December 2006

An Integrative Economic Optimization Model to IS Development Risk Management

Michel Benaroch
Syracuse University

James Goldstein
Syracuse University

An Integrative Economic Optimization Model to IS Development Risk Management

Michel Benaroch
Martin J. Whitman School of Management
Syracuse University
mbenaroc@syr.edu

James Goldstein
Martin J. Whitman School of Management
Syracuse University
jcgoldst@syr.edu

ABSTRACT

This research develops an integrative model to managing IT investment risk from an economic optimization perspective by consolidating and building on the strengths of two research streams. The traditional stream is concerned with software development risk management and its focus on the "building" stage in the IT investment lifecycle enables addressing granular risks using well-established project management practices, but precludes managing risk from a comprehensive economic perspective. By contrast, the more recent stream uses real options theory (ROT) to study the economic implications of risk in relation to the flexibility one can build into IT investments to enable deployment of contingent risk countermeasures. However, this stream's macro level perspective is not geared towards granular risk management practices at the execution level. The economic optimization orientation of our model follows from the use of ROT as an economic basis for unifying micro- and macro-level risk management practices studied by both streams.

Keywords

Information Systems Risk, Real Options Theory, Project Management.

INTRODUCTION

Recently there is much renewed interest in the management of information systems (IS) development risk (e.g., Barki, Rivard and Talbot, 2001; Benaroch, 2002; Jiang, Klein and Discenza, 2002; Keil, Lyytinen and Schmidt, 1998; Lyytinen, Mathiassen and Ropponen, 1998; Ropponen, 1999; Schmidt, Lyytinen, Keil and Cule, 2001). This work falls into two distinct streams. One stream largely follows in the footsteps of early work on software development risk management. It is subject to three known weaknesses. First, although software development is a value-creation activity (Boehm and Sullivan, 2000), this research looks to control only the cost side of software development, ignoring business managers' concerns over how risk affects the payoffs that every IS development project is expected to generate. Second, by limiting its scope to software development risks arising in the investment "building" stage, this research fails to see that risk management decisions pertaining to the building stage affect and can be affected by decisions pertaining to earlier and/or later stages in the investment lifecycle (Benaroch, 2002). However, a strength that follows from its limited scope is a richness of details that permits integrating risks into "micro" level project management decisions. Finally, although the notions of risk and risk countermeasures have clear consequences on investment costs and payoffs, this research offers no adequate ways to quantify these notions and link them to the net value of an IS development project. As a result, this work precludes managing IS risk from an economic optimization perspective – it is impossible to know whether any specific combination of risk countermeasures pursued for a target IS investment is optimal or even adds value.

A more recent research stream on IS risk management looks to address some of the above drawbacks within the context of real options theory. This work looks at ways to use real options to build flexibility into an investment so as to enable management to favorably alter the variation in expected outcomes and bring risk under control (Amran and Kulatilaka, 1999; Kumar, 2002; Kim and Saunders, 2002). For example, a recently developed option-based risk management framework offers a comprehensive way to use different types of real options to manage various specific forms of IS investment risks (Benaroch, 2002). However, this research stream has its own weaknesses. First, its primary focus is on the construction and evaluation of a business case for a target IS development investment opportunity. As such, it takes a somewhat static view of the risk management endeavor, unlike the way more traditional work views IS risk management as an ongoing iterative endeavor. Second, while it looks at risk management in the context of the entire IS development investment lifecycle, it is concerned with "macro" level business decisions (invest or not, investment timing, investment scope, etc.). Consequently, it is not geared towards capturing granular details that allow for integration with "micro" level project management practices.

This research develops an integrative model for managing IS development risk from an economic optimization perspective. The model is integrative in the sense that it builds on the strengths of the two research streams reviewed above, while fitting the richness of details of the micro technical view within the holistic approach of the macro business level view. The economic optimization orientation of the model follows from the use of real options theory as a unifying economic foundation for integrating risk management practices at both the micro (stage) and macro (lifecycle) levels as well as for treating risk management as a dynamic iterative problem-solving process. We show how the dynamic ongoing micro level technical decisions affect and are affected by the flexibility afforded by embedded options created by macro level decisions, demonstrating that real options theory is a viable vehicle for effectively linking both levels into a single economic model for optimal IS risk management. Such a model will bridge the gap between both research streams, allowing managers to understand how the technical decisions made during the building stage impact the overall net investment value.

MODELING APPROACH

Based on well-established practices in the domain of financial investment and financial risk management, the model considers IS risk management to be a problem-solving process that aims at favorably changing the distribution of the expected net investment value (see Figure 1). This process involves four activities: (1) identify and quantify relevant risks, (2) map the risks to plausible risk countermeasures, (3) plan which of these countermeasures to apply over time based on their expected cost and their expected impact on investment payoffs, and (4) monitor risk in light of new information and reiterate. Thus, at its core, this process is about planning managerial interventions that provide a desired (or optimal) level of balance between the likelihood of acceptable and unacceptable investment outcomes. Applying proper interventions modifies various risky traits of the investment and its contextual environment, thereby favorably skewing the distribution of net investment value (see Figure 1).

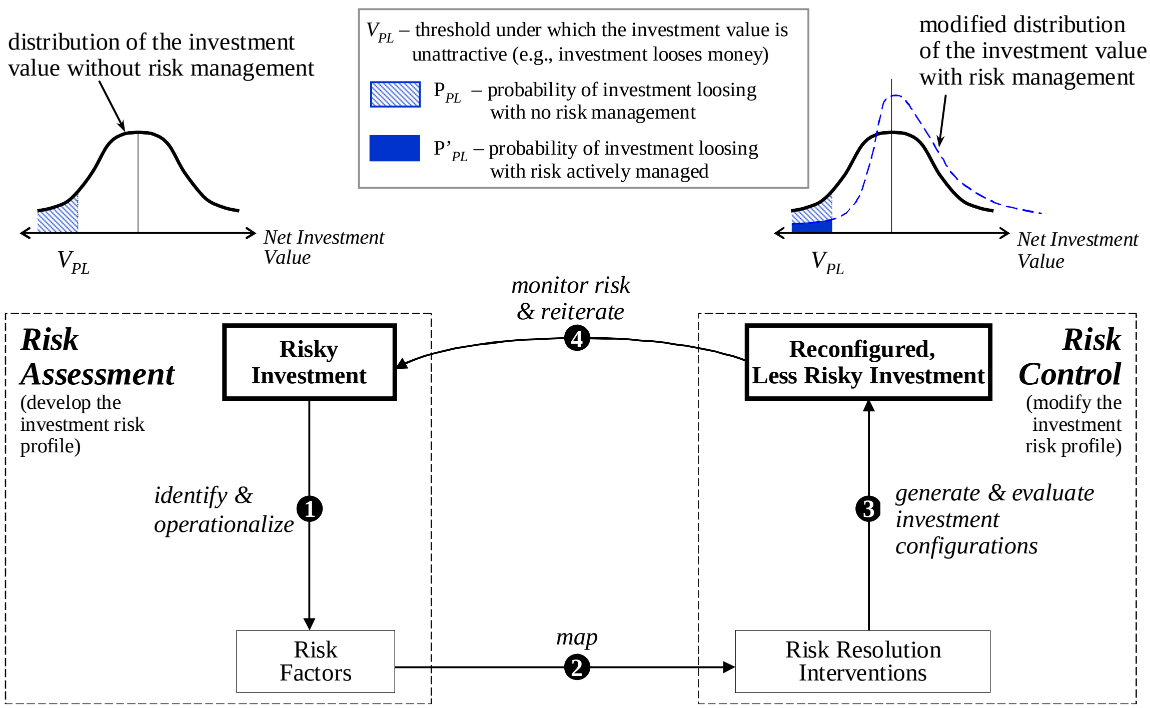

Figure 1

A prerequisite to managing IS development investment risk is having the flexibility to deviate from a predetermined course of action in response to the materialization of risks affecting an investment and its contextual environment. It has been shown empirically that 'flexibility' is one of five cultural variables of an organization having a significantly positive correlation with successful IS development (Harper and Utley, 2001).

The ability to apply risk countermeasures at a reasonable cost is missing unless the requisite flexibility exists from the outset. When management does not have the flexibility to apply risk interventions, the investment value is usually measured by the passive NPV, NPV^P. When management has the flexibility to take (economically) rational corrective actions in response to risk, the value of the investment is measured by the active NPV, NPV^A:

$$NPV^A = NPV^P + \textit{value of managerial flexibility permitting to deploy risk interventions} \quad \textbf{(1)}$$

However, flexibility is not inherent in any IS investment – it must be proactively planned and built in a target investment, based the specific risks one seeks to control using specific risk interventions. The flexibility built into an IS investment is economically counterproductive if: (1) there are no risks present, and (2) it is not linked to specific interventions that are adequate for the risks present. Moreover, recognizing that flexibility and risk interventions have a cost associated with them, the question in need of an answer is:

How much, and what forms of, flexibility should risk management build into an IS development investment in order to optimize the expected net investment value?

