Technovation ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Technovation

journal homepage: www.elsevier.com/locate/technovation

An economic–probabilistic model for risk analysis in technological innovation projects

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ARTICLE INFO

Keywords:
Risk analysis
Economic evaluation
Probabilistic evaluation
Technological innovation
Stochastic simulation

ABSTRACT

This paper presents the application of an economic–probabilistic model to conduct risk analysis in technological innovation (TI) projects. The model integrates risk and economic analysis by quantifying both value and probability of occurrence of cash flow deviations, thus resulting in an economic–probabilistic analysis of the expected returns. The main risk categories and factors in TI projects are identified and associated to cash flow groups. The model allows to calculate risk-adjusted values for cash flow groups and project net present value through stochastic simulation. As a result, the model provides both the risk-adjusted project economic return with the associated probability distribution to its NPV and the variability that each risk factor generates in the project return. The model offers important benefits from the point of view of practitioners, including a condensed list of independent risk factors and the use of a monetary scale to assess risk impact which is familiar to most decision makers.

1. Introduction

In the last decades, the evolution and diffusion of information technology led to a significant increase in the use of data to support decision making in business. However, this abundance of data does not always guarantee sound decisions. In some occasions, large amounts of data imply in a myriad of decision variables that cannot be effectively contemplated (Chavas, 2004). In other situations, the specific data required is either not available or not accurate and/or timely enough. In fact, although information technology is now pervasive and the importance of using valid data to support decision making is generally accepted, the current competitive scenario is still laden with all kinds of uncertainties—and, consequently, risks (Sun and Ma, 2005; Shehabuddeen et al., 2006).

Moreover, new technologies and increasingly dynamic organizational factors are responsible for rapidly changing environments that are subject to almost uncontrollable risks (Wu and Ong, 2008). In this complex and volatile context, a particular type of decision-making that is especially prone to risk is the one associated with technological innovation (TI) (Wang and Lu, 2008; Kohler and Som, 2013). Technological change is particularly fast and the impacts of technological innovations are usually difficult to accurately foresee. Moreover, investments in TI projects tend to be massive, even if only incremental innovations are to be achieved, and failures are almost unacceptably common—especially when radical innovation projects are pursued (McDermott and O′Connor, 2002). The growing strategic role of technology in the business environment has contributed to greater complexity and difficulty in TI investment evaluations (Joshi and Pant, 2008; Wang et al., 2010).

Thus, it is largely accepted that TI projects are normally risky endeavors (Klein and Sorra, 1996). In this context, the use of risk analysis techniques and methods in TI projects is growing in importance in both academic and practitioner circles (Bannerman, 2008; Wang et al., 2010; Taylor et al., 2012). This issue is even more pressing if one considers that traditional project evaluation mechanisms are not robust enough to capture the complex dynamics of TI projects neither inclusive regarding risk assessment (Wu and Ong, 2008; Salmeron and Lopez, 2012). Traditional approaches to risk assessment in projects normally focus on measures such as net present value (NPV) and internal rate of return (IRR), both, in turn, based on discounted cash flow (DCF) analysis (Clemons, 1991; Ho and Liao, 2011). However, such approaches assume that future cash flows can be predicted with reasonable accuracy and that assumptions assumed before the project was even initiated will remain valid for the duration of the project. The analysis of a deterministic discounted cash flow is not enough to correctly assess a project managerial flexibility regarding risk (Smart et al., 2004; Putten and Macmillan, 2004).

As an alternative to circumvent difficulties associated with traditional approaches to risk analysis, some models use fuzzy-logic to assess risk in projects (Morote and Vila, 2011; Salmeron

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http://dx.doi.org/10.1016/j.technovation.2014.01.002

