolidation (Sweeney, Davis, and Jeffery 2002).

The incremental cash flows that result from subtracting the consolidated pro-forma from the base case are shown in Fig. 5 (c). The 5 data mart project in this example evaluated by traditional methods has a positive NPV = $3.1 M and an anticipated IRR = 36%. Hence based on traditional DCF methods this project is one that should be considered for funding. However, the analysis does not include risk and the option value of phase-wise deployment.

We created different cash flow statements for each possible phase in Figure 3. The difference between these cash flows is the number of data marts consolidated in the phase and the time that the phase is anticipated to start. Phases that start in Year 2 and Year 3 are assumed to have higher costs than phases that start at time zero since hardware, personnel salaries and overhead are inflated in the future. In addition, cost saving benefits are also delayed. Hence, with discounting back to time zero, phases started in later time periods can have a significantly lower NPV than the same phase started at time zero. This is because of two factors; inflation in costs and the time value of money since the cost reduction benefits are not realized until one or two years in the future.

Using the traditional DCF method the single-phase deployment has the highest NPV, since hardware and professional services costs can be negotiated to a minimum at the start of the project. In addition, the benefits of reduced costs from the integrated system are realized sooner than for either of the two phase-wise strategies. However, this approach clearly has the highest risk since management is committing to consolidate all 15 data marts in a single phase.

Multi-stage real options framework

Valuation of IT infrastructure investments can be very complex, because these projects are often implemented in phases and are subject to varying uncertainties in each phase. Management has the flexibility at every phase to either continue or abandon the investment depending upon the success of the earlier phases and the resolution of other uncertainties. Valuation of this management flexibility can be accomplished using real options. These real options involve multi-stage decisions, and exercise of an option unlocks not only incremental positive cash flows after every phase but also additional options.

The value of real options in the context of multi-stage project implementation is an important consideration. This is because the overall value generated as a result of a bundle of sequential and multi-stage investments maybe more than the value realized by individual projects in isolation. These multi-stage investments can be viewed as compound call options where the underlying asset is the combination of the project value, the present value of expected incremental cash flows as a result of investment, and the value of future options with the exercise price being the necessary investment outlay.

Real options embedded in a phase-wise data mart consolidation project belong to the category of compound growth options. This is because data marts can be consolidated with the centralized data warehouse in phases, but not necessarily in any particular order. These phase-wise investments can be treated as options, because management has the flexibility to either make or not make an investment before each phase, and this flexibility has a value. These options are independent in the sense that they operate on separate incremental cash flows (underlying assets).

The underlying asset of a real option contains not only the present value of incremental cash flows but also the option value of future options that are generated as a result of exercise of the option. As an example, in a phase-wise data mart consolidation project the investment in Phase I of the project not only results in cost savings and efficiency (positive incremental cash flows) but also opens up the possibility for additional options (additional phases leading to full EDW deployment and CRM applications) that can generate their own positive incremental cash flows. Since this paper focuses only on cost containment aspects of the EDW project, CRM initiatives and their associated options are not considered in the present analysis.

Consider the 5-10 data mart deployment strategy of Figure 3 (b) and Figure 4 (a). After an investment I_1 in Phase I of the project, consolidation of the first 5 data marts, management has an option to implement a full EDW, all remaining 10 data marts, at a follow-up cost I_2 at a later period. This investment is contingent upon the success of Phase I of the project. This is equivalent to saying that firm pays a relatively low entry fee (I_1) to acquire the right, but not the obligation, to undertake a full EDW implementation project at a later date. This is the definition of a real option, since management has the option to continue with the full EDW implementation similar to a financial CALL option on a stock. It is also a growth option, since there is a follow-on investment necessary for a profitable opportunity.

Committing a relatively small initial investment at time zero to execute Phase I of the project has the advantage that if the project is unsuccessful financial losses are limited. In addition during Phase I of the project there are many opportunities to learn about the problems faced in the implementation. This information can not only be used to assess if it makes sense to continue with the full EDW project at a substantial investment level, but also to address the implementation problems more effectively in a full EDW implementation. That is, Phase I of the project helps resolve uncertainties in project implementation schedules and resource allocation for the full EDW.

In summary, for the two-phase 5-10 deployment strategy Figure 3 (b) and Figure 4 (a), a relatively small investment in Phase I of the project creates an option to implement the full EDW in the future. If the Phase I of the project is unsuccessful, management has the flexibility to not fund additional consolidation into the full EDW. In the worst case the Phase I project will not be a total loss, since the Phase I consolidated system can be used as a data mart. However if the Phase I is successful, management has acquired the strategic value of being able to exercise an option to do the follow-on full EDW project and receive the value of incremental cash flows for a full EDW project. Similarly for a three-phase 5-5-5 strategy, Figure 3 (c) and Figure 4 (b), the second phase of the project contains the same series of options discussed above for Phase I, but applied to the follow on opportunity to implement Phase III of the project.

Following are additional characteristics, and important assumptions, regarding a real option associated with a phase-wise EDW deployment strategy:

- The option is a sequential and is part of stream of future options (CRM etc.) available to management.
- The option does not overlap in time with other future options.
- The option is a European option, that is, it has a pre-determined maturity date of one year as a result of time required to complete each prior phase of the project and budgetary cycle issues.
- The option has its own underlying asset equal to the incremental cash flows as a result of exercising the option plus the value of future options.
- Additional phases of the project can be implemented independent of one another and do not have to occur in any specific order.

Binomial and Black-Scholes option valuation

There are two well known methods for calculating the value of real options: discrete time models and continuous time models. Cox, Ross, and Rubinstein's (1979) binomial approach is a simple technique to value options in discrete time using a binomial lattice. The formulation of real option valuation in continuous time is based on the seminal work of Black and Scholes (1973) and Merton (1973) for pricing financial options.

The discrete time binomial model assumes that the value of the risky underlying asset V follows a multiplicative binomial distribution. Starting at time period zero, in one time period V may increase in value to uV or decrease in value to dV. The probability that the value will rise is assumed to be q and the probability the value V will fall is $1 - q$, where $d < 1$, $u > 1$, $d < r < u$ and $r = 1 + r_f$ where r_f is the risk free rate. The terminal value of the call option C in the up or down state is then

$$C_u = \max[0, uV - I] \quad \text{or} \quad C_d = \max[0, dV - I] \qquad (1)$$

Where I is the investment required to exercise the option, and the up and down states have probabilities q and $1 - q$ respectively. By setting $p \equiv (r - d)/(u - d)$, the value of the call option C at $t = 0$ can be calculated as (see Cox et al. 1979):

$$C = \frac{p\, C_u + (1 - p)\, C_d}{r} \qquad (2)$$

or equivalently substituting Eq. (1) into (2):

$$C = \frac{p \max[0, uV - I] + (1 - p) \max[0, dV - I]}{r} \tag{3}$$

The assumption of a binomial distribution implies that the up and down movements follow the equations:

$$u = exp(\sigma\sqrt{t/n}) \qquad d = exp(-\sigma\sqrt{t/n}) \tag{4}$$

where n is the number of steps in the binomial lattice and σ is the volatility, defined as the standard deviation of the log normal distribution of the continuously compounded returns of the value of the project.

Equations (1) – (4) enable the calculation of a call option value when there is a one step up or down management decision. These formulas are easily extended to a lattice with multiple up and down steps with spacing Δt. Algorithmically, one begins at the end states of the tree (time = n x Δt) and works backwards on the lattice to t = 0 calculating the option value at each previous node from Eq. (3). This method is used to calculate the multi-stage options in Figure 3, and the details are discussed in the next section.

When the binomial model is used to value a call option on a stock, the time to maturity is divided into small intervals Δt. As the number of periods in the lattice approaches infinity, the multiplicative binomial model approaches the log-normal distribution of underlying asset returns. In other words, the binomial formula converges to the continuous-time Black-Scholes formula in the limit that Δt goes to zero. For a real call option the Black-Scholes formula is:

$$C = V N(d_1) - (I / \exp(r_f t))\, N(d_2)$$

$$d_1 = [\ln(V/I) + (r_f + \sigma^2/2)\, t\,] / \sigma\sqrt{t} \tag{5}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

Where C is the value of the growth call option, I is the investment to be incurred to exercise the option, V is the present value of expected incremental cash flows, r_f is the risk-free interest rate, t is time to expiration, and $N(d)$ is the cumulative normal distribution function. Similar to Eq. (4), the volatility of the project, σ, is the standard deviation of the continuously compounded returns of the value of the project.

The Black-Scholes option pricing formula Eq. (5) relies on a number of restrictive assumptions that limit their applicability to valuing real options. These assumptions are:

- There is only one real option modeled and valued at a time. So, the option is contingent on only one underlying asset. This assumption restricts the applicability of the Black-Scholes model to value compound options, which consist of more than one real option.
- There is only one source of uncertainty (that is, only one uncertainty can be dealt at one time) and the variance is known and constant. For projects subject to several sources of uncertainties, the Monte Carlo approach to determine overall uncertainty is a good alternative. As discussed in the following sub section, we use Monte Carlo simulations to determine the overall volatility of project value returns, and this assumption is not violated.
- The process governing the value of the underlying asset follows a stochastic diffusion Weiner process (geometric Brownian). This is essential because the Black Scholes formula is based on this assumption.
- The risk-free rate is constant and known.
- The underlying asset does not pay any dividends. This assumption can be relaxed with appropriate modifications to the formula; but we assume no dividends.
- The options are European (can expire only at maturity). EDW options are European due to the nature of data mart consolidation work and budget cycle constraints.

- The exercise price is known and constant (that is, expected cost to implement the project cannot change).
- Markets are complete, the firm is risk-neutral, or risk is fully diversifiable.

These assumptions impact the present work, since the first assumption is violated for the three-phase project, shown in Fig. 3 (c) and Fig. 4 (b). For this case, the individual option value of the first two phases of the project operate on two underlying assets – the cash flows for that particular phase, and the value of the option for the future phases of the project. Hence, as noted by Herath and Park (2002), the binomial model must be used for three-phase compound option valuation.

In spite of the restrictive nature of the Black-Scholes formula, the equations are applicable to a broad class of real problems and have the advantage of being in closed form: this enables sensitivity analysis through examination of the partial derivatives. It is also interesting to compare the results derived using the binomial approach Eq. (3) to the results derived using the Black-Scholes Eq. (5), for the two-phase consolidation strategy.

Incorporating risk – volatility calculations

The binomial and Black-Scholes methods discussed in the previous sub-section enable one to quantify the value of delaying management decisions for projects that have risk, this is the option value embedded in the phase wide deployment strategies. The key parameter in both models is the volatility σ of the project – this volatility most directly quantifies the risk of the project. The challenge in any real options valuation model is to accurately calculate the volatility of the project. There are two important variables in the EDW consolidation project that are directly observable and that will have a high impact on the actual returns and their volatility: the implementation project schedule and personnel staff reductions.

As discussed in previous sections, the data warehousing project has risks including the quality of existing data in the data marts, development technology hardware and software, project team effectiveness etc. These risks impact the project in aggregate primarily through the length of time spent completing the project. For example, if the development tools do not work correctly, and new software and practices are needed to improve data quality in particular marts, then the project will take longer than expected. The extension of time on the project significantly impacts the NPV and IRR since there is a high cost of professional services and personnel. In addition, delays in the project delay the realization of cost saving benefits which additionally impact the total NPV.

The other major driver of ROI for the project is the reduction in staff count. The new EDW in principle needs fewer people to service and support the consolidated system. This translates into a major cost saving for the project, and is the main driver for the cost containment ROI. Hence, if management does not re-allocate personnel from existing data marts to other projects that are not billed to the EDW, no significant cost saving will take place. The personnel issue is closely related to management commitment to the project, and other organizational change risks. Since if management is not committed to the project, staff will not be reduced and the project will fail to deliver the anticipated ROI.

Project implementation schedules and personnel reductions are known to be the two major factors that impact ROI for data mart consolidation. The average and standard deviation of the project implementation schedule were obtained from historical data. Standard deviations for the range of variability of the number of different personnel required to staff the new system were obtained from anecdotal discussions with management executives. Interviews with Teradata management and other EDW implementation consultants enabled an understanding of the distributions of these parameters in terms of their expected values, maximum and minimum values, and their standard deviations. These parameters collectively are summarized in Table 1, and are used in Monte Carlo simulations to determine the overall volatility of the project returns.

In addition to the project schedule and personnel reductions, there are qualitative factors which are not included in the cash flows. Including these additional factors will increase the volatility which in turn will increase the value of the option. Hence, our option valuation is based upon conservative assumptions since we only include the two major risk factors that can be quantified and directly observed.

The project volatility is the standard deviation of the logarithmic annual project returns z defined by (see Copeland et al. 2001):

$$z = \ln \left(\frac{PV_{n+1} + FCF_{n+1}}{E\,(PV_n)} \right) \tag{6}$$

where the numerator is the free cash flows FCF in time period n+1 plus the PV in time period n+1of the cash flows starting in time period n+2. The numerator changes as uncertain variables in the financial model vary. The denominator $E(PV_n)$ is the expected present value of the cash flow starting in time period n based on today's information about the expected values of uncertain variables. The denominator stays the same throughout the simulation iterations.

There are a total of six uncertain variables in the cash flows, see Table 1. All are assumed to follow a normal distribution with minimum and maximum truncation values. The Teradata business impact modeling (BIM) team provided estimates for the input parameters that are given in Table 1. Monte Carlo simulations of Eq. (6) were run using @Risk software overlaid on an Excel spread sheet that contained the financial model with project returns. The time periods were either t_n equal 1 year, 2 years or 3 years depending upon the consolidation strategy, see Fig. 3 and 4. Figure 6 shows the distribution of the logarithmic returns for a typical simulation run with 10,000 Monte Carlo cycles. This output variable is the percent changes in the value of the project from one time period to the next (logarithmic returns of the value of project from one period to the next). The volatility is just the standard deviation of this distribution in Fig. 6, which is 10.17% for the example in the figure.

The Monte Carlo approach is a good alternative to consolidate uncertainties originating from multiple sources and to determine the overall volatility of a projects return. However, our volatility analysis captures only two major uncertainties, and the managers interviewed may be conservative in their estimates of the standard deviations - this may explain why the magnitude of the volatility is not very large.

REAL OPTION VALUATION OF THE TWO-STAGE AND THREE-STAGE DEPLOYMENT STRATEGIES

The option valuation methods and volatility calculations of the previous section enable us to calculate the option values of the two-stage and three-stage deployment strategies. We follow the methodology discussed previously and shown schematically in Fig. 2. We first apply the Black-Scholes and binomial methods to the two-stage strategy Fig. 3 (b) and Fig. 4 (a), and then analyze the more complicated three-stage strategy of Fig. 3(c) and Fig. 4 (b) using a two-step binomial method. We also compute the compound option value using a multi-step binomial model. These various computational methods are compared in the following section.

Option valuation of the two-phase strategy: Binomial and Black-Scholes approach

The traditional NPV is calculated for both phases of the project using the company's cost of capital (WACC) of 14%. Figure 7 (a) shows the calculation of the traditional NPV for both phases of the project. The traditional NPV is the expected value of the NPV and is calculated by using the expected values for all uncertain variables and the initial investment.

The option value for the two phase strategy of Fig. 4 (a) is relatively straight forward to calculate. A summary of all the major option parameters are given in Table 2 (a). Using the binomial method, a first approximation for the management decision is a one step tree, $n = 1$. That is, by executing the 5 data mart Phase I project management has purchased the option in one year to consolidate the remaining 10 data marts into the full EDW. The full consolidation will only take place if Phase I is successful at the end of year 1.

For a one-step binomial process, Eq.'s (1) through (4) are directly applicable, where $V = V_1$ is the value of the future cash flows from the Phase II 10 data mart consolidation at the end of year 1, and $I = I_1$ is the investment required to implement Phase II at the end of year 1. So that the call option value for Phase II is calculated from Eq. (3):

$$C_1 = \frac{p \max[0, uV_1 - I_1] + (1 - p) \max[0, dV_1 - I_1]}{1 + r_f} \quad (7)$$

The up and down parameters are calculated from Eq. (4), and the risk neutral probabilities are derived from $p = (r - d)/(u - d)$.

The call option C_1 in Eq. (7) is added to the net cash flows from the initial investment in Phase I. Since the call option C_1 is the expanded NPV of Phase II of the project, the expanded NPV of the entire project (Phase I and Phase II) is given by

$$C_0 = V_0 - I_0 + C_1 \tag{8}$$

Where V_0 is the present value of the incremental cash flows created from the Phase I consolidation and I_0 is the investment required for Phase I so that $NPV_0 = V_0 - I_0$. Following the framework shown schematically in Figure 2, the option premium O_p is then the difference between the expanded NPV Eq. 8 and the traditional NPV of the entire project:

$$\begin{aligned} O_p &= (V_0 - I_0 + C_1) - \left(V_0 - I_0 + \frac{V_1 - I_1}{1 + r_f}\right) \qquad (9) \\ &= C_1 - \left(\frac{V_1 - I_1}{1 + r_f}\right) \end{aligned}$$

The quantities in the first set of parentheses are the expanded NPV from Eq. 8. The quantities in the second parentheses are the traditional NPV of Phase I and Phase II, where Phase II has been discounted back one year to time zero. The option premium is therefore the difference between the call option value C_1 calculated in Eq. (7) and the traditional NPV of the Phase II project discounted to time zero.

Figure 7 (a) is a summary of the numerical values that result from the binomial method option premium calculation for the two-phase strategy. The option premium is \$696,779 which is 11.4% of the traditional NPV for the whole project. Hence, the original NPV calculated without options is expanded by \$696,779 due to the management flexibility to defer the decision to consolidate the full EDW by 1 year.

An alternative approach to value the option for the two-stage project is to use the Black-Scholes Eq. (5). The input parameters to these equations and the expected values of the incremental cash flows for Phase I and Phase II are given in Table 2. Similar to the binomial approach discussed above $V = V_1$ in Eq. (5) and $I = I_1$, the present value of the cash flows and the investment cost respectively for Phase II. We use Black-Scholes option pricing functions in Excel spreadsheet software that were written using the built-in macro language Visual Basic for Applications (VBA). The functions were written by McDonald (1996) at the Kellogg School of Management.

Similar to the binomial model, the call option calculated from Eq. (5) is added to the NPV of Phase I to give the total expanded NPV of the EDW Phase I and Phase II project. Hence, Eq. (9) is also applicable to calculate the option premium when C_1 is calculated from the Black-Scholes formula. The numerical values for the traditional and expanded NPV's, and the option premium for the Black-Scholes method are summarized in Figure 7 (a). The option premium calculated using the Black-Scholes method for the two phase strategy is \$705,773.

As the above results indicate, the option premium calculated using the Black-Scholes method is different from the option premium calculated using the 1-step binomial method. This is because the Black-Scholes formula uses a continuous time approximation. That is, the value of the project is assumed to vary continuously in a random walk from time zero to the end of Phase I in one year. The one-step binomial process on the other hand, is a first order approximation to a random walk, assuming only a single up and down movement that is binomially distributed.

Assuming the project value evolves due to a random walk, a better binomial calculation would include management and risk event interactions with the project. For a large enterprise project, the program management will review the project monthly or weekly, and will take corrective action where necessary. In addition, random risk events will impact the project on a time scale of days or weeks. Hence the lattice should not have one step, but multiple steps in one year.

We used the binomial calculation spreadsheet developed by McDonald (1996), and the Eq. (9) to calculate the real call option value C_1 using a 52 step binomial lattice, corresponding to weekly program reviews and risk interactions. For 52 steps the call option value C_1 is \$3,670,269, compared to the 1-step Binomial method, \$ 3,379,953, and the Black Scholes value of \$ 3,670,644. Hence, for the large enterprise project assuming weekly interactions, the binomial option value is within 0.01% of the Black-Scholes method.

Option valuation of the three-phase strategy

As discussed previously, the three-phase strategy incorporates a multi-stage compound growth option so that the Black-Scholes formula is not applicable. Instead, we use the binomial lattice model assuming a two-step lattice, see Fig. 8. Similar to the analysis discussed previously for the one-step binomial process applied to the two-phase EDW strategy, we apply the binomial Eq's (1) – (4) to a two the stage lattice shown schematically in Fig. 8 (a) and (b). The respective formulas for calculating the parameters to build a lattice structure are given in Fig. 8 (c).

Figure 8 (a) depicts the binomial tree and shows the movement of gross project value V at every node. In Fig. 8 (a), the project value V_1 is the value of the second phase of the project at time zero. V_1 can take either of the two values $V_1^+ = u_1 V_1$ or $V_1^- = d_1 V_1$ at time 1 year. Similarly, the project value V_2 is the value of the third phase of the project at time 1 year. V_2 at time 1 year can take either of the two values $V_2^+ = u_2 V_2$ or $V_2^- = d_2 V_2$ at time 2 years[1]. At time zero, the initial investment I_0 will be incurred, and this investment will create the option to invest in Phase II of the project C_1 at time 1 year.

[1] Here we are making the assumption that only the gross project value underlying a particular option is subject to a multiplicative binomial distribution. In addition, we assume that the value of the immediate predecessor option will remain constant (see Herath 2002). This assumption is valid since at any decision node only the current or future options are alive.

Since the options in the data warehousing project are European, at every node management can chose either to make an investment in the next phase, or abandon the next phase of the project, see Fig. 4 (b). The calculation of option value at time zero is accomplished by working backwards on the lattice Fig. 8 (b), from time 2 years, calculating the values at each node. That is, the most downstream option C_2 is calculated first, then the option C_1 is calculated, and finally the first option C_0 is calculated. Both the options, C_1 and C_0 have the characteristics of compound option (or nested options), and the option C_2 is a simple real CALL option.

Figure 8 (b) depicts the option payoffs associated with the real CALL options in the three-phase deployment strategy assuming a two-step binomial process. The option payoffs are indicated at every node. At time 2 years, the decision will be made to either invest I_2 in the next Phase III or abandon the project. The decision will be based on if there is a positive payoff as a result of the investment. The outcome of this decision will be the option payoff at that node. In Fig. 8 (b) the payoffs are given next to the nodes 1 and 2. The payoffs at nodes 3 and 4 are calculated similar to nodes 1 and 2.

The option value at nodes 5 and 6 at time 1 year are calculated using the risk-neutrality approach discussed previously for the two-phase strategy. The option payoffs at terminal nodes 1 and 2 are multiplied by their respective risk-neutral probabilities, and their addition is discounted by the risk-free rate for one period of the lattice (one year) to calculate the option value C_2 at node 5. Due to the symmetry of the project value tree, the option value at node 6 is also C_2.

At time 1 year, management will make the decision whether to invest in the second phase of the project. The up-stream option C_1 is a compound option, since the investment I_1 will generate both the incremental positive cash flows V_1 and the next option C_2. Again, the decision to invest will be made if there is a positive payoff ($V_1 - I_1 + C_2 > 0$) at node 5 [2]. That is, if the investment I_1 is more than the combination of the gross project value V_1 and the next option C_2, the option will be exercised. The options payoffs are given next to nodes 5 and 6 in Fig. 8 (b).

Once the option values at nodes 5 and 6 are calculated, the terminal option value C_1 at node 7 can be obtained using a similar process to the two-phase strategy. Similar to the option to invest in the second phase of the project, the option to invest in the first phase of the project is a compound option. The full compound option C_0 is the NPV of Phase I, $V_0 - I_0$, plus C_1.

Extending Eq. (9), the two-stage compound option premium resulting from the options C_1 and C_2 can be calculated from:

$$O_p = C_1 - \frac{(V_1 - I_1)}{1 + r} - \frac{(V_2 - I_2)}{(1 + r)^2} \quad . \tag{10}$$

Note that C_1 has already incorporated the value of future options including the option C_2, so that we are subtracting the NPV of Phase II and Phase III discounted back to time zero. Figures 9 (a) and (b) summarize the numerical solutions at each node for the project value tree and the option payoff tree respectively for the three-phase data warehousing deployment strategy. Figure 7 (b) summaries the numerical solution, and the option premium is calculated to be \$909,635.

As noted in the previous sub-section, the one-step binomial method is a first order approximation to the option value calculated using a continuous time method. For multi-stage options, the single-step binomial method is often used (Copeland et al. 2001). However, a more accurate model includes management and risk event interactions with the project on a more frequent basis. Hence, we have developing a multi-step binomial lattice algorithm in order to more

[2] Even though the underlying asset of a compound option comprises of the present value of incremental cash flows generated as a result of the investment, and the future real option value, we make the assumption that the volatility of the underlying asset depends solely on the changes in the present value of incremental cash flows.

accurately value complex multi-phase deployment strategies. The results of the 52-step binomial calculation for the three-phase multi-stage option are summarized in Fig. 7 (b). Single-step vs. multi-step real option valuation is discussed further in the following section.

There are two important observations to be made regarding the above calculations, see Figure 7 for a comparison of the numerical results. First, the traditional NPV for the two-stage deployment strategy is more than the traditional NPV for the three-stage deployment strategy, due to time value of the realized benefits. For the three-stage strategy deployment benefits are realized later - this reduces the net present value of the project. The second point is that even though the NPV for the three-stage deployment is less than the NPV for two-stage deployment, the option premium resulting from management flexibility is more for the three-stage deployment strategy. This is because the additional stage-gate in the three phase project strategy increases management flexibility, and hence the option value.

DISCUSSION

In this section we discuss the implications of the analysis of the previous section. Specifically, we discuss the impact that real option value can have on IT portfolio selection, the importance of using a multi-step binomial model for option valuation for large enterprise projects, and the implications real options have for the selection of optimal project deployment strategies.

Option Value and Portfolio Selection

IT portfolio management is the process of optimizing the return from all assets and projects under the control of the management and information systems department. For large companies, the IT budget can be a significant fraction of sales revenues ranging from 3.3% of sales for a manufacturing company to 8.4% for a telecommunications company (Meta Group 2003). As an example Merrill Lynch, the financial services company, reports an IT budget of $2.5 Billion. These large IT expenditures translate to hundreds or even thousands of IT projects running simultaneously. In a large organization the process of new project IT portfolio selection often involves the ranking of projects on various dimensions (Jeffery and Leliveld 2002).

In a basic, or defined, process the ranking is most often based upon the business value of the projects, which will often include the ROI of the projects. In a more advanced process, management uses a score card to align projects with the business objectives and to quantify the risk of the project. Projects are then ranked and plotted on a matrix with the dimensions of value to the business and ability to succeed. The portfolio is therefore broken into different components, and management decisions are made based upon the rankings within these components (Jeffery and Leliveld 2002).

The real option approach has the advantage of quantifying both risk and management flexibility to actively manage projects during execution. Even though IT budgets may be a significant fraction of sales revenues, there are rarely enough funds to execute all positive NPV projects. In this environment it is essential to accurately quantify the value of projects. Ranking of projects invariably involves a high weighting to the ROI, or NPV, of the project. As we have seen from the analysis of the previous section, real options can add significantly to the NPV of a technology project.

As an example, for the two-stage EDW deployment strategy, the traditional NPV for the whole data warehousing project was $6,104,130. This value does not capture the value of management flexibility – the option to either commit to the Phase II of the project so as to exploit the upside potential or not make an investment in the Phase II of the project so as to mitigate losses.

The expanded NPV incorporates this flexibility and is equal to \$6,809,903. The option premium is therefore \$705,773. The real option represents almost 12% of the traditional NPV of the full EDW project, that is, the option expands the traditional NPV of the full EDW project by 12%. The value of the Phase I of the project with the real option is significantly more than the NPV of the stand alone Phase I of the project. Hence, in an IT portfolio management selection process including the real option value would increase the relative ranking of the Phase I project relative to similar NPV projects that do not have real option value.

Figure 10 shows the traditional NPV and expanded NPV of the two-phase data mart consolidation project as a function of the underlying asset present value, or PV of future cash flows from the project. The option premium, the difference between the dashed line and solid line, is substantial averaging approximately 10% for a large range of underlying asset values. Hence, real option value is a significant fraction of the traditional NPV for this project.

IT departments often experience capital rationing so that the challenge is to select investments that have the most 'bang for the buck.' In other words, one must select projects that have the greatest returns for a given dollar of investment. A useful ratio capturing this idea is called the profitability index, usually defined as the ratio of the project NPV to the investment amount (Brealey and Myers 2000). A more useful ratio should incorporate real options embedded in the projects. This expanded profitability index can be defined as:

$$\textit{Expanded Profitability Index} \equiv \frac{\textit{Expanded Net Present Value}}{\textit{Investment}}. \tag{11}$$

Hence projects ranked using this expanded profitability index should give management more objective information for funding decision making.

Real option value can therefore be a significant fraction of a technology projects NPV, and can help executives make more objective capital budgeting decisions. The expanded profitability index is a potential tool to enable objective comparison of projects incorporating real option values. Real options have long been thought of as a way to justify investing in what might otherwise be a negative NPV project. A real value of real options, however, is the insights they provide to business executives to more effectively manage the portfolio of information technology assets under their control.

Single-step vs. multi-step binomial valuation

The analysis section detailed the calculation of option value for the two-phase and three-phase EDW deployment strategies. For the two-phase strategy we used three calculation methods: a one-step binomial method, the Black-Scholes model, and a 52 step binomial method. Several authors have used the Black-Scholes model to value technology options (see Benaroch 1999 and Panayi 1998) and many others have used the one- or two-step binomial method to demonstrate real options methodology (Herath 2002 and Copeland 2001).

An important consideration is which model to use when valuing options in large enterprise technology projects. As noted in the analysis section, the one-step binomial model gives a different option value than the Black-Scholes method. The two methods effectively set bounds on the option value for a large project. The one-step binomial method is a first order approximation to the real option value, and assumes that the underlying project value is varying only at the end time of the project. The Black-Scholes method is at the other extreme – the method assumes continuous time fluctuations of the underlying asset value following a Weiner diffusion process. Translated into practice, this implies management intervention and risk events impacting the project continuously on an infinitesimally small time scale.

The Black-Scholes model is derived from the binomial method in the limit that the number of lattice steps goes to infinity. As the number of lattice steps increases, the option value converges. Hence, the one-step binomial processes is a first order approximation to the continuous time Black-Scholes method, and may under or over estimate the actual option value.

Figure 11 is a plot of the expanded NPV for the two-phase and three-phase deployment strategies calculated as a function of the number of steps in the binomial model. For the two-phase project, Fig. 11 (a), the option value converges rapidly from below with some oscillations to the Black-Scholes value steady state, the dashed line in the figure. Figure 11 (a) shows that for this EDW project, beyond 100 steps the binomial model is within a fraction of a percent of the continuous time model. Figure 11 (b) is a calculation for the three-phase deployment strategy using a multi-stage compound option binomial method. In this case, beyond 200 steps the option value has converged from above with some oscillations approximately to steady state. These analyses demonstrate the difference between a few binomial steps and multiple steps in real option valuation of enterprise technology projects such as EDW.

For real enterprise technology projects the program management team will most likely monitor the project on a weekly or monthly basis, and depending on the project the CIO executive level will review status monthly or quarterly. Risk events will also impact the project on a weekly or daily time scale, and management will attempt to counter these events as soon as they are observed by management – which could again be on a daily or weekly time scale. Hence an appropriate binomial lattice spacing for a 1 year enterprise technology project would be in the range of 365 or 52 corresponding to the number of days or weeks in a year respectively.

The one-step binomial process is applicable to small projects where management's interaction, and major risk events that impact the project, occur on a time scale that is large relative to the length of time for the project. Large enterprise technology projects require a finer lattice spacing to more realistically model the management activities and risk events that impact the project. Our analysis has shown that using a lattice with 52 steps, assuming a weekly interaction time scale, the option value is within 0.01% of the Black-Scholes method. Note that the Black-Scholes method can not be used to value multi-stage compound options.

The one-step binomial valuation method has the advantage that it is easy to explain and understand, and it is straightforward to use this method and incorporate multi-stage compound options. However this method does not accurately calculate the option value for a large technology project. A more accurate approach has binomial lattice spacing on a time scale that is comparable with management and risk event interactions with the project, such interactions occur on the scale of days or weeks for a typical large enterprise technology project.

Option value defined deployment strategy

The analysis section demonstrated that for EDW investments options value is a significant fraction of the traditional NPV of the project. We also showed that the option value for the three-phase project is greater than the two-phase project, since management has an additional real option to defer the decision for funding the last stage of the project.

Figure 12 (a) is a breakdown of the three different deployment strategies considered in the previous section for the EDW deployment. For the volatility calculated using the Monte Carlo method, we see that the expanded NPV's of the two- and three-phase strategies are both less than the traditional NPV of the single-phase strategy. This is because breaking the EDW project into phases delays the realization of cash reduction benefits from the project. This delay, due to the time value of money, thus reduced the traditional NPV of the phase-wise deployment compared to the single phase deployment. In Fig. 12 (a) the expanded NPV is the expected value of the net project cash flows with the real option included. Hence, in this case, the value of the real option is not large enough to compensate for the loss in NPV due to the delayed realized benefits in the phase-wise deployment. Based on these numbers, management should select the single phase strategy, since this has the highest total NPV compared to the phase-wise strategies.

Figure 12 (b) is an example of the three deployment strategies where the volatility of the individual phases of the project is increased to 35%. In this case the expanded NPV of the two-phase strategy is now greater than the single-phase deployment NPV. The three-phase strategy has an even larger option premium than the two-phase strategy; however this does not offset the time value of money impact to the delay in cash benefits from delaying the project. Hence, in this case management should choose the two–phase deployment strategy, since the embedded real options significantly increase the expected value for the entire project, and this value is greater than the three-phase strategy.

Figure 13 is a plot of the expanded NPV's of the two-phase and three-phase deployment strategies as a function of volatility. When the volatility of the project is such that the expanded NPV's of the multi-phase strategies are greater than the traditional NPV of the single–phase deployment strategy, management should select the appropriate multi-phase deployment strategy.

For a high volatility project, the management decision to execute in two-, three-, or *n*-stages depends upon how phase-wise deployment reduces the traditional NPV of the project by deferring net benefits. For the special case where breaking the project into multiple phases has the same NPV as the single phase project, the multi-phase project will always have a larger expanded NPV.

Hence, in this case the largest number of phases that can be practically implemented will give the project the highest expected value for the expanded NPV, since the real option value is maximized. Real options can therefore be utilized to help define the optional deployment strategy for a large enterprise technology project in the presence of risk.

SUMMARY AND CONCLUSION

Real options are often applied to management selection of technology projects that have a negative traditional NPV. When real options are incorporated, these projects may have an expanded NPV greater than zero, thus justifying funding. However, the reality of most IT departments is that capital is limited, or rationed, so that positive NPV projects are not always funded. The challenge in practice is therefore rarely to justify negative NPV projects that have option value, but to objectively select an optimal project portfolio given capital budgeting constraints. We examined enterprise technology projects that have a positive traditional NPV. Incorporating option value enables management to (1) more objectively compare and rank projects in a capital rationed IT portfolio management process using an expanded profitability index, and (2) decide upon the optimal deployment strategy for the project.

As an example, we have analyzed different phase-wide deployment strategies for large enterprise data warehouse data mart consolidation projects. Management has the choice to consolidate all of the data marts in one phase, or to consolidate using multi-phase strategies. We consider single-phase, two-phase and three-phase consolidation strategies in the presence of risk.

We calculate option values using the binomial and Black-Scholes models. Risk in the EDW cost containment data mart consolidation project is incorporated through two major components in the cash flows: personnel reduction and project duration risk. The mean and standard deviation of input variables were obtained from historical data and interviews with management executives. All costs incorporated in the model were representative of actual data mart and EDW operating costs. The volatility in each possible phase of the project was then calculated by varying several variables in the cash flows for 10,000 Monte Carlo iterations.

We also examined the lattice granularity necessary so that discrete time option valuation models more accurately describe large enterprise projects. The single-step binomial model is appropriate for short projects (three months or less) where management will have limited opportunity to influence the outcome of the project. However, large enterprise projects will have management reviews quarterly and even weekly, and risk events will impact the project with a random periodicity. Since there is a significant opportunity during the life of the project for management to influence the expected value of the project cash flows, a more realistic solution would use a binomial lattice with multiple steps.

We calculate two-phase option values assuming a lattice with 52 steps, corresponding to weekly management reviews during a year. Our results show that a multi-step (52 stage) binomial model more accurately calculates the option value with results within 0.01% of the Black-Scholes model. We also developed a multi-step binomial algorithm to value multi-stage options, and show how the option value converges as the lattice granularity is increased.

Different deployment strategies with different underlying net present values and volatilities were compared. Increasing the number of phases in the project has the advantage of increasing the number of individual options that constitute a full compound option. However, in the EDW data mart consolidation considered, adding additional phases also delays the realization of cost saving benefits thus reducing the traditional NPV of each phase. There is therefore a management tradeoff between option value from deferring management decisions, and delaying cost saving benefits.

For the specific case example of the Teradata EDW the calculated volatility of the project is relatively low (~11%). In this case the management decisions should be to consolidate the entire 15 data marts in a single phase, since the option premium resulting from phase-wise deployment does not compensate for the time delay in cost savings.

However, in general if the volatility of the project is large, the option premium added to the NPV of the delayed phase may be larger than the NPV of the single phase project. For the EDW example, volatility greater than 26% would have made the expanded NPV of the two phase strategy greater than the traditional NPV. In this case, the multi-phase strategy is preferred since the expected value of the entire project is improved and the expanded NPV of the two-phase strategy with the real options will be larger than the single-phase NPV. We discussed how the selection of a particular phase-wise strategy (2-phase vs. 3-phase vs. *n*-phase) depends upon the traditional NPV of each project phase and the volatility of the project phases.

These results show that the traditional NPV of the project combined with additional option premiums can provide important insight into the selection of an optimal deployment strategy for an enterprise technology project. In addition, the option value of phase-wise deployment and other real options embedded in projects are important factors to consider when ranking and selecting projects in the typical capital rationed IT portfolio management process. Our results are applicable to a large class of IT investment decisions where managers may consider single-phase versus multi-phase deployment in the presence of project risk.

References

Black, F., and Scholes, M. "The Pricing of options and corporate liabilities," Journal of Political Economy, vol. 81, pp. 637-659, May-June, 1973

Benaroch, M., and Kauffman, R. "A Case for Using Real Options Pricing Analysis to Evaluate Information Technology Project Investments," Information Systems Research, vol. 10, No. 1: 70-87, March 1999

Brealey, R., and Myers, S. Principles of Corporate Finance, Sixth Edition, Irwin McGraw-Hill, 2000.

Copeland, T., and Antikarov, V. Real Options – a Practitioner's Guide, TEXERE LLC, 2001

Cox, J., Ross, S., and Rubinstein, M. "Option Pricing: A simplified approach," Journal of Financial Economics, vol. 7, no. 3: 229-263, 1979.

Davenport, T. "Putting the Enterprise into the Enterprise System," Harvard Business Review, July-August, pp: 121-131, 1998.

Dean, J. Capital Budgeting, Columbia University Press, 1951.

Hayes, R., and Abernathy, W. "Managing our way to economic decline," Harvard Business Review, vol. 58, no. 4: 66-77, 1980.

Hayes, R., and Garvin, D. "Managing as if tomorrow mattered," Harvard Business Review, vol. 60, no. 3: 71-79, 1982.

Herath, H., and Park, C. "Multi-Stage Capital Investment Opportunities as Compound Real Options," The Engineering Economist, vol. 47, no.1, 2002

IDC, "Worldwide Data Warehousing Tools Forecast and Analysis, 2000-2005," 2000.

Jeffery, M., and Leliveld, I. "Survey: IT Portfolio Management Challenges and Best Practices," Kellogg School of Management and DiamondCluster International, 2002. Posted online at: www.kellogg.northwestern.edu/ITsurvey

Kasanen, E., and Trigeorgis, L. "A market utility approach to investment valuation," European Journal of Operational Research, vol. 74, no. 2: 294-309, 1994.

M. Keil, M., Cule, P., Lyytinen, K., and Schmidt, R. "A Framework for Identifying Software Project Risks," Communications of the ACM, vol. 41, no. 11: 76-83, 1998.

Kelly, S. Data Warehousing in Action, John Wiley & Sons, Chichester, 1997

Kumar, R. "A Note on Project Risk and Option Values of Investments in Information Technologies," Journal of Management Information Systems, vol. 13, no. 1: 187-193, 1996.

Kumar, R. "Understanding DSS Value: An Options Perspective," Omega, The International Journal of Management Science, vol. 27, pp. 295-304, 1999.

Kumar, R. "Justifying Data Warehousing Investments," Journal of Database Management, vol. 11, no. 3: 35-36, July-Sept, 2000

Lander, D., and Pinches, G. "Challenges to the Practical Implementation of Modeling and Valuing Real Options," The Quarterly Review of Economics and Finance, vol. 38: 537-567, 1998

Mason, S., and Merton, R. "The role of contingent claims analysis in corporate finance," In Recent Advances in Corporate Finance, ed. E. Altman and M. Subrahmanyam, Irwin, 1985.

McDonald, R. Option Pricing Spreadsheet. Kellogg Graduate School of Management, Finance Department, 1996

McFarlan, F. "Portfolio Approach to Information Systems," Harvard Business Review, vol. 59, no. 5: 142-150, 1981.

Merton, R. "Theory of rational option pricing," Bell Journal of Economics and Management Science, vol. 4, no. 1: 141-183, 1973.

Meta Group, Benchmarking Report, 2003

Panayi, S., and Trigeorgis, L. "Multi-stage Real Options: The cases of Information Technology Infrastructure and International Bank Expansion," The Quarterly Review of Economics and Finance, vol. 38, Special Issue, pp. 675-692, 1998.

Rigby, D., Reichheld, F., and Schefter, P. "Avoid the Four Perils of CRM," Harvard Business Review, February, pp: 101-109, 2002.

Sweeney, R., Davis, R., and Jeffery, M. Case Study, "Teradata Data Mart Consolidation: Return on Investment at GST," 2002. Posted online at: www.kellogg.northwestern.edu/IT/portfoliocases

Sweeney, R., Davis, R., and Jeffery, M. Case Study, "ROI for a Customer Relationship Management Initiative at GST," 2002. Posted online at: www.kellogg.northwestern.edu/IT/portfoliocases

Taudes, Feurstein, M., and Mild, A. "Options Analysis of Software Platform Decisions: A Case Study," MIS Quarterly, vol. 24, no. 2: 227-243, June 2000.

Thomas, R. "Business value analysis: - coping with unruly uncertainty," Strategy & Leadership, vol. 29, no. 2, p:16 Mar-Apr, 2001.

Trigeorgis, L. Real Options – Managerial Flexibility and Strategy in Resource Allocation, The MIT Press, 1996.

Verity, D., "Real Options – An Analytical Approach to Aligning Risk Management and Corporate Strategy," Corporate Finance Review, July 1999.

Watson, H., Annino, D., and Wixom, B. "Current Practices in Data Warehousing," Information Systems Management, pp: 47-55, Winter 2001.

Watson, H., Matyska, R., and Thilini, T. "Data Warehousing Stages of growth," Information Systems Management, vol. 18, no. 3: 42-50, Summer 2001.

Wiell, P., and Broadbent, M. Leveraging the New Infrastructure – How Market Leaders Capitalize on Information Technology, Harvard Business School Press, 1998.

Wixom, B., and Watson, H. "An empirical investigation of the factors affecting data warehousing success," MIS Quarterly, vol. 25, no. 1: 17-41, March 2001.

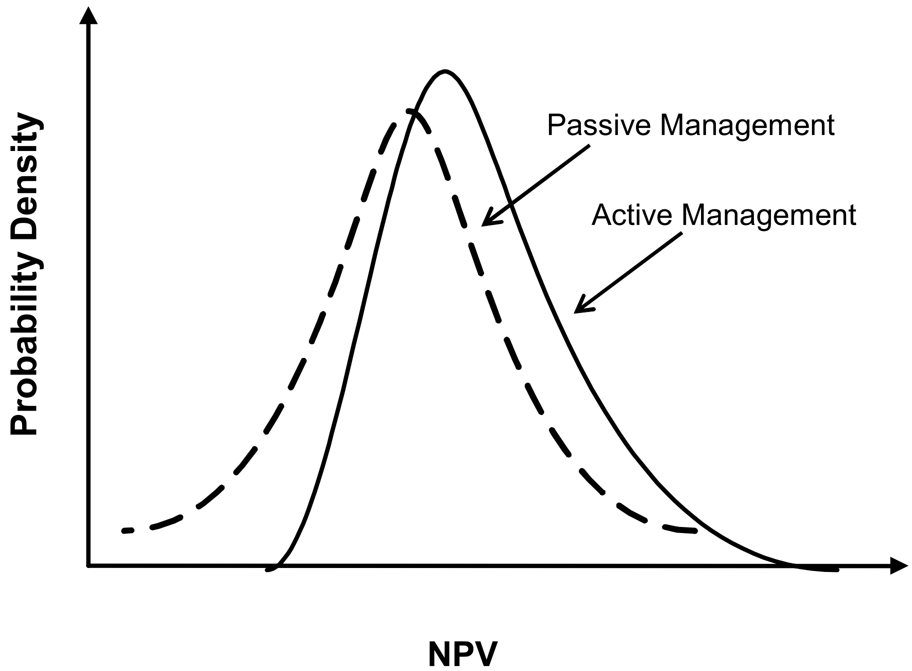


Figure1. Uncertainty under passive and active management of the project (Modified from Trigeorgis 1996)

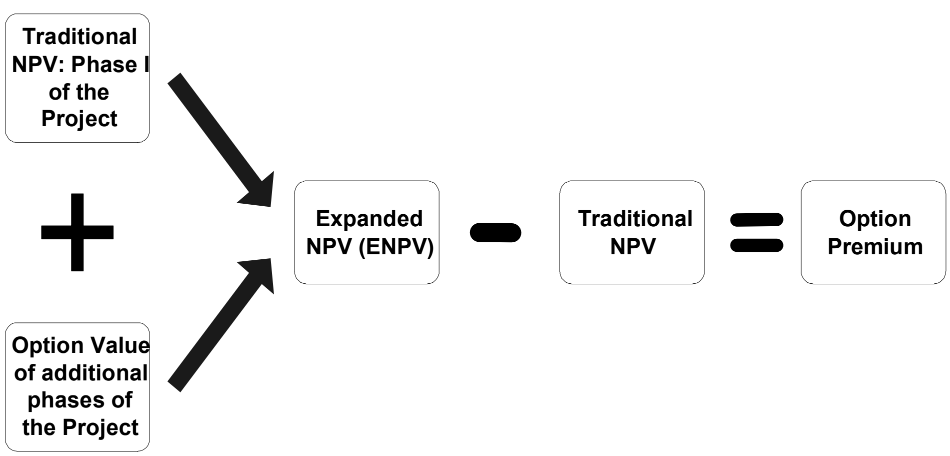


Figure 2. Real options model: Basic framework.

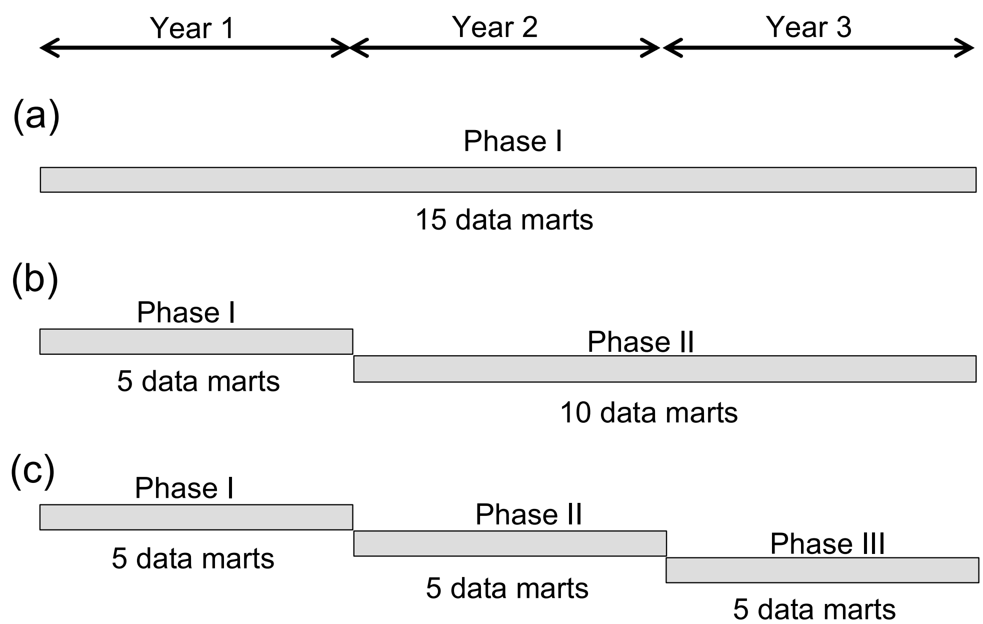


Figure 3. Data mart consolidation strategies: (a) single-phase data mart consolidation, (b) two-phase data mart consolidation, and (c) three-phase data mart consolidation into an enterprise data warehouse.

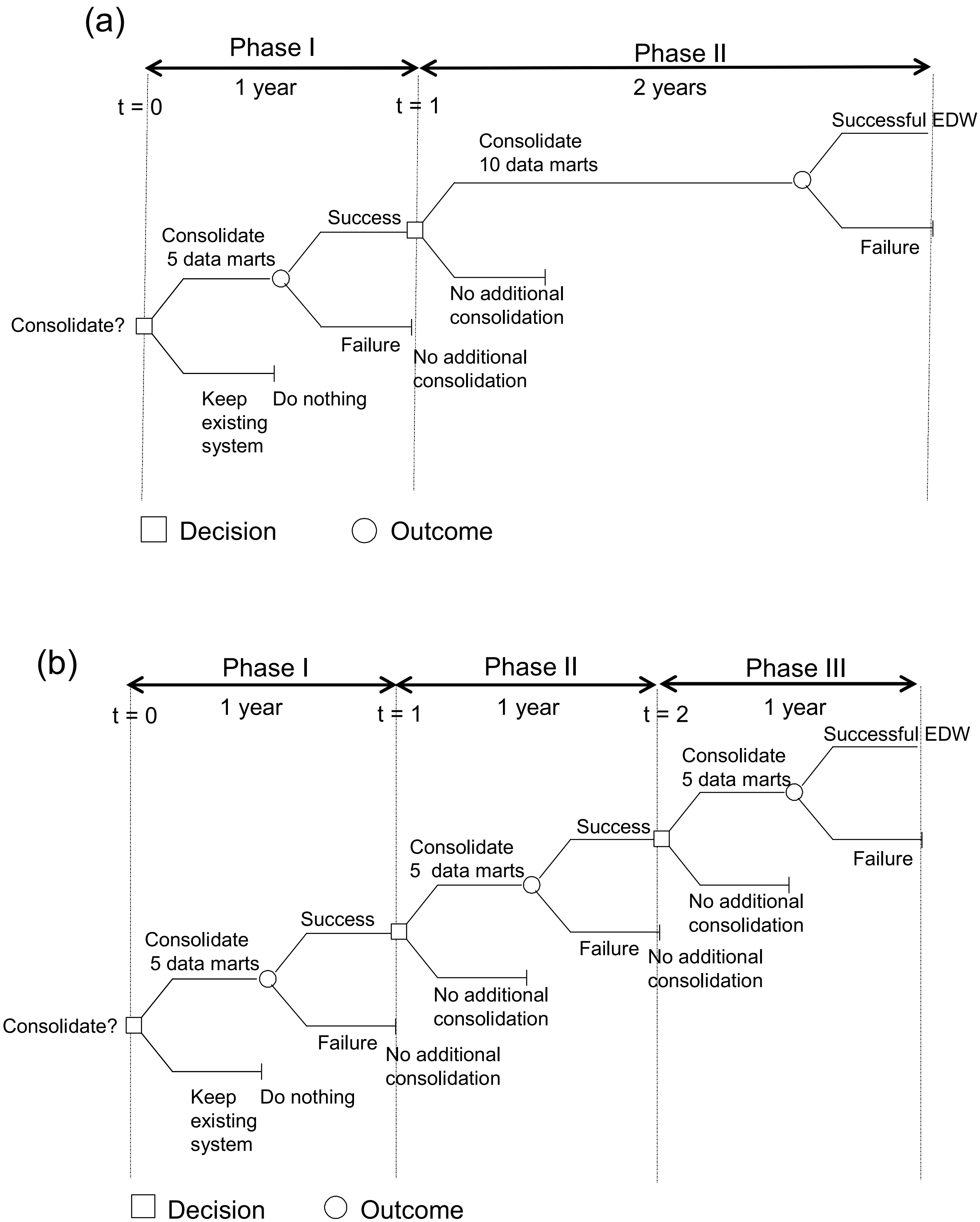


Figure 4. Possible event trees for the data mart consolidation EDW project: (a) two-phase data mart consolidation, and (b) three-stage data mart consolidation.

(a)

Base Case

	Year 0	Year 1	Year 2	Year 3	Year 4
Salary and Benefits		5,677,000	5,904,080	6,140,243	6,385,853
Training		0	0	0	0
Profession Services		0	0	0	0
Maintenance/Upgrade		430,000	430,000	430,000	430,000
Non Personnel Support		5,800,000	6,090,000	6,394,500	6,714,225
Total		11,907,000	12,424,080	12,964,743	13,530,078
After Tax Cash Flows		7,382,340	7,702,930	8,038,141	8,388,648
Less: Tax Rate * Depreciation		0	0	0	0
Total Cash Flows (US $)	0	7,382,340	7,702,930	8,038,141	8,388,648

(b)

Proposed Consolidation

	Year 0	Year 1	Year 2	Year 3	Year 4
Salary and Benefits		4,322,500	3,086,720	3,210,189	3,338,596
Training		90,000	180,000	90,000	0
Profession Services		1,080,000	0	0	0
Maintenance/Upgrade		430,000	268,000	268,000	268,000
Non Personnel Support		4,850,000	4,095,000	4,299,750	4,514,738
Total		10,772,500	7,629,720	7,867,939	8,121,334
After Tax Cash Flows		6,678,950	4,730,426	4,878,122	5,035,227
Upfront Costs of Consolidation	(5,351,094)				
Less: Tax Rate * Depreciation		(406,683)	(650,693)	(390,416)	(585,624)
Total Cash Flows (US $)	(5,351,094)	6,272,267	4,079,733	4,487,706	4,449,603

(c)

Incremental Cash Flows

	Year 0	Year 1	Year 2	Year 3	Year 4
Net Incremental Cash Flows	(5,351,094)	1,110,073	3,623,196	3,550,435	3,939,045

Net Present Value (US $)	$ 3,139,259
Discount Rate	14%
Tax Rate	38%
Internal Rate of Return (IRR)	35.87%

Figure 5. Traditional NPV calculation for Phase I (5 DMs) of the project: (a) the base case cash flows for old configuration, (b) the cash flows for new consolidated configuration, and (c) the incremental cash flows, NPV, and IRR calculation.

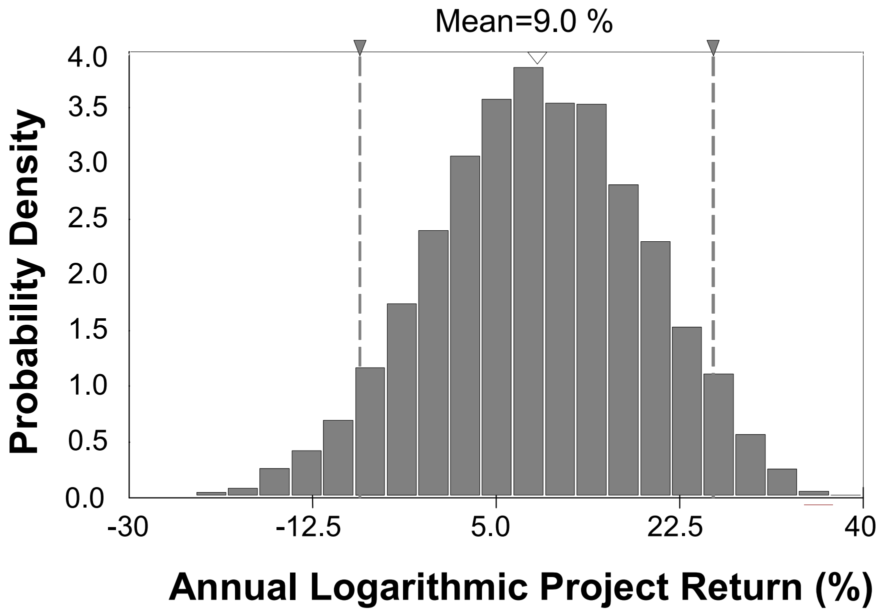


Figure 6. Distribution of project returns for Phase II of the two-phase project, 10 data mart consolidation. Project return refers to the percent changes in the value of the project from one period to the next, see Eq. 6. 90% of the project returns fall between the dashed lines.

(a) Two-stage project Valuation

Traditional Approach

NPV - Phase 1 (5 DMs)	$	3,139,259
NPV - Phase 2 (10 DMs)	$	2,964,871
Total NPV of the Project (Static NPV)	$	6,104,130

Real Option Approach	**1-Step Binomial**		**52-Step Binomial**		**Black Scholes**	
Traditional NPV - Phase 1 (5 DMs)	$	3,139,259	$	3,139,259	$	3,139,259
Real Option Value - Phase 2 (10 DMs)	$	3,379,953	$	3,670,269	$	3,670,644
Total NPV of the Project (Expanded NPV)	$	6,800,909	$	6,809,528	$	6,809,903
Option Premium	$	696,779	$	705,398	$	705,773

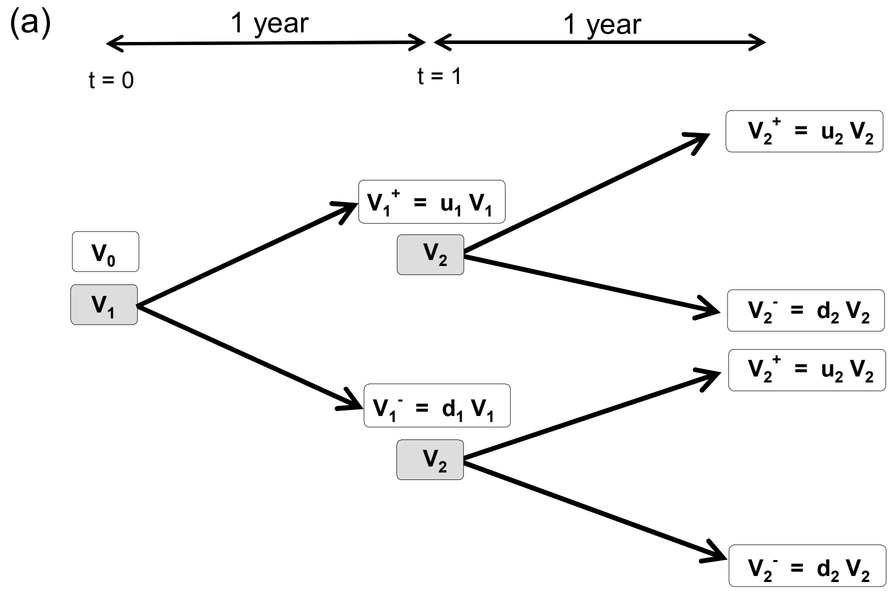
(b) Three-stage project Valuation

Traditional Approach

NPV - Phase 1 (5 DMs)	$	3,139,259
NPV - Phase 2 (5 DMs)	$	965,549
NPV - Phase 3 (5 DMs)	$	(255,824)
Total NPV of the Project (Static NPV)	$	3,848,984

Real Option Approach	**1-Step Binomial**		**52-Step Binomial**	
Traditional NPV - Phase 1 (5 DMs)	$	3,139,259	$	3,139,259
Real Option Value (Compound Option - Phase 2 and Phase 3)	$	1,619,360	$	1,565,780
Total NPV of the Project (Expanded NPV)	$	4,758,619	$	4,705,039
Option Premium	$	909,635	$	856,055

Figure 7. Real option calculation: (a) two-stage project using the single-step binomial method, a 52-step binomial method, and the Black Scholes method, (b) three-stage project using the single-step binomial method and a 52-step binomial method



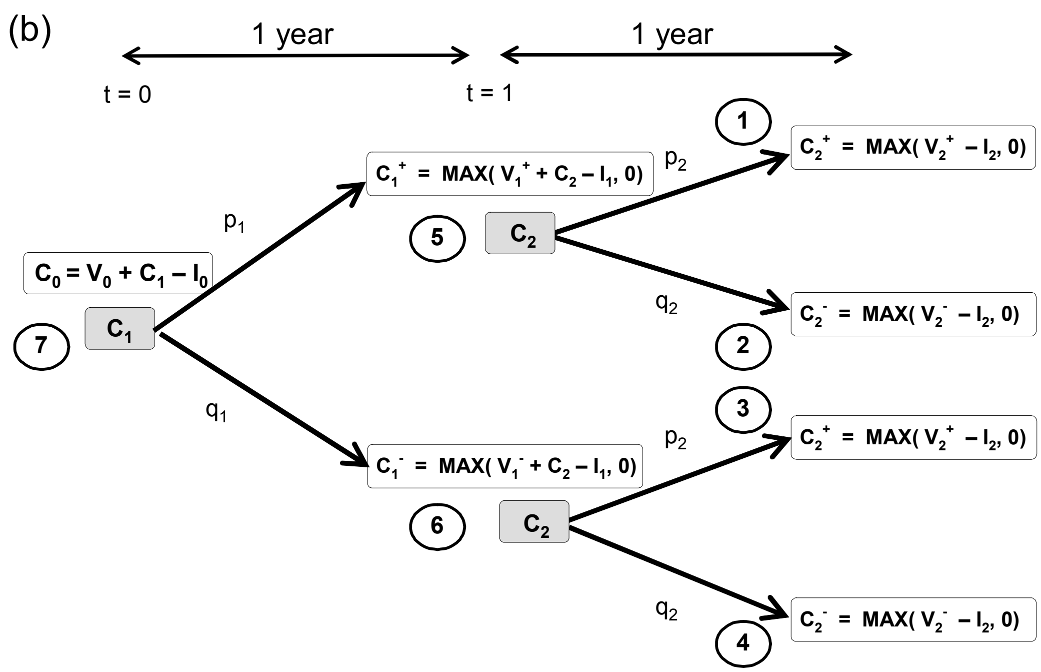


Figure 8. (a) Project value binomial lattice for the real options in the three-stage deployment strategy. (b) Call option payoff diagram for the real options in the three-stage deployment strategy, and (c) formulas for the option parameters used in the binomial method, where $r = 1 + r_f$ and r_f is the risk free rate.