This question frames risk management as being about creating the right amount of flexibility needed for a carefully planned set of interventions, whose expected cumulative cost is optimally balanced against the value that they are expected to add to the investment.

A useful way to refine the above question is using the notion of real options. Real options are surrogates of the forms of flexibility needed to deploy beneficial countermeasures when relevant risks materialize (Benaroch and Kauffman, 2001). Real options can be viewed as high-level strategies for managing risk. In fact, some of the risk countermeasures most commonly identified in the IS risk literature have clear parallels with, or even map directly to, real options. Some options are in themselves risk countermeasures; e.g., prototyping, staging (incremental development), fee-based outsourcing contracts, resource leasing contracts, and abandonment (Boehm, 1991; Fairley, 1994). Other options simply create the flexibility needed to deploy more granular risk countermeasures; e.g., deferral provides time to cross-train personnel to counter risk due to an unstable emerging technology. Moreover, another appealing reason to build on the notion of real options has emerged from a recent empirical study showing that IS managers follow the logic of real options theory (ROT) in managing IT investment risk, although purely based on intuition (Benaroch, Lichtenstein and Robinson, 2006).

Figure 2 depicts the interactions between flexibility that the macro-level business decisions build into an IT investment and risk resolution interventions that micro-level decisions employ to mitigate the impact of IS development risk factors. Through outlining these relationships, we can see that micro-level technical decisions made in response to risk factors enable or constrain macro-level business decisions. For example, the organization could make the technical decision to go with a modular design in response to the risk factor that functionality requirements may change. The flexibility created by the design would then enable management to build the additional functionality at a lower cost if the risk factor did indeed manifest. Without that flexibility, building additional functionality could turn out to be cost prohibitive. A high-level sketch of the economic optimization model we fully develop is as follows:

$$\underset{\substack{\text{plausible RRIs} \\ \text{for controlling} \\ \text{the risks present}}}{\textbf{MAX}} \quad NPV^A = \left[NPV^P + f(\text{risk, embedded options, risk countermeasures planned}) \right] \quad \textbf{(2)}$$

Our model examines the way the probability density function of investment returns can be affected by the addition of specific forms of flexibility and the risk countermeasures that they enable. The model builds on two important measures developed by research on software development risk management – risk exposure (RE) and risk resolution intervention (RRI) (Boehm, 1991). RE is a measure of risk defined as:

$$RE = \text{Probability of a risk event * Loss expected if risk event occurs} \quad \textbf{(3)}$$

RRI is a cost-benefit measure of a risk intervention, defined as:

$$RRI = \frac{RE^{\text{before}} - RE^{\text{after}}}{\text{cost of intervention}} \quad \textbf{(4)}$$

We reframe these two measures in terms that can be naturally fitted into formal real option valuation models. Overall, our model is expected to enable organizations to determine the effect of IT investment risk on the net investment value, and to manage that risk in an economically optimal manner.