Risk Category	Risk Factor	References
Costs	Budget conformity	6, 11, 13, 18, 20, 21, 24, 27
	Financial exposition	8, 11, 12, 13, 18, 20, 26, 27
	Estimates and contingencies	2, 10, 12, 16, 24, 25, 26
Benefits	Benefit clarity	3, 4, 11, 13, 15, 17, 19, 24
	Benefit reliability	3, 4, 10, 18
	Benefit validation	3, 4, 11, 13, 18
	Benefit achievement plan	3, 4, 11, 13, 17, 18
	Benefit measurement	3, 4, 6, 15, 21, 25
	Benefit metrics and targets	3, 4, 15, 17, 19, 21
	Benefit capture process	13, 15, 18, 20, 25
Skills and experience	IT skills	5, 6, 8, 9, 10, 11, 12, 13, 16, 17, 20, 21, 22, 24, 27
	Business skills	5, 7, 8, 10, 12, 14, 15, 19, 21, 25
	Project Management skills	5, 6, 7, 8, 9, 10, 12, 14, 15, 16, 17, 19, 22, 23, 24, 25, 27
Size and complexity	Project size	5, 7, 8, 9, 10, 12, 14, 18, 19, 20, 23, 24
	Project complexity	5, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 23, 24
	Dependence on other projects	5, 7, 8, 14, 15, 24, 27
	Dependence on individuals	5, 6, 7, 14, 19, 21
	Dependence on suppliers	5, 10, 12, 17, 18
Architecture and performance	Architecture aligment	12, 15, 19, 20, 21, 26
	Safety	10, 12, 18, 21, 23
	Critical performance point	1, 2, 18, 21
Schedule	Development time	1, 6, 10, 17, 19, 21, 25, 26
	Development termination	17, 18
Scope clarity	Future state clarity	5, 7, 8, 12, 22
	Results clarity	5, 7, 8, 12, 19, 21, 24
	Area focus clarity	8, 12, 18, 21
Organizational support	Business areas involvement	2, 8, 12, 19, 21, 24
	Support from areas impacted by the change	5, 8, 9, 12, 15, 17, 19, 21, 22, 24
	Sponsor disposition	5, 7, 8, 12, 18, 21
	Sponsors	5, 7, 8, 10, 12, 15, 19
	Resource source commitment	2, 8, 12, 18, 21, 22
	Computational operations support	12, 14, 17, 18
	Top management involvement	8, 9, 10, 15, 17, 19, 21, 22, 24
Change impact	Change extension	5, 7, 14, 18, 19
	Change competences	5, 12, 15, 17, 19, 21, 22
Business environment	Adaptive capability regarding business changes	7, 8, 10, 12, 23, 25, 27
	Business environment sensibility	7, 12, 21, 26, 27
	Changes in customer needs	7, 12, 17, 18, 20, 21, 24, 25, 26, 27
Technological maturity	IT maturity	5, 7, 10, 11, 12, 13, 17, 19, 20, 21, 22, 24, 27
	IT sofistication	5, 6, 7, 8, 9, 12, 14, 17, 19, 24, 27
Risk management	Guidelines planning	8, 10, 12, 15, 18, 23
	Quality assurance	8, 10, 12, 18, 23, 25
	Decision-making	12, 15, 16, 18, 19

1. Boehm (1988)
2. Boehm and Identzhing (1991)
3. Clemons (1991)
4. Kemerer and Sosa (1991)
5 Barki *et al.* (1993)
6. Karolak (1996)
7. Moynihan (1997)
8. Keil *et al.* (1998)
9. Jiang *et al.* (2000)
10. Barki *et al.* (2001)
11. Benaroch (2001)
12. Schmidt *et al.* (2001)
13. Benaroch (2002)
14. Jiang *et al.* (2001)
15. Iversen *et al.* (2004)
16. Kliem (2004)
17. Wallace *et al.* (2004)
18. Benaroch *et al.* (2006)
19. Lientz and Larssen (2006)
20. Benaroch *et al.* (2007)
21. OGC (2007)
22. Chen *et al.* (2009)
23. Parent and Reich (2009)
24. Warkentin *et al.* (2009)
25. Wang *et al.* (2010)
26. Fang *et al.* (2013)
27. Abbassi *et al.* (2014)

Fig. 1. Main risks associated with IT projects (Abbassi et al., 2014; Barki et al., 1993; Barki et al., 2001; Benaroch, 2001; Benaroch, 2002; Benaroch et al., 2006; Boehm, 1988; Fang et al., 2013; Iversen et al., 2004; Jiang et al., 2000; Keil et al., 1998; Kemerer and Sosa, 1991; Kliem, 2004; Lientz and Larssen, 2006; Moynihan, 1997; OGC—Office of Government Commerce, 2007; Parent and Reich, 2009; Schmidt et al., 2001; Wallace et al., 2004; Warkentin et al., