Using Value-at-Risk for IS/IT Project and Portfolio Appraisal and Risk Management

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Abstract: This paper makes the case for adopting a risk measure from the finance sector for IS/IT project and portfolio evaluation. The proposed value-at-risk approach constitutes a well-tested approach in high-risk environments, especially banking, and reports the expected maximum loss (or worst loss) over a target horizon within a given confidence interval. Value-at-risk is computed using either an analytical, parametric approach, or resorting to simulation, either based on historical samples or Monte Carlo methods. The main advantages of using value-at-risk measures are that they are methodologically consistent with modern IS/IT evaluation approaches like real options, that they offer possibilities for management and assessment of IS/IT project portfolios, and that the results are easy to interpret.

Keywords: IT investment, risk management, value-at-risk, project portfolio

1. Introduction

In the last years, the evaluation of IS/IT projects has been the centre of much debate. One of the reasons for this debate has been the e-Commerce and Internet hype on the trading floors, and the fact that the respective bubble later on exploded. Naturally, investments into new technology, especially IS/IT, and respective start-ups need to be carefully analysed, especially in this new environment. Associated with this trend, risk management, either within an organisation performing one or multiple IS/IT projects or for an investment in several start-ups has become a center of attention (Remenyi 1999, Benaroch 2002, DeMarco and Lister 2003).

Regarding valuation of IS/IT projects, the real options approach (Trigeorgis 1998) gained prominence in MIS literature (Santos 1991, Benaroch and Kauffman 1999, Taudes 1998). This approach is based on option theory from finance, and tries to incorporate the management's flexibility into decision making. Especially several possible options like abandonment, or expansion (growth) options offered by pilot projects are of interest in IS/IT projects. In the literature, several applications for real options have been described, including software growth options used in evaluating software platform decisions (Taudes 1998, Taudes et al. 2000), or investment timing in the development of point-of-sale (POS) debit services (Benaroch and Kauffman 1999, Benaroch and Kauffman 2000). In the last years, the focus has shifted from evaluating one (or more) known options embedded in an IS/IT project towards active management and planning of options in IT investments for controlling risks (Benaroch 2002).

Extending the approach of using analogies with finance, this paper argues for adopting a value-at-risk approach in evaluating IS/IT projects and for risk management. The main advantages of using value-at-risk measures are that they are methodologically consistent with modern IS/IT evaluation approaches like real options, constitute a tested and used approach in high-risk environments, especially banking, that they offer possibilities for management and assessment of IS/IT project portfolios including existing dependencies, and that the results are easy to interpret.

The structure of this paper is as follows: First, an introduction to value-at-risk will be given, highlighting both shortly its history in the finance sector and the main points of the computation itself. Then, the application for evaluating a single IS/IT project will be discussed, afterwards detailing the use for IS/IT project portfolio risk management. In both cases, small illustrative examples are given and discussed.

2. Introduction to value-at-risk

2.1 History and applications

The history of value-at-risk is deeply interwoven with the finance sector and especially banking. In the strive for financial stability, a first landmark decision was the 1988 Basle accord by the central banks from the G-10 countries, which defined a minimum standard of capital requirements for commercial banks, using a percentage of risk-weighted assets (Basel Committee on Banking Supervision 1988). As this first approach has faced criticism, including that neither portfolio risk, nor netting, nor market risk have been accounted for, modifications have become necessary. In 1993, one of the most important documents, the Group of Thirty's report on derivatives was published, explicitly endorsing value-at-risk for

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measuring market risk (Group of Thirty 1993). This concept was then popularized by the RiskMetrics system originally developed by J.P. Morgan (Morgan Guaranty Trust Company 1994). The Basle accord, after an amendment for market risk in 1996 (Basel Committee on Banking Supervision 1996), in its latest version from 2001 now also 'strongly recommends' that banks disclose their value-at-risk. The U.S. Securities and Exchange Commission (SEC) also now requires all large U.S. publicly traded corporations to report quantitative data on market risk in their report to the SEC, listing value-at-risk as one of three possible methods for doing so (SEC 1997, Jorion 2001, Jorion 2002). Recently, it has been empirically shown that value-at-risk disclosures of banks are significantly related to future market risk (Jorion 2002).

In the last years, applications of value-at-risk measures have started to begin in areas other than finance, including inventory management (Luciano et al. 2003), the purchasing process (Sanders and Manfredo 2002) or even real estate investement (Kevenides 2002).