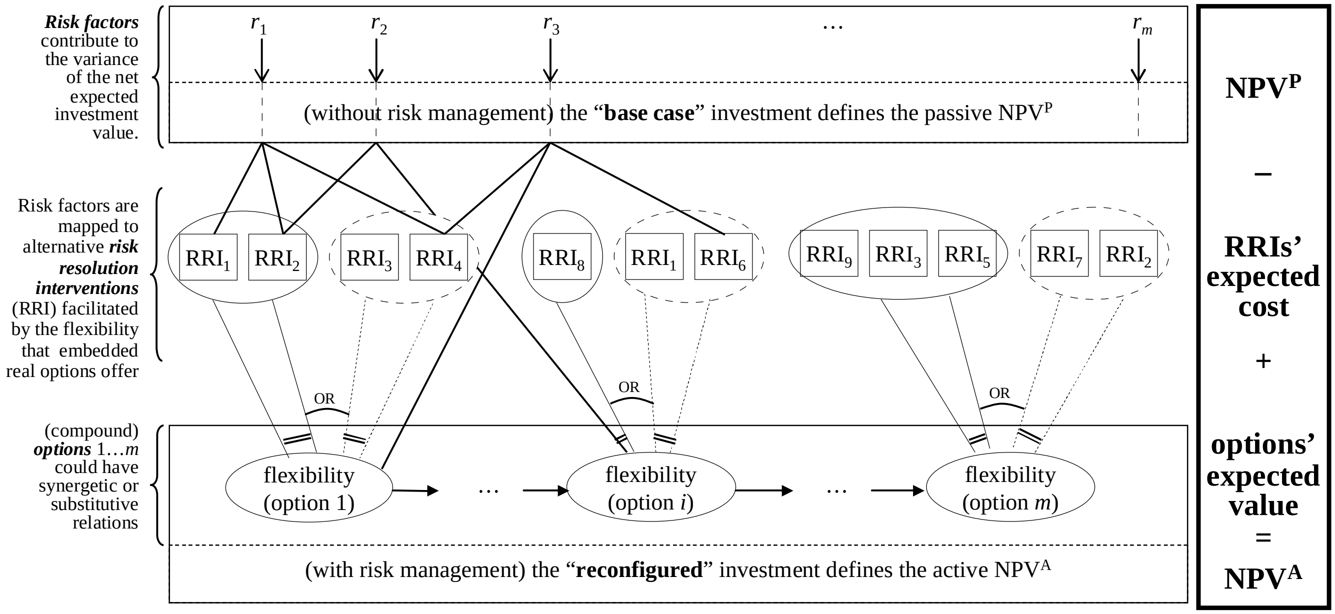

Figure 2

CONCLUSION

Recognizing that software development is a value-creation activity, this research seeks to provide organizations a means to manage IS development risk in an economically optimal manner. The approach involves explicitly modeling the value-creation perspective within a real options framework, which is suitable for establishing the economic link between technical decisions made at the micro level and strategic business decisions made at the macro level. The ongoing effort to conceptualize and formalize the risk management model using this approach is to be followed by two other steps. One is the identification and adaptation of a suitable option valuation algorithm for solving the resulting model. The other is the development of realistic illustrations to demonstrate the economic link and its practical implication on real-world software development decision-making.

ACKNOWLEDGEMENTS

This research was supported by a grant from the IBM Fund and the Brethen Institute for Operations Research, Whitman School of Management, Syracuse University.

REFERENCES

1. Alter, S. and Sherer, S.A. (2004) A general but readily adaptable model of information risk, *Communications of the Association for Information Systems*, 14, 1-28.
2. Amran, M. and Kulatilaka, N. (1999) Disciplined decisions: Aligning strategy with the financial markets, *Harvard Business Review*, 77, 1, 95-104.
3. Barki, H., Rivard, S. and Talbot, J. (2001) An integrative contingency model of software project risk management, *Journal of Management Information Systems*, 17, 4, 37-69.
4. Benaroch, M. (2002) Managing investments in information technology based on real options theory, *Journal of MIS*, 19, 2, 43-84.
5. Benaroch, M., Lichtenstein, Y. and Robinson, K. (Forthcoming, 2006) Real options use in IT investment risk management: An empirical investigation, *MIS Quarterly*.
6. Benaroch, M. and Kauffman, R.J. (1999) A case for using real options pricing analysis to evaluate information technology project investment, *Information Systems Research*, 10, 1, 70-86.
7. Boehm, B. W. (1991) Software risk management: Principles and practices, *IEEE Software*, 32-41.
8. Boehm, B. and Sullivan, K. (1994) Software economics: A roadmap, *Proceedings of ICSE'2000*, June 8, 2000, 321-343.
9. Fairley, R.E. (1994) Risk management for software projects, *IEEE Software*, 1, 3.

10. Harper, G. and Utley, D. (2001) Organizational culture and successful information technology implementation, *Engineering Management Journal*, 13, 2.
11. Jiang, J.J., Klein, G., and Discenza, R. (2001) Information system success as impacted by risks and development strategies, *IEEE Transactions of Engineering Management*, 48, 1, 46-55.
12. Keil, M., Cule, P.E., Lyytinen, K. and Schmidt, R.C. (1998) A framework for identifying software project risks, *Communications of the ACM*, 41, 11, 76-83.
13. Kim, Y.J., and Sanders, L.G. (2002) Strategic actions in information technology investment based on real option theory, *Decision Support Systems*, 33, 1– 11.
14. Kumar, R.L. (2002) Managing risks in IT projects: An options perspective, *Information and Management*, 40, 63-74.
15. Lyytinen, K., Mathiassen, L. and Ropponen, J. (1998) Attention shaping and software risk – a categorical analysis of four classical risk management approaches, *Information Systems Research*, 9, 3, 233-255.
16. McFarlan, W. (1982) Portfolio approach to information systems, *Journal of Systems Management*, 33, 1, 12-19.
17. Ropponen, J. (1999) Software risk management: Foundation, principles and empirical findings, Jyväskylä University Printing House, Jyväskylä.
18. Schmidt, R., Lyytinen, K., Keil, M. and Cule, P. (2001) Identifying software project risks: An international delphi study, *Journal of Management Information Systems*, 17, 4, 5-36.