Figure 8 continued…

(c)

	Real Call Option - C_1		Real Call Option - C_2	
	Multiplication Factor	***Risk Neutral Probability***	***Multiplication Factor***	***Risk Neutral Probability***
Up Movement	u_1 = exp (σ_1*sqrt(Δt))	p_1 = (r - d_1)/(u_1 - d_1)	u_2 = exp (σ_2*sqrt(Δt))	p_2 = (r - d_2)/(u_2 - d_2)
Down Movement	d_1 = 1 / u_1	q_1 = 1 - p_1	d_2 = 1 / u_2	q_2 = 1 - p_2
Up Movement			u_2 = exp (σ_2*sqrt(Δt))	p_2 = (r - d_2)/(u_2 - d_2)
Down Movement			d_2 = 1 / u2	q_2 = 1 - p_2

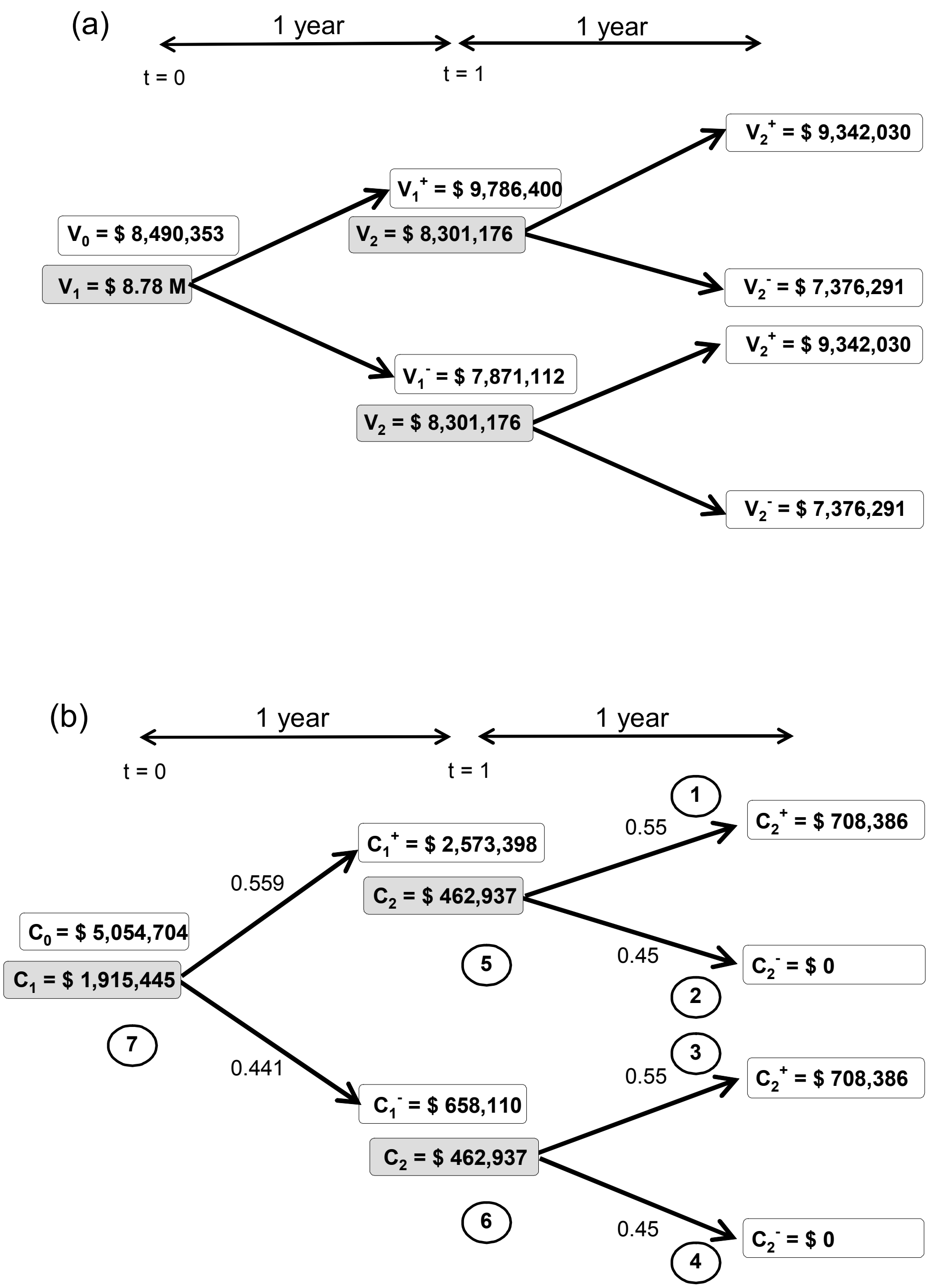


Figure 9. (a) Binomial lattice with the actual numerical project values for each component of the three-stage deployment strategy, and (b) the numerical call option payoffs for the real options in the three-deployment strategy.

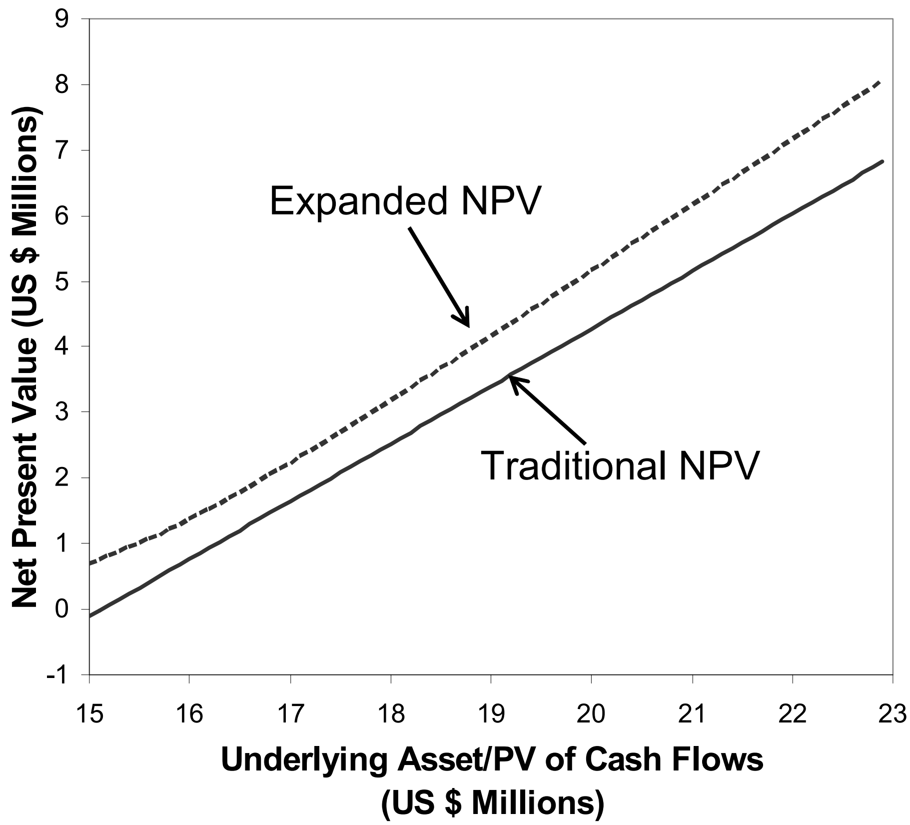


Figure 10. Sensitivity Analysis: expanded NPV as a function of the underlying asset for the two-stage deployment strategy.

