Singapore Management University
Institutional Knowledge at Singapore Management University

Research Collection School Of Information Systems

School of Information Systems

1-2007

Value-at-Risk in IT Services Contracts

Robert J. KAUFFMAN
Singapore Management University, rkauffman@smu.edu.sg

Ryan SOUGSTAD
University of Minnesota - Duluth

Follow this and additional works at: https://ink.library.smu.edu.sg/sis_research

Part of the Computer Sciences Commons, and the Management Information Systems Commons

Citation

VALUE-AT-RISK IN IT SERVICES CONTRACTS

Robert J. Kauffman and Ryan Sougstad

MIS Research Center, Carlson School of Management, University of Minnesota
{rkauffman; rsougstad}@csom.umn.edu

ABSTRACT. *As information systems (IS) and technology solutions become increasingly service-driven, managers are faced with the task of choosing parameters such as service-levels, pricing, and contract duration. Information technology (IT) services vendors manage portfolios of contracts in which parameters, decided at inception, are often subject to future risks. The contract profit maximization decision may adversely affect the risk position of the firm's portfolio of services contracts. We propose a model to inform vendors on setting optimal parameters for IS contracts subject to acceptable levels of risk. The analytic model presented draws from IS economics research and the principles of value-at-risk (VaR) from financial economics. We provide examples which illustrate the trade-offs of profit maximizing contractual decisions to portfolio profit-at-risk (PaR). The contribution of this research is the application of VaR analysis to IS contractual decisions and the conceptualization of an economic model of IS service contracts which embeds value-at-risk constraints.*

Keywords: Contract evaluation, financial economics, IT services, managerial decision making, mechanism design, value-at-risk.

1. INTRODUCTION

Recent advances in open-standards architecture, information and communications technologies (ICTs), and the realization of large offshore talent pools have led to an increase in service-driven IT solutions [41]. New mechanisms such as grid computing, Web services, application service providers (ASPs) and business process outsourcing (BPO) allow firms to adopt flexible, service-driven solutions. Some pundits predict the end of the aforementioned traditional model of IT acquisition in favor of a purely service-driven technology marketplace [19]. In addition, many technology vendors such as IBM (On-Demand), HP (Adaptive Enterprise) are now touting flexible, service-driven approaches to IT delivery. Service-driven IT strategies reduce the requirements for upfront investments for user firms and permit shared exposure of many technology risks with the vendors through contracts [38].

However, IT services contract structure poses unique challenges for service vendors. With the increased flexibility offered by service-driven IT solutions comes increased complexity and exposure to risk. IT services contracts typically cover a vast array of terms, such as service level, quality, timeliness, and penalties and incentives around these contractual parameters. Such contractual obligations, in fact, are contingent liabilities to which the vendors are obligated.

Underscoring many of these liabilities are risks involving technology costs, standards and skills. Established IT service vendors with multiple contracts across a diverse client base can be thought of as managers of financial portfolios, the value of which will be determined by the interaction of underlying risk factors among client contracts. Decisions regarding an individual contract may impact the overall risk exposure of a client's portfolio. For example, a manager may obligate the firm to provide a specialized programming skill as part of a contract to which the firm already faces availability constraints. While the manager may have made a profit or revenue- maximizing decision regarding the structure of the contract, the added contingent liability may subject the firm to unacceptable risk to the profitability of its overall IT services contract portfolio. We propose an analytic model to quantify the fundamental tradeoff between IS contract service levels, profitability and risk.

Sourcing IT solutions in the form of services implies a new breed of risks for user firms, such as misappropriation of sensitive information and incentive alignments [21,32,43]. Indeed, such risks and approaches to risk mitigation have long been the subject of IS research [4,20]. However, IT services also mitigate risks. Bhargrava and Sunderasan [17] model a pricing scheme for utility computing services. They show that the service vendor is an aggregator of user *demand risk*. User firms can increase capacity in their contract without the upfront investment required in a traditional IT solution strategy. Thus, the vendor takes on the risk of the individual user firm's demand uncertainty.

Service-driven IT solutions allow for a great deal of managerial flexibility and risk sharing between IS users and their service vendors. However, this flexibility brings an increased number of decision criteria for both clients (user firms) and vendors. In a service-driven solution, the contract contains many parameters which parties must negotiate. These parameters will affect not only the value of the solution or contract at hand, but also will affect the value of the overall portfolio of contracts a firm holds. Contractual parameters such as service and security level, service sourcing, timing, incentives and penalties in aggregate, present a web of endogenous and exogenous risk factors. These contractual risk factors will either amplify the overall risk exposure of a firm, or lessen it due to negative correlations which allow for *strategic hedging* of IT services contracts. Managers are faced with a fundamental tradeoff: how to maximize the profitability of services

contracts while maintaining an acceptable level of risk exposure to the overall contract portfolio.

New methods and quantitative tools are required to actively manage both individual contractual profitability and overall portfolio value and risk tolerance. Thus, we ask the following fundamental research questions: (1) How should an IT services vendor optimally set contractual parameters given an acceptable level of firm-wide contract portfolio risk? (2) How can we achieve a better understanding of risk exposure in IT services contracts to inform managerial decision making? We develop our evaluative approach using value-at-risk (VaR) concepts from financial economics, a theory base that offers unique potential for the study of IS management issues [6,21,44].

2. BACKGROUND LITERATURE

This research draws on three primary theoretical perspectives. The value-at-risk literature from financial economics informs managerial decision making with regards to risk tolerance. IS real option analysis informs the modeling of IS risk factors and the value of managerial flexibility. Finally, the pricing of IT services and information economics provides insights in the formulation of our model.