2.2 Computing value-at-risk

While several definitions for value-at-risk can be formulated, it basically indicates the greatest potential loss of a position or a portfolio, which can be verified with a certain probability, in a defined time horizon (Tardivo 2002, Best 1998). Or, as Jorion puts it, value-at-risk summarizes the expected maximum loss (or worst loss) over a target horizon within a given confidence interval (Jorion 2001). These definitions already hint at several important characteristics of value-at-risk: It can be computed both for a single position or for a diversified portfolio, and it has some discretionary power, in that both the holding period (time horizon, target horizon) and the confidence interval need to be defined by the user. The holding period should be set with the type of portfolio considered taken into account, setting a horizon corresponding to the period necessary for orderly liquidation (Jorion 2001). For example, a bank computing their value-at-risk for a portfolio of highly liquid currencies might even use one day as holding period. The confidence interval chosen should necessarily either reflect regulatory imperatives, risk attitude, or depend on characteristics of the underlying distribution. Having set both holding period and confidence interval, value-at-risk is computed by estimating the probability distribution of gains and losses of the considered position or portfolio over the time horizon, and then finding the point at which the probability of incurring greater losses corresponds to the set confidence interval (in fact to one minus the confidence interval). Therefore, value-at-risk reports one, easy to interpret figure: The loss of money that is not exceeded at the probability of the confidence interval over the defined time horizon. In the most general form, value-at-risk can therefore be derived from the distribution of the future portfolio value $f(w)$, finding for a given confidence interval c the worst possible realization W^* such that:

$$c = \int_{W^*}^{\infty} f_\tau(w)\, dw. \quad (1)$$

The value-at-risk can be either reported relative to the mean (the expected portfolio value) or as absolute loss relative to zero.

For computing value-at-risk in practice, three approaches are proposed, each with specific strengths and weaknesses. These are the parametric, or analytical or variance-covariance approach, historical and Monte Carlo simulation (Pearson and Smithson 2002, Stambaugh 1996). Sometimes the latter two are grouped together under the name of simulation or full valuation methods (Best 1998, Jorion 2001, Tardivo 2002). While historical simulation necessitates large historical samples (and attendant assumption of stable volatilities), Monte Carlo simulation naturally can become complex and costly in computer resource for large real-world portfolios (although in the last years several ways were proposed to increase the speed of Monte Carlo simulations (Pearson and Smithson 2002)). Most often used, due to being the first version having been developed, ease of implementation and conceptual fit with modern portfolio theory, is the parametric approach.

The main hypothesis behind the parametric approach is that the future portfolio values (and hence returns) follow a parametric distribution, the most common assumption is that they follow a normal distribution. Therefore, value-at-risk can be derived directly from portfolio standard deviation σ (using a multiplicative factor α dependent on the chosen confidence level). For a single position with initial investment W_0, the value-at-risk below the mean then is given by:

$$VAR(mean) = W_0 \alpha \sigma \sqrt{\Delta t}. \quad (2)$$

For a portfolio of assets, as the return of each single asset is assumed to be normally distributed, the portfolio return as a linear combination of normal variables is necessarily normally distributed as well. Due to the diversifying effects of a portfolio, the value-at-risk of a portfolio is not the sum of the value-at-risks of all single positions, but needs to incorporate the respective covariance matrix. The delta-normal method defines relations between financial positions and underlying, primitive risk factors which again are normally distributed. For an instrument whose value depends on a single underlying risk factor S, first the portfolio value at the initial point is computed, together with the first partial derivative Δ_0 with respect to the underlying risk factor *S*, the sensitivity of value to changes in the risk factor at the current position, termed delta for derivatives. The potential loss in value dV is then computed as

$$dV = \Delta_0 \times dS, \qquad (3)$$

using the potential change dS in the underlying risk factor. If the distribution is normal, the value-at-risk can be derived from the product of the exposure and the value-at-risk of the underlying variable:

$$VAR = |\Delta_0| \times VAR_S = |\Delta_0| \times (\alpha\sigma S_0). \qquad (4)$$

For a portfolio, the delta-normal method uses a set of primitive risk factors, onto which the positions are mapped using the respective delta-positions denoted by vector χ, and the covariance matrix Σ between risk factors over the target horizon together with the specified confidence level to compute the portfolio value-at-risk:

$$VAR = \alpha\sqrt{\chi'\Sigma\chi}. \qquad (5)$$

Especially with derivatives like options, due to their non-linear nature, including the second derivative using delta-gamma approximation is recommended to increase the fit.

For a more thorough treatment of value-at-risk than is possible here, the works of Jorion (2001), Best (1998), Pearson (2002) and Allen, Boudoukh and Saunders (2004) are useful starting points.

3. Value-at-risk for IS/IT project evaluation

The first and most important question is whether the value-at-risk can in general be determined for an IS/IT project. Following the most generic terms and definition of value-at-risk, it can naturally be derived. Every IS/IT project has a certain amount of uncertainty, therefore a probability distribution of gains and losses over a set time horizon exists. Necessarily, any arbitrary confidence level can thus be set, and the cutoff point in the probability distribution specifying the loss not exceeded with corresponding probability can be determined.

Before specific problems of computation, uses and advantages and disadvantages are addressed, specification of both confidence level and time horizon in the context of IS/IT projects need to be discussed. While the confidence level can be determined quite analogous with classic value-at-risk, e.g. using 95% or 99%, but keeping in mind possible characteristics of the underlying distribution, the time horizon needs to be more carefully evaluated. Depending on the reason for project evaluation, the holding period should be set accordingly. In finance, the holding period could correspond to the time period necessary for orderly liquidation of the asset considered. For IS/IT projects, liquidation is most often available by stopping a project, which is normally possible at short notice or immediately. Due to the fact that IS/IT projects (normally) are not traded assets, this would mean exercising an abandonment real option, forfeiting any further benefits but also costs. While this analogy would lead to assume very short holding periods, the volatility of an IS/IT project's gains and losses over short periods of time will be small. Therefore longer holding periods should be considered in the context of IS/IT projects. If a single project is considered, the holding period could even be set to the assumed project length. For application within a larger organization performing several concurrent projects, evaluation of a start-up portfolio or similar as will be detailed in the next section, the holding period should necessarily be reduced to be in the area of one or several months, maybe a quarter.

For illustrative purposes, a first simple project will be considered. This project will, over its projected length of one year, necessitate costs of about 100 monetary units (MU), and is projected to generate positive cash flows of 140 MU with probability $p_1 = 0.4$, of 120 MU with probability $p_2 = 0.2$, of 100 MU with probability $p_3 = 0.2$, of 80 MU with probability $p_4 = 0.1$ and of 0 MU with probability $p_5 = 0.1$. No embedded options are considered at this stage. The resulting probability distribution for project value after one year therefore is discrete and is easily constructed. Setting a confidence level of 95% allows to easily determine the cutoff point in this distribution, leading to an absolute value-at-risk below zero of 100 MU, or a relative value-at-risk to the mean $E(P)=8$ of 108 MU. While this seems straightforward and trivial in this simple case, stating these figures already offers additional information regarding risk for the project, and might serve as an important complement to reporting only mean project value, or a measure like discounted cash flows.

Next, we will consider the case of a software growth option, implementing a web-based e-commerce system, embedded into a platform change from SAP R/2 to SAP R/3. All data for this option are taken from Taudes, Feurstein and Mild (2000). They give the spot price S_0 with 880,000 MU and volatiliy $\sigma = 0.8$. Valuation of this American call option using the Black-Scholes formula gives 514,000 MU, with a delta of 0.7756. Using delta-normal valuation and 95% confidence level (corresponding to $\alpha = 1.645$) in equation (4) results in a value-at-risk of 898,207 MU.

In the evaluation of single projects, value-at-risk measures can be computed both at the beginning (normally using project length as holding period), and also during the project for continuous monitoring. At the point of an investment decision at project start, value-at-risk measures allow for easy to understand, monetary quantification of associated risks, and therefore offer a good complement for other measures like net present value. On the downside, computing value-at-risk is either trivial and therefore offers little additional information, necessitates strong assumptions like normal distributions or gets complex if Monte Carlo simulation is employed. Using historical simulation will be mostly problematic due to missing large historical samples.

4. Value-at-risk for IS/IT project portfolios and risk management

There are numerous examples for when an IS/IT project portfolio needs to be evaluated regarding the contained risks. These include the classic case of a large software developing organisation that performs several projects. In that case, overall risk assessment is of high interest, especially if a diversification effect is in place or is strived for. The next possible application is for evaluating a portfolio of IS/IT start-ups, as held or being built by an investor. While this is more akin to a classical finance application, start-ups in this area can also be seen as IS/IT projects.

The last, and maybe the most often occurring possibility is a portfolio of an IS/IT project with several embedded options. In that case, an assessment of underlying risk factors is necessary. If only a portfolio of a project and an embedded option for example to defer investment, priced as an American call on the gross present value of the completed project (Trigeorgis 1998) is considered, there is only one underlying risk factor, project value, which eliminates diversification effects and reduces the associated covariance matrix Σ in the delta normal method to a scalar, the risk factor's variance σ, with a vector χ of two delta-positions describing the exposure of both positions, project and option, to the risk factor (see equation 5). On the other hand, options on a different underlying asset, thus maybe depending on one or more other primitive risk factors, embedded in a project would necessarily lead to assessing the risk of a portfolio composed of one project and one or more options. In this case, diversification might be present, and needs to be included in the computation of the portfolio value-at-risk. In the second example given in the last section, a growth option for implementing a web-based e-commerce system was evaluated according to its value-at-risk on its own. As this option was embedded into a platform change from SAP R/2 to SAP R/3 together with four others, with these option values leading to a positive expanded (strategic) net present value of the platform change (Taudes et al. 2000), the whole portfolio of platform project and real options needs to be evaluated together. Simply evaluating each component separately and summing the resulting value-at-risks would negate any benefits from diversification. While two of the options implement EDI-based solutions, the others including the e-commerce system and the main platform project would be exposed and mapped to different risk factors.