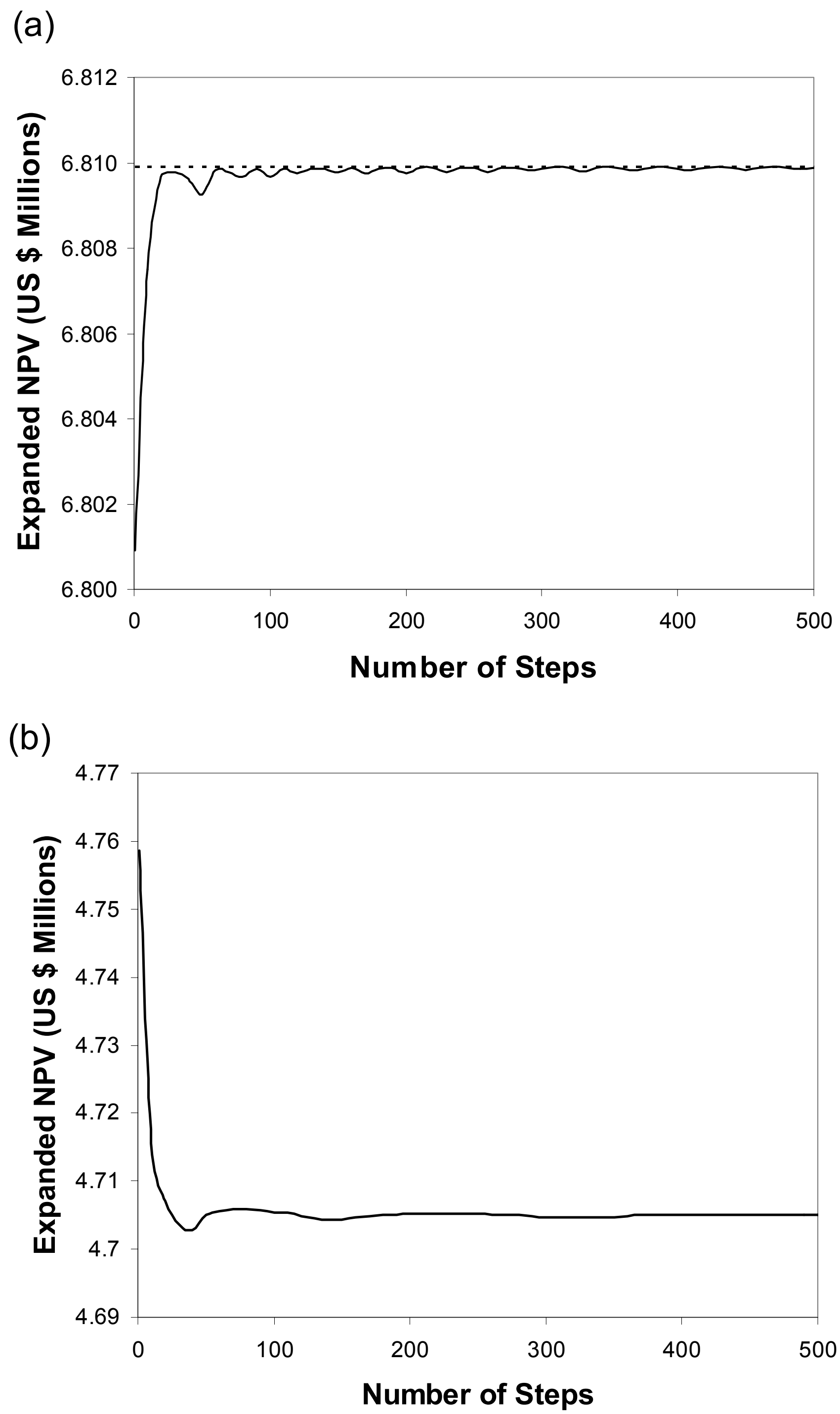


Figure 11. Expanded NPV as a function of number of binomial lattice steps (a) for the two-phase deployment strategy, the dashed line is the Black-Scholes numerical calculation, and (b) for the three-phase deployment strategy.

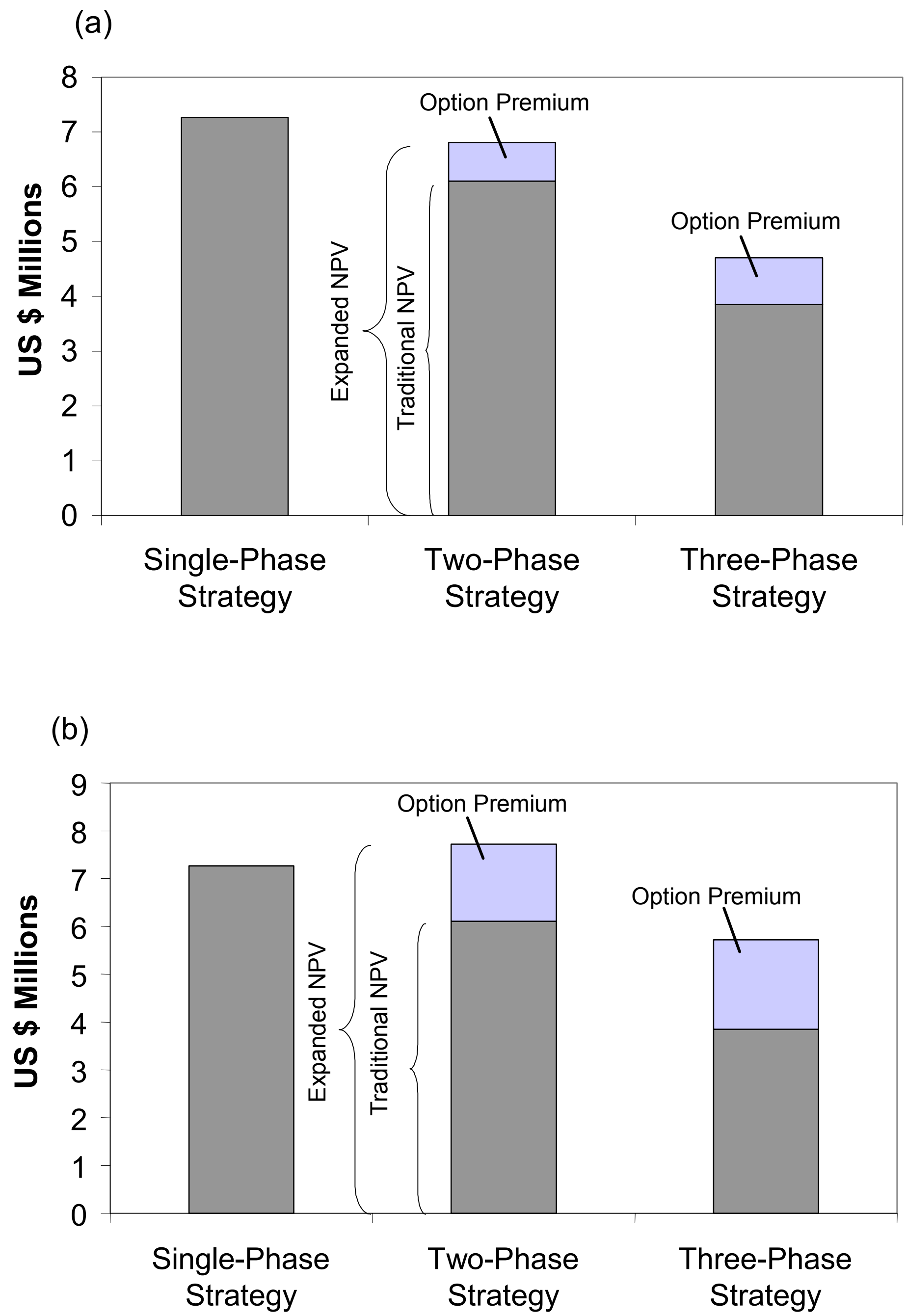


Figure12. (a) Comparison of traditional NPV and expanded NPV for the three deployment strategies. Note that the real option analysis was performed using a 52-step binomial method. (b) Comparison of traditional NPV and expanded NPV for the project subject to higher risk and a volatility of 35%.

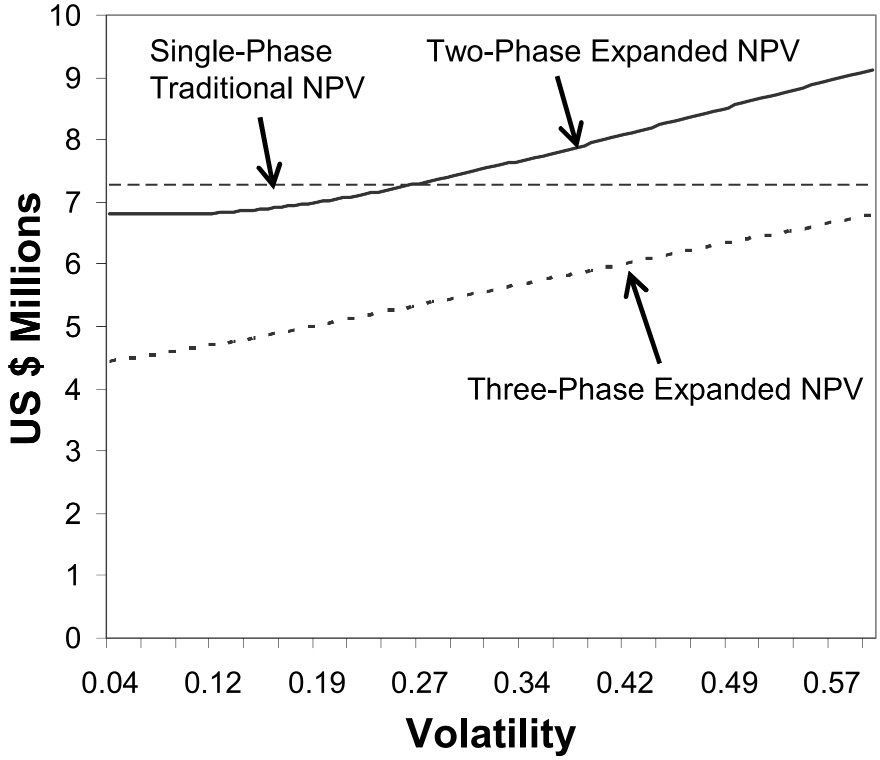


Figure 13. Optimal deployment strategy: Tradeoff between the risk of the project and the deployment strategy.

Table 1. Uncertain Variables that impact project returns for the two-stage deployment strategy.

Uncertain Variable	Type of Distribution	Mean	Standard Deviation	Minimum Truncate	Maximum Truncate
DB Analyst	Normal	16	4	8	22
ETL Programmer	Normal	8	16	4	20
Querry Programmer	Normal	20	20	12	30
Support Staff	Normal	6	4	2	20
Decommission Period	Normal	8	4	4	12

Table 2. Option Value Parameters: (a) the real option parameters for options embedded in two-stage strategy, and (b) the real option parameters for options embedded in three-stage strategy.

(a) Option parameters for the real options in the Two-Stage Project

Option Description	Option Type	Underlying Asset	Exercise Price	Volatility	Time to expire
Phase I (5DM) at T_0 (C_0)	Nested European CALL	Expected PV of Incremental Cash Flows (V_0) \$ 8,490,353	Investment (I_0) \$ 5,351,094	σ_0 9.70 %	At T_0
Phase II (10 DM) at T_1 (C_1)	Standard European CALL	Expected PV of Incremental Cash Flows (V_1) \$ 18,505,154	Investment (I_1) \$ 15,125,201	σ_1 10.17%	At T_1 (One Year from T_0)

(b) Option parameters for the real options in the Three-Stage Project

Option Description	Option Type	Underlyying Asset	Exercise Price	Volatility	Time to expire
Phase I (5DM) at T_0 (C_0)	Nested European CALL	Expected PV of Incremental Cash Flows (V_0) \$ 8,490,353	Investment (I_0) \$ 5,351,054	σ_0 9.70 %	At T_0
Phase II (5 DM) at T_1 (C_1)	Nested European CALL	Expected PV of Incremental Cash Flows (V_1) \$ 8,776,665	Investment (I_1) \$ 7,675,939	σ_1 10.89%	At T_1 (One Year from T_0)
Phase III (5 DM) at T_2 (C_2)	Standard European CALL	Expected PV of Incremental Cash Flows (V_2) \$ 8,301,176	Investment (I_2) \$ 8,633,645	σ_2 11.81%	At T_2 (One Year from T_1)