2.1. Real Options

Real options research in IS represents one of the first attempts to consider the value of managerial flexibility in the face of IS investment risks. Real options research has its genesis in the field of finance with Black and Scholes's [15] development of their option pricing model. An *option* gives the bearer the right, but not obligation to purchase (call) or sell (put) an asset at a specific price at a later date in time. Researchers, Dixit and Pindyck [26], recognized that a broad context of investment decisions can be conceptualized as *real options*. For example, managers often invest in a pilot project which then enables them the option to invest in a full-scale rollout depending on how conditions, initially subject to uncertainty, materialize. Such options can be evaluated using financial economics methods.

Researchers have extended real options thinking with applications of other theory from decision sciences, economics and finance. Rob Kauffman (in [58]) has referred to this as the "third image" of real options research in IS. Dai [25] and Zhu [60] incorporated game-theoretical approaches to real option analysis. This blend of economic optimization with options thinking, in our view, will be helpful to inform the modeling of optimal contract parameters for systems services. In addition, Fichman et al. [29] and Tallon et al. [58] stress the need to view real options as a strategic management tool. In many respects, the analysis of optimal contractual parameters is an extension of option thinking in which managers become aware of the value of managerial flexibility and the risk-return trade-offs in contract portfolios.

Recent trends in IS research on real options provide useful guidance for the contractual parameters, as well as the portfolio-level impacts. Kauffman and Li [42], for example, developed a model to identify the optimal timing of technology investments using real options. They model the uncertainties surrounding competing technologies which could be applied in a portfolio hedging analysis of contractual parameters involving competing technology standards. Bardhan et al. [8] model the effects of forgoing or delaying a project in an interrelated portfolio of IS investments. Bardhan et al. [7] further develop a model for optimizing time-wise dependencies on IT investment portfolios.

2.2. Value-at-Risk (VaR)

Value-at-risk portfolio analysis techniques were pioneered by a team at JP Morgan in New York City. VaR has its roots in the aftermath of several major financial calamities in the late 1980s and early 1990s, including the fall of Barings Bank of the Netherlands [45] and other international financial problems, and the Orange County, California treasury disaster [28,36,37]. VaR provided management with a new means to better understand and control firm-wide risk exposure. A related approach called *risk-adjusted return on capital* (RAROC) was under simultaneous development at Bankers Trust New York [23]. Many of the VaR concepts come from the early derivative pricing work of Merton, Black and Scholes, and Cox et al. [15,24,52], the modern portfolio theory of Markowitz [51 and the capital asset pricing model and asset risk management ideas of Sharpe [55] and Lintner [47].

Value-at-risk can be defined as *a measurement of the worst expected loss over a given time horizon under normal market conditions at a given confidence interval* [36]. Initially, financial institutions used VaR analysis for passive information reporting to understand their risk exposures. However, VaR techniques quickly grew towards *defensive information reporting*, where firms began to implement standards and controls to avoid large-scale disasters. As a result, VaR is now used as an active risk management tool. Today, VaR theory and the associated methodologies for controlling risk in lending and credit, money market and derivative instrument trading, and investment management operations are advanced. VaR methods are almost universally accepted as a basic part of a financial firm's risk management tool kit, which is essential for the effective management of overall portfolio risks.

Several researchers have examined optimal portfolio construction under VaR constraints. Liebowitz and Kogelman [46] and Lucas and Klaasen [48] were among the first to construct optimal portfolios subject to shortfall constraints in the form of minimum returns. Campbell et al. [18] develop a model to optimize portfolio selection between stock and bond investments in

a VaR framework. Anderson et al. [3] produce a model of credit risk optimization under *conditional value-at-risk*, which alleviates the issue of kurtosis by taking a mean value of expected losses. [1]

2.3. IT Services Pricing

Research in IT services pricing has its roots in auction economics. Westland [59] model IT services prices based on congestion and network externalities. Gupta et al. [31] develop a model for dynamic pricing of network access based on usage. Bhargrava and Sundaresan [16,17] present an optimization model for quality-contingent IT services and later develop a model to price grid computing solutions with demand uncertainty using an auction mechanism. Cheng and Kohler [22] further describe optimal pricing policies for Web-delivered applications using queuing theory. Sundararajan [57] examines fixed fee vs. usage-based pricing of information goods in situations of incomplete information. Huang and Sundararajan [34] model the adoption patterns of firms utilizing on-demand computing.

One of the few works that incorporates VaR theory in an IT setting is Paleologo [53]. He introduces a method for pricing utility computing services called *price-at-risk*. He argues that traditional cost-based pricing is not value-maximizing given the dynamics of utility computing services due to the reduced contract duration (vs. traditional outsourcing), low customer switching cost, high levels of demand uncertainty, high sunk costs, and the short product life cycle of a utility computing infrastructure. He models these uncertainties with a confidence interval approach which has similarities to a VaR model. He also uses a stochastic process for market adoption using a form of the Bass [10] model for technology adoption.

3. MODEL DEVELOPMENT

IT services encompass a broad range of application domains. Software development and business process outsourcing, IS security services, utility computing and Web-delivered application services are all areas in which pricing, service levels, and other parameters act as decision variables which will affect the overall profitability of the services contract. Examples of optimization parameters to consider are security and performance levels, contract timing (e.g., when to start, ability to abandon contract), amount a firm can sub-contract within the overall contact, and incentives and penalties.

3.1. Model Specification

One of the key characteristics of parameter selection

---

[1] The interested reader should examine the financial evaluation literature involved with the pricing of real options for technology and other corporate projects [2, 11, 12, 13, 14, 27, 39,49,53], portfolio risk and hedging methods [1,17,18], and additional VaR-specific methods [9,14,30,48]. See [55] for a more critical evaluation of the application of VaR methods.

is that the decision affects the customer demand, or *willingness-to-pay* (WTP) for the service. Thus, the contract can be thought of as a complex product with differing dimensions of quality, with service levels acting as quality parameter. For the model in this paper, we consider a *base case* in which a firm enters into an outsourcing contract for business process outsourcing (BPO). The firm chooses to offer a certain service level mix. In this example, we consider dedicated or pooled BPO resources, such as an IT help desk. We define *pooled resources* as either subcontracted, offshore or near-shore services, for example, a help desk call center owned by the vendor. The customer will prefer *dedicated resources* though; they will value the continuity and stability that dedicated resources provide. Thus the client's WTP is modeled as a function of the service level. The firm then selects a service level to maximize contract profits, subject to some level of value-at-risk.

The *value-at-risk constraint* in the proposed model is an application of VaR thinking to the IT services contract parameters. We model the costs of providing IT services as a stochastic variable. Costs will have an expected future value, as well as a random volatility component. The costs can be modeled as a Gauss-Weiner process, $dc = \mu dt + \sigma dz$. That is, the future costs will have a mean value, μdt, along with a random component, σdz, which may increase or diminish depending on market conditions or other risk factors.

To specify the value-at-risk constraint, we must consider four factors or value-at-risk inputs. See Table 1 and Appendix A for definitions.

Table 1. Value-at-Risk Inputs

Symbol	Value-at-Risk Input	Risk Equivalent
M	Mark-to-market position	C, estimated parameter cost at $t = 0$
σ	Risk factor variability	Future cost volatility
T	Time horizon	Time horizon
α	Confidence interval	Confidence interval
Note: *Mark-to-market* position represents an initial valuation of the asset or project. σ is the standard deviation of asset returns or other project factors. α is the confidence interval set by management that a threshold, called the *value-at-risk*, will not increase beyond over the time horizon, T.		

A contract will affect the firm's overall exposure to the cost parameters which the firms are liable to endure to provide services. We will examine not only the value-at-risk of an individual contract, but also the effect of a VaR position on the *aggregate liability* that the firm holds as a result of its portfolio of contracts.

3.2. Value-at-Risk Analysis Approach

We consider a monopoly IT services vendor that offers two distinct levels of service: high (H) and low (L). The service levels represent *dedicated on-site resources* vs. *pooled offshore resources*. We assume that

the service vendor negotiates with a firm that requires D fixed demand hours of service. We further assume that the service levels are substitutes from an efficiency standpoint, so that the service level does not affect the number of hours to complete the project. However, the high service level costs more for the vendor to provide and is more volatile because the vendor has less flexibility in shifting and sharing resources. The high service level is preferred by customers, reflected in the *willingness-to-pay* (WTP) *function. Service level S is* the percentage of the hours demanded which will be fulfilled with high service level costs, C_H. See Table 2 for our modeling notation.

Table 2. Definitions of Notation in the Model

NOTATION	DESCRIPTION
π	Firm profits
$V(S)$	Willingness-to-pay (WTP)
$TC(S, C_H, C_L)$	Total cost
$VaR(S, \sigma_H, \sigma_L, \rho_{HL}, t, \alpha)$	Value-at-risk of cost inputs
D	Services contract hours, fixed demand
S	Service level mix (0 to 1)
C_H, C_L	High (low) service level, H (L) cost
σ_H, σ_L	Stddev high (low) service level H (L) cost
ρ_{HL}	Correlation of H and L service costs
σ_P	Portfolio value at risk
$\alpha; T$	Confidence interval; time horizon
k	Arbitrary constant for VaR constraint
G	Firm WTP for high service level ($S = 1$)

The objective function is:

$$\text{Max}_{(S)}\ \pi = V(S) \cdot D - TC(S, C_H, C_L) \cdot D$$

$$\text{s.t. } VaR(S, \sigma_P, t, \alpha) \le k$$

$$0 \le S \le 1$$

The VaR constraint is a function of the exogenous cost volatilities, as well as the correlation of the high and low service level costs. [2] In an expanded version of the model, portfolio level risks are incorporated, such that the hours demanded in the contract and the decision variable S affect the existing portfolio. For example a firm might have a portfolio of contractual liabilities of 60 hrs of C_H and 30 hours of C_L. An additional contract for 10 hours would affect the overall portfolio of contracts depending on service level S. Thus, if $S = .5$, the total mix of the contract portfolio would be 65 hours of C_H (+5 hours) and 35 hours of C_L (+5 hours), resulting in a portfolio service level $S = .65$.

Thus the general constraint to the objective function

---

[2] The reader should note that we will use the term *profit-at-risk constraint* (or *PaR constraint*) in the next section, as we develop the analytical model to examine business process outsourcing contracts in IT services optimization.

in the portfolio context is:

$$VaR(S, \sigma_P(\sigma_H, \sigma_L, \rho_{HL}, \omega_H, \omega_L), t, Z) \le k$$

where $\sigma_P(\sigma_H, \sigma_L, \rho_{HL}, \omega_H, \omega_L) =$

$$\sqrt{(\omega_H^2 \sigma_H^2 + \omega_L^2 \sigma_L^2 + 2\omega_H \omega_L \sigma_H \sigma_L \rho_{HL})}.$$

In the illustrative example to follow we only consider the contract-level portfolio, where $S = \omega_H$, and within-contract risks.

3.3. Simulation

To illustrate the model at work, we present a simplified example with an assumed functional form for the WTP parameter of $V(S) = G \cdot S^{1/2}$. This function states that as the mix of high level services nears one, the firm's WTP for the services bundle approaches the standalone value of the onsite services. This function appears reasonable in that the customer firm will be willing to pay close to the full value, G, when S nears 1. However, the client will pay much less for the services as S approaches 0. Our intuition is that the customer is asking for dedicated on-site services and the vendor wishes to negotiate flexibility to augment on-site services with pooled shared services. The objective function becomes:

$$\text{Max}_{(S)}\ \pi = G \cdot S^{1/2} \cdot D - (S \cdot C_H + (1-S) \cdot C_L) \cdot D$$

$$\text{s.t. } VaR(S, \sigma_P(\sigma_H, \sigma_L, \rho_{HL}, \omega_H \omega_L), t, \alpha) \le k$$

In the unconstrained case, we can see that the first and second order necessary and sufficient conditions for maximization are as follows with respect to S: $S^* = (G/(2 \cdot (C_H - C_L)))^2$, and $d^2\pi/d_2S = -1/4 G \cdot D \cdot S^{-3/2}$, where G, D, and S are strictly greater than 0. The related input assumptions and model results are in Tables 3 and 4.

Table 3. Initial Numerical Inputs for the Model

INPUT	DESCRIPTION	VALUE
D	Services contract hours, fixed demand	100
C_H	Cost of high (H) service level	17
C_L	Cost of low (L) service level	3
σ_H	Std dev, high (H) service level costs	0.6
σ_L	Std dev, low (L) service level costs	0.2
ρ_{HL}	Correlation, H and L service level costs	0
ω_H	% of portfolio in High (H) service level	.51
ω_L	% of portfolio in Low (L) service level	.49
α	Confidence interval	95%
T	Time horizon	1
G	Firm WTP for high services ($S = 1$)	20

4. MODELING ANALYSIS AND RESULTS

We first examine the base case of the single contract. We then extend the simulation to incorporate portfolio effects. We consider the sensitivity of the results to timing elements and correlations. We also consider the managerial impact of contract investment and the option value of contract length.

4.1. Base Case Analysis: A Single Contract
   Unconstrained Profit. Table 4 illustrates our initial

simulation of optimal profits unconstrained by any *profit-at-risk* (PaR) lower limits. We refer to profit-at-risk as an instantiation of our value-at-risk construct for the purposes of this particular analysis setting.

Table 4. Unconstrained Profit-at-Risk (PaR)

MAX PAR	NONE	$0	$50	$100	$120	NONE
WTP ($)	14.28	12.92	12.16	11.00	9.98	15.49
Service Lvl. Balance	**51%**	42%	37%	30%	24%	**60%**
Contract SD	32%	28%	26%	20%	21%	37%
Revenue ($)	1,428	1,292	1,216	1,100	997	1,549
Expected Cost ($)	1,014	884	818	723	648	1,140
Max Cost ↑ (95%) ($)	1,559	1,292	1,166	1,000	877	1,842
Contract E(π)($)	414	408	399	376	349	409
Contract PaR ($)	-130	0	50	100	120	-292

Note: Confidence interval for analysis: 95%. PaR = profit-at-risk, an instantiation of the value-at-risk construct for the present analysis. $0, $50, $100, $120 denote different PaR levels, constraints in analysis. WTP=willingness-to-pay. SD = std. dev. Service level balance stated with high service level costs as % of total costs. Costs, profits are in $.

The second column in Table 4, None, illustrates our base case. In this scenario, the firm has *expected unconstrained optimal contract profits*, E(π), of $414, with an *expected minimum expected contract profit-at-risk* (PaR) of -$130. The optimal *service level balance* is $S = 51\%$ in high service level costs (and thus 49% in the low service level costs).

Profit Constrained at 95% Confidence Interval. If the firm wishes to be 95% certain (confidence interval) that its IT services contract will not lose money (3rd column from left, 0), then the firm's optimal service level to rebalance to 42% high service level costs and 58% low service level costs. Note that in this case the expected profits are reduced by only $6, from $414 to $408. Thus, for a relatively small reduction in profits, a firm can reduce its risk exposure by $130.

**4.2. Trade-Off Analysis: Profit vs. Risk Reduction**

Profit-at-Risk Constrained at $100. Moving right in Table 4 shows the trade-off between profitability and risk reduction. For example, a manager concerned with meeting a specific earnings target might require that the firm's minimum profitability should be $100. Then, the column marked $100 is relevant. Here we see that the loss in expected profits E(π) of $38 (= $414-$376) is substantial in financial terms.

Agency and Managerial Incentives. A new issue arises regarding agency, governance and managerial incentives. Note the far right hand column in Table 4 now (also marked with None). In this scenario, a manager has set a service level of 60% (i.e., 60% high service level costs and 40% low service level costs). This is not an optimal profit structure, even though the impact to profits is marginal at $6 (= $414-$409). How-

ever, the risk exposure more than doubles—from -$130 to -$292. What's more troubling is that the overall revenue of the contract is higher than the optimal contract at a 51% service level (again, $414 vs. $409). We should point out that many firms reward lower-level management on revenue targets, and do not consider the potential losses that may accrue <u>at any confidence level</u> whatsoever. So, depending on how a firm's incentives are aligned, a manager might want to "sell" this sub-optimal contract to the upper management—an instance where the principal's and agent's incentives for mechanism design are not in unison. This simulation of value-at-risk indicates that the impacts to contractual decisions in IT services can go far beyond the analysis of pure profitability.

Constraint: Profit-at-Risk > 0. Figure 1 shows the relationship between contract profitability and profit-at-risk, and supports Table 4.

Figure 1. Contract Profit vs. Profit-at-Risk (PaR)
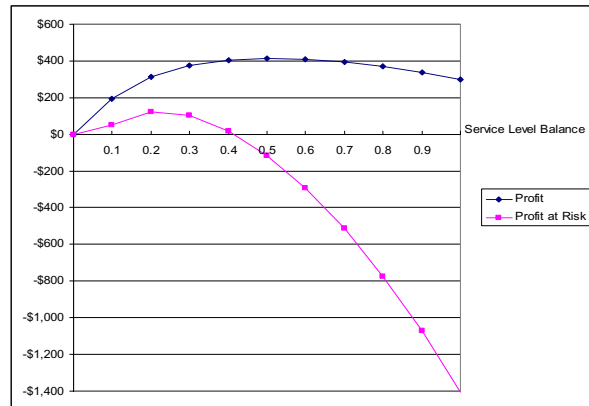
Note: Figure 1 shows the simulated results of changes in the service level balance and the impact on both expected profit and profit-at risk using the inputs of Table 3. Profit-at-risk is the constraint, and it is set by management. For example, if management requires the minimum profits to be positive with 95% certainty, than the optimal profit point ($S = .5$) will fall outside the constraint boundary.

Profit maximization occurs at the service level balance of $S = .51$ (x-axis). The profit-at-risk curve acts as a constraint which is imposed by management. For example, if management requires the firm to have a positive expected profit with 95% confidence (PaR > 0), then the optimal service level balance would violate the constraint.

As illustrated in Table 4, if we constrain profit-at-risk below $120, we shift the profit maximization point to the left. Under these parameters, profit maximization will then occur at the local maximum where the profit-at-risk constraint holds with equality. However, if the profit maximization point occurs to the left of the apex of the profit at risk line, the constraint will not hold with equality. In such a scenario, the firm's profit maximization decision will occur at a point at which the minimum expected profit at risk is higher than the constraint set by management—clearly not appropriate.

Such intuition can be useful, especially when considering such a contract in a portfolio of services contracts.

4.3. Portfolio Impacts

Adding a New Contract. We now consider the impacts of adding the contract examined above to an existing portfolio of services contracts. See Table 5.

Table 5. Portfolio Impacts

High-Low Svc Balance	S=.51	S=.42	S=.39
Contract E(π) ($)	414	408	403
Contract PaR ($)	130	0	32
Initial Portfolio			
Portfolio E(π) ($)	4,081	4,081	4,081
Portfolio PaR ($)	-32	-32	-32
Portfolio with New Contract			
New Portfolio E(π)($)	4,496	4,489	4,484
New PaR ($)	-151	-32	0
Note: This table shows the impacts of adding a contract to an initial portfolio of services contracts. The optimal profits occur when the service balance is .51, by lowering the service value and sacrificing profits, the firm can actually reduce the risk of its overall contract portfolio (S = .42).			

Here the firm has aggregated its obligations for providing the skills in question to its existing contract portfolio of 1,000 total hours. We examine the impact on the portfolio of adding another contract.

The column where the balance between high and low service costs is 51% and 49% (*S*=51%), the unconstrained optimal, shows that the additional contract adds -$119 (=-$151-(-$32)) to the risk exposure of the firm's new profit-at-risk of -$151. We can see if the firm has previously established a profit-at-risk constraint of $100, then it might prefer the high-low service costs balance of *S*=42%, where the new contract adds no additional risk exposure. However, the initial portfolio implies that the risk exposure may be out-of-balance and that the firm may wish to set expected profits to a non-negative dollar value. Thus, the manager should chose the right-hand column, where *S*= 39%, to obtain useful guidance with risk management. Here again, the firm sacrifices profits of $9 from the optimal structure (= $414-$403), but has a 95% confidence interval (or certainty), that the firm will not incur losses over the next year.

Leveraging a Risk Cushion. Table 6 illustrates a different scenario. Here the portfolio is initialized under conditions in which the profit-at-risk is relatively high. Thus, the manager may wish to consider the *risk cushion* within the contract portfolio which might enable strategic decisions to be made. For example, consider a customer who refuses to negotiate for IT services terms with less than 51% of services at the dedicated on-site high service level. As shown earlier, this structure, while profitable for the firm, implies significant risk exposure, with a contract profit-at-risk of $195. However, the portfolio is able to absorb some

slack. Profit-at-risk for the portfolio as a whole falls from $195 to $83, which is still strictly greater than zero. Thus, if the customer firm is of strategic value, the IT services vendor may be willing to sign this contract since the overall portfolio profit-at-risk is still positive.

Table 6. Portfolio Risk Absorption

High-Low Svc Balance	S = .51
Contract E(π) ($)	414
Contract PaR ($)	-130
Initial Portfolio	
Portfolio E(π) ($)	4,081
Portfolio PaR ($)	195
Portfolio with New Contract	
New Portfolio E(π) ($)	4,463
New PaR ($)	83

5. OPPORTUNITIES AND ISSUES

The model that we have presented can aid several other dimensions of managerial decision making. Correlated risk factors and strategic portfolio hedging—two especially interesting potential applications of VaR methods—can be encompassed in this analysis. Most technology risk factors will exhibit correlations by which an increase in one risk factor will likely be accompanied by an increase or decrease in another separate risk factor. We consider three instances of related risk factors: negative correlation, positive correlation and weak or very low correlation.

Negative Correlation of Risk Factors. A *negative correlation* of risk factors often occurs when two technologies are competing for standards adoption. For example, the recent competition between Bluetooth and Wi-Fi has led to negatively-correlated risk factors. Due to the need for standards in wireless technologies, success in one platform is likely to lead to the failure, from a market perspective, of the other technology. For IT services vendors, this negative correlation would likely affect the overall risk profile of their portfolio of contractual liabilities to support their customers. The cost of supporting a non-standard technology would be likely greater than the cost of supporting the "standards winner." Thus the vendor could observe from the marketplace the relative likelihood of success of the two technologies. Rather than making an "all-or-nothing" choice of which standard to support, the vendor would attempt to hedge its position by taking on contracts supporting each standard. As the technologies evolve and the uncertainty around a standards war lessens, managers can take corrective action by taking on new contracts or opting out of existing contracts.

Positive Correlation of Risk Factors. Many of the risk factors in IT services are likely to have positive correlations with one another. For example, an increase in labor costs around a particular technology is likely

6

to be seen across labor markets, whether for offshore or dedicated resources. However, the impacts are not likely to be equivalent in both labor markets (which would imply perfect correlation). Even competing standards can exhibit forms of positive correlation. For example, the standards for digital music of Apple and Microsoft may in fact exhibit positive correlations, as the success in Apple's format, driven by iPod sales, is also contributing to growth in Microsoft's standards, given the latter's shear dominance of the desktop platform and recent capabilities in support of digital music and media. For vendors managing positive correlations in risk factors, it is important to identify how much the technologies are likely to co-vary due to changes in shared exogenous or endogenous risk factors.

Low and Negligible Correlations for IT Services Risk Factors. There are many IT services in which the risk factors will exhibit low or negligible correlations. For example, IT security services and software development outsourcing are likely to involve different technologies and related skills. VaR analysis can help inform vendors as to the markets in which they may wish to expand. Adding additional uncorrelated practices or offerings will allow the vendor to lesson its overall risk position within its portfolio of contracts.

One of the main obstacles to the correlation analysis is finding appropriate estimations or proxies for correlations which could be used in the model. Technology diffusion models and simulations could aid in this endeavor, as we have seen in the research of Paleologo [53] of IBM. In addition, historical data on labor rates may provide estimates for correlations between particular skills. Managers should carefully scrutinize such estimations and conduct sensitivity analysis to evaluate the impact of deviation from any estimates.

6. CONCLUSION

The analytic modeling approach presented in this paper only scratches the surface in terms of potential applications and methods. One interesting factor is the idea of the confidence interval. Here it is presented at extreme tails or 95% confidence interval as used by financial services firms. However, a manager may be more interested in evaluating less extreme scenarios. For example, a 50% confidence interval would imply that there is a 50% chance that profits would dip below a certain level. That may be more informative for firm trying to manage revenue flows on a per project basis. On the other hand, a firm may be interested in the 95% confidence interval when evaluating the ongoing risk and return of the contract portfolio, regardless of any contract addition. Another interesting approach would be to derive an *implied confidence level* by which managers would identify a profit-at-risk level, and then use a VaR analysis to calculate the probability that profit levels would dip below a certain level. This is akin to

the calculation of *implied volatility* in option pricing, where the analyst computes the variance of returns on the underlying asset consistent with a given asset price, risk-free rate of interest, strike price for the option, and time horizon to option expiration.

Incorporating real option-based thinking will be a key modeling extension. We introduced an initial illustration of how such thinking can structure contracts with value-at-risk constraints. Many parameters of contracts can be thought of as options, for instance penalties and buyout clauses in service level agreements can be priced via real option analysis. These pricing decisions could in turn be considered in a VaR portfolio context. In addition, contractual liabilities may be conceptualized as corporate bonds, with the default boundary priced as the *option to abandon* the contract. An additional consideration involves the ongoing investment in the services portfolio. For instance, a firm may make hiring decisions in order to mitigate the uncertainty surrounding skill constraints. In the broader context of outsourcing, parties may structure contracts such that vendor receives a base payment to maintain an ongoing IS service with the expectation that the vendor will keep up with technology advancements. So the vendor must make decisions regarding the optimal size and timing of investments with regard to its portfolio of service obligations.

Several obstacles exist to implementing the kind of VaR analysis that we have described. Preeminent among them is the estimation of the volatility of cost factors. Labor markets could provide proxies for wage volatility. In addition, modeling techniques and simulations could be used to model technology risk (e.g., adoption, cost deflation, Moore's law). Correlation is also a difficult input parameter to estimate. *Sensitivity analysis* should always be performed when estimates of volatility are used. *Simulation techniques* may also prove useful. For example, for contracts around technology standards, correlation may be modeled by simulating competing technologies' market diffusion. In addition, the use of *conditional value-at-risk* [3] may reduce the impact of *kurtosis* and *non-normal distributions*, which are likely to occur when modeling technology risks. We expect that as firms implement this methodology, they will build competencies in estimating volatility and other input parameters.

From an analytic modeling standpoint, a full closed form solution to the robust model outlined in this paper will provide insights that stand on their own (i.e. identification of conditions in which higher or lower service levels should be chosen). Joint optimization considering simultaneous risk minimization and revenue maximization could be considered. However, from a decision support standpoint, the analysis must be augmented by sensitivity analysis to understand the vulnerability to input estimations. In addition, further

work is needed to estimate the demand functions for various IT services and understand the sensitivity that occurs as a result of any assumed functional form.

This work provides a contribution to IS literature in two ways. First, it represents one of the first robust applications of VaR methods and qualitative risk and reward trade-offs. Second, it incorporates VaR analysis in an optimization model of IS service parameters which provides useful managerial decision support. We illustrate several scenarios where a profit-maximizing decision is not optimal relative to managements' tolerance of risk. In addition, we model the impact of contract duration and structure to risk exposure and provide scenarios where managers can structure the timing of contracts to mitigate risk. This new realm of *services sciences* [33,35] represents a new frontier for IS researchers. With IS solutions increasingly service-driven, IS researchers can provide unique insights into a new realm, where the technology, business processes and services can all be brought together.

Recent work in automated IT services management and "sense and respond" mechanisms [40] could provide sources of data to our model; thus enabling the analysis of intricate risks associated with business process outsourcing and service-level monitoring. From a managerial standpoint, this work offers the promise of new techniques to match contractual parameters based on an overall risk portfolio. Just as financial institutions realize profits by matching interest rates offered to a thorough understanding of risk exposure, so can IT services vendors realize competitive advantage by strategically matching contractual risk exposure to their services offerings. Customers of IT services will also benefit as providers will be more willing to absorb new client risks in IT services offerings. Future research may also explore a *dual formulation* of our "primal model." The dual might be a useful means to examine how to optimize a large customer's IT services contract management. We expect that the methods that we have described can also be applied in other IS settings, for example, risk assessment in the bundling of information goods [5], evaluation of information security services, and other information practices in the firm.

REFERENCES

[1] Agarwal, V., and Naik, Y. Risks and portfolio decisions involving hedge funds. *Review of Financial Studies*, 17, 1, 2004, 63-98.