For illustration, we will now expand on our treatment of the option presented above, complemented with the main platform project. Again, data are taken from Taudes, Feurstein and Mild (2000), although a volatility for the main project of $\sigma_{project} = 0.2$ is introduced. Data for the web-based e-commerce system remain unchanged from last section. Furthermore, we presume the presence of two risk factors, with each position exposed to one of them, the option according to delta-normal method with delta 0.7756, the platform project with its full value at -416,500 MU. Lastly, a correlation of 0.3 is assumed between the risk factors. Using equation (5) at confidence level 95% corresponding to $\alpha = 1.645$ gives

$$VAR_{div} = 1.645 \sqrt{\begin{bmatrix} -416{,}500 & 0.7756 \times 880{,}000 \end{bmatrix} \begin{bmatrix} 0.2^2 & 0.3^2 \\ 0.3^2 & 0.8^2 \end{bmatrix} \begin{bmatrix} -416{,}500 \\ 0.7756 \times 880{,}000 \end{bmatrix}}$$
$$= 828{,}907.$$

The portfolio value-at-risk therefore is 828,907 MU, due to diversification smaller than the sum of individual value-at-risks (the undiversified value-at-risk) of

$$VAR_{undiv} = VAR_{project} + VAR_{option}$$
$$= (1.645 \times 0.2 \times |-416{,}500|) + 898{,}207$$
$$= 137{,}028 + 898{,}207 = 1{,}035{,}235.$$

In analysing portfolio value-at-risk, the change in value-at-risk due to addition of a new position can also be computed, termed incremental value-at-risk, as well as component value-at-risk, giving the reduction of the portfolio value-at-risk resulting from removal of a position. Due to diversification, both measures would in most cases be different than the individual value-at-risk of the position. This allows for in-depth analysis of components in a portfolio, or could even be used as a constraint for portfolio optimization (Yiu 2004).

One main point to consider when using value-at-risk to evaluate an IS/IT project and/or option portfolio is which primitive risk factors to choose, and how to map the positions to them, if the delta-normal method is to be applied. A survey of literature yields several risk factors commonly associated with IS/IT projects, including technological and organizational risk (Taudes et al. 2000). The most complete taxonomy to be found is by Benaroch, who distinguishes between firm-specific risks, including monetary, project, functionality and organizational risk, competitive risks and market risks including environmental, systemic and technological risk, and argues for real option analysis to assist in risk management by deliberately embedding options to address the various risks and thus optimally configuring the investment (Benaroch 2002). This line of research shows distinctive relationship with the value-at-risk approach argued for in this paper, with value-at-risk offering a way of quantifying risk reduction afforded by embedding certain options into the investment portfolio.

5. Conclusion

This paper has argued for adopting the value-at-risk approach in the evaluation of single IS/IT projects and also portfolios constructed from these projects and/or related real options. As has been detailed, value-at-risk is a common and accepted measure in the finance sector, and offers several advantages also in the area of IS/IT projects. While several approaches for computing value-at-risk exist, not all of these might be applicable for IS/IT projects, as large historical samples will mostly be absent. On the other hand, both Monte Carlo simulation and an analytical approach seem feasible.

Using small, illustrative examples, we have shown that value-at-risk can indeed offer additional information in evaluating single IS/IT projects or real options on such projects, offering an easy to interpret way of quantifying and comparing associated risks, and especially in evaluating IS/IT project and/or option portfolios, as this method explicitly accounts for diversification effects. In addition, the changes in risk due to changes in the portfolio, both from eliminating and adding new elements, can easily be determined, making value-at-risk a useful tool for risk management, complementing and extending the real options approach.

If value-at-risk is indeed adopted, many further enhancements are possible, including the introduction of risk adjusted performance evaluation of business units or project managers, using profit over value-at-risk for assessment. Naturally, many further issues still need to be investigated in the context of value-at-risk for IS/IT projects, especially the definition of primitive risk factors, the mapping of positions to these and others. Nevertheless, adopting value-at-risk might provide important additional information for IS/IT decision makers, and might constitute a necessary step towards IS/IT risk management.

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