[2] Ahn, D., Boudoukh, J., Richardson, M., and Whitelaw, R. F. Optimal risk management using options. *Journal of Financial Management,* 54, 1, 1999, 359-375.

[3] Anderson, F., Mausser, H., Rosen, D., and Uryasev, U. Credit risk optimization with conditional value-at-risk criterion. *Mathematical Programming*, Series B, 89, 2001, 273-291

[4] Aron, R., Clemons, E.K. and Reddi, S. Just right outsourcing: Understanding and managing risk. *Journal of Management Information Systems*, 22, 2, 2005, 35-56.

[5] Bakos, Y., and Brynjolffson, E. Bundling information goods: Pricing, profits, and efficiency. *Management Science*, 45, 12, 1999, 1613-1630.

[6] Bakos, Y. and Kemerer, C.F. Recent applications of economic theory in information technology. *Decision Support Systems* 8, 5, 1992, 365-386.

[7] Bardhan, I.R., Kauffman, R.J., and Narapanawe, S. Optimizing an IT project portfolio with time-wise interdependencies. In R. Sprague (Ed.), *Proceedings of the 39th Hawaii International Conference on Systems Science*, Kauai, HI, IEEE Computing Society Press, Los Alamitos, CA, 2006.

[8] Bardhan, I.R., Sougstad, R., and Bagchi, S. Prioritization of a portfolio of information technology projects. *Journal of Management Information Systems*, 21, 2, 2004, 33-60.

[9] Basak, S., and Shapiro, A. Value-at-risk-based risk management: Optimal policies and asset prices. *Review of Financial Studies*, 14, 2, 2001, 371-405.

[10] Bass, F. M. A new product growth model for consumer durables. *Management Science*, 15, 1, 215-227.

[11] Benaroch, M. Managing information technology risk: A real options perspective. *Journal of Management Information Systems,* 19, 2, 2002, 43-84.

[12] Benaroch, M., and Kauffman, R. J. A case for using real options pricing analysis to evaluate information technology project investments. *Information Systems Research,* 10, 1, 1999, 70-86.

[13] Benaroch, M., and Kauffman, R. J. Options analysis of software platform decisions: A case study. *MIS Quarterly,* 24, 2, 2000, 197-225.

[14] Berkowitz, J., and O'Brien, J. How accurate are value-at-risk models at commercial banks? *Journal of Finance*, 57, 3, 2002, 1093-1111.

[15] Black, F., and Scholes, M. The pricing of options and corporate liabilities. *Journal of Political Economy*, 81, 3, 1973, 637-665.

[16] Bhargava, H.K., and Sundaresan, S. Contigency pricing for information goods and services under industry-wide performance standards. *Journal of Management of Information Systems*, 20, 2, 2003, 113-136.

[17] Bhargava, H.K., and Sundaresan, S. Computing as utility: Managing availability, commitment, and pricing through contingent bid auctions.

Journal of Management of Information Systems, 21, 2, 2004, 201-227.

[18] Campbell, R., Huisman, R., and Koedijk, K. Optimal portfolio selection in a value-at-risk framework. *Journal of Banking and Finance*, 25, 9, 2001, 1789-1804.

[19] Carr, N. The end of corporate computing. *Sloan Management Review*, 46, 3, 2005, 67–73.

[20] Clemons, E.K., and Hitt, L. Poaching and the misappropriation of information: Transaction risks of information exchange. *Journal of Management Information Systems*, 21, 2, 2004, 87-107.

[21] Clemons, E.K., and Weber, B. Strategic information technology investments: Guidelines for decision making. *Journal of Management Information Systems*, 7, 2, 1990, 9-28.

[22] Cheng, H.K., and Koehler, G. Optimal pricing policies of Web-enabled application services. *Decision Support Systems*, 35, 2003, 259-272.

[23] Crouhy, M., Galai, D., and Mark, R. M. *Risk Management.* McGraw Hill, New York, NY, 2001.

[24] Cox, J., Ross, S., and Rubenstein, M. Option pricing: A simplified approach. *Journal of Financial Economics,* 7, 3, 1979, 229-263.

[25] Dai, Q. Understanding the performance of B2B e-markets. Unpublished doctoral dissertation, Carlson School of Management, University of Minnesota, Minneapolis, MN, 2004.

[26] Dixit, A. and Pindyck, R. *Investment under Uncertainty*. Princeton University Press, Princeton, NJ, 1994.

[27] Dos Santos, B. Justifying investments in new information technologies. *Journal of Management Information Systems* 7, 4, 1991, 71-90.

[28] *E-Risk.com.* Case study: Barings Bank, 2005, www. erisk.com/Learning/CaseStudies/ ref_case_barings.asp, last accessed June 9, 2006.

[29] Fichman, R.G., Keil, M., and Tiwana, A. Beyond valuation: Options thinking in IT project management. *California Management Review*, 47, 2, 2005, 74-96.

[30] Glasserman, P., Heidelberger, P. and Shahabuddin, P. Variance reduction techniques for estimating value-at-risk. *Management Science,* 46, 10, 2000, 1349-1364.

[31] Gupta, A., Stahl, D., and Whinston, A. Managing computing resources in Intranets: An electronic commerce perspective. *Decision Support Systems*, 24, 1998, 55-69.

[32] Han, K., Kauffman, R.J., and Nault, B. Information exploitation and interorganizational systems ownership. *Journal of Management Information Systems,* 21, 2, 2004, 109-135.

[33] Horn, P. The new discipline of services sciences. *BusinessWeek Online*, January 21, 2005. Available at www.businessweek.com/technology/content/jan2005/tc20050121_8020.htm. Last accessed on September 10, 2006.

[34] Huang, K.W., and Sundararajan, A. Pricing models for on-demand computing. Working paper, Stern School of Business, New York University, November 2005.

[35] IBM Corporation. IBM creates new academic curriculum to improve services innovation. TJ Watson Research Center, Yorktown Heights, NY, May 23, 2005.

[36] Jorion, P. *Value-at-Risk: The New Benchmark for Controlling Market Risk,* 2nd Edition*.* Irwin, New York, NY, 2001.

[37] Jorion, P. *Financial Risk Manager Handbook,* 3rd Edition. John Wiley and Sons, New York, NY, 2005.

[38] Joyce, E. Rough sailing for EDS's Navy contract. Internetnews.com, May 8, 2003. Available at www.internetnews.com/bus-news/article.php/2203091. Last accessed on September 9, 2006.

[39] Kambil, A., Henderson, C.J., and Mohsenzadeh, H. Strategic management of information technology investments. In R. Banker, R. J. Kauffman and M. A. Mahmood (Eds.), *Strategic Information Technology Management: Perspectives on Organizational Growth and Competitive Advantage,* Idea Group Publishing, Harrisburg, PA, 1993, 161-178.

[40] Kapor, S., Bhattacharya,K., Bucksley, S., Chowdary, P., Ettl, M., Katircioglu, K., Mauch, E., and Phillips, L., A technical framework for sense-and-respond business management. *IBM Systems Journal*, 44, 1, 2005.

[41] Karamouzis, F. Positions 2005: Global sourcing and the impact of new delivery models on IT services. Gartner Research, Stamford, CT, March 2005.

[42] Kauffman, R. J. and Li, X. Technology competition and optimal investment timing: A real options perspective. *IEEE Transactions on Engineering Management* 52, 1, 2005, 15-30.

[43] Kauffman, R.J., and Mohtadi, H. Proprietary and open systems adoption: A risk-augmented transactions cost perspective. *Journal of Management Information Systems*, 21, 1, 2004, 137-166.

[44] Kauffman, R.J., and Walden, E.A. Economics and e-commerce: Survey and research directions.

International Journal of Electronic Commerce, 5, 4, 2001, 4-115.

[45] Leeson, N., and Whitley, E. *Rogue Trader: How I Brought Down Barings Bank and Shook the Financial World.* Little, Brown and Co., Boston, MA, 1996.

[46] Leibowitz, M.L., and Kogelman, S. Asset allocation under shortfall constraints. *Journal of Portfolio Management*, Winter 1991, 18-23.

[47] Lintner, J. The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets. *Review of Economics and Statistics*, 47, 1, 1965, 13-39.

[48] Lucas, A., and Klassen, P. Extreme returns, downside risk, and optimal asset allocation. *Journal of Portfolio Management*, Fall 1998, 71-78.

[49] Luciano, E. and Marena, M. Portfolio value-at-risk bounds. *International Transactions in Operations Research*, 9, 5, 2002, 624-641.

[50] Margrabe, W. The value of an option to exchange one asset for another. *Journal of Finance,* 33, 1, 1978, 177-186.

[51] Markowitz, H. M. Portfolio selection, *Journal of Finance*, 7, 1, 1952, 77-91.

[52] Merton, R. On the pricing of corporate debt: The risk structure of interest rates. *Journal of Finance*, 29, 2, 1974, 449-470.

[53] Paleologo, G.A. Price-at-risk: A methodology for pricing utility computing services. *IBM Systems Journal,* 43, 1, 2004, 20-31.

[54] Schwartz, E. and Zozaya-Goristiza, C. Investment under uncertainty in information technology: Acquisition and development projects. *Management Science,* 49, 1, 2003, 57-70.

[55] Sharpe, W. F. Capital asset prices: A theory of market equilibrium under conditions of risk. *Journal of Finance*, 19, 3, 1964, 425-442.

[56] Stybo Beder, T. VaR: Seductive but dangerous. *Financial Analyst's Journal*, 51, 5, 1995, 12-24. www.cfapubs.org/faj/issues/v51n5/abs/f0510012a.html, last accessed June 9, 2006.

[57] Sundarajan, A. Non-linear pricing of information goods. *Management Science*, 50, 12, 1660-1673.

[58] Tallon, P.P. Kauffman, R.J., Lucas, H.C. Jr., Whinston, A.B., and Zhu, K. Using real option analysis for evaluating uncertain investments in information technology: Insights from the ICIS 2001 debate. *Communications of the AIS*, 9, 2002, 136-167.

[59] Westland, C. Congestion and network externalities in the short-run pricing of information systems services. *Management Science*, 38, 992-1099.

[60] Zhu, K. Strategic investment in information technologies: A real options and game-theoretic approach. Doctoral dissertation, School of Industrial Engineering, Stanford University, Stanford, CA, 1999.

Appendix. Value-at-Risk Analysis Terminology

COMPONENT	DEFINITION
Value-at-risk	The worst expected loss which an investment will incur over a discrete time period at a specified confidence interval.
Mark-to-market position	The value of an asset or a portfolio based on current market value. In the case of systems and technology investments, this will be the current project value or the current expected cost of a project input.
Variance of asset value or returns	Measures the variability of a risk factor that underlies asset value, usually stated as a variance or a standard deviation.
Time horizon	Time frame over which value-at-risk is to be assessed, based on managerial discretion relative to the risk perspective. The time horizon is typically chosen based on the asset's liquidity. For example, inter-bank loan analysis is typically done with daily increments, whereas a mutual fund may use a 30 or 90-day time horizon.
Confidence interval	The probability bounds on the observation of a specified value-at-risk outcome, chosen based on a firm's desire to manage payoff and return outcomes up to a predetermined likelihood.
Correlation of asset value or returns	Measures the extent to which asset returns co-vary with one another. The values could range from -1 (perfect negative correlation), to 0 (no correlation), to +1 (perfect correlations). This input is used when looking at portfolio-level value-at-risk.

Note: The material here is adapted from Crouhy et al. [23] and Jorion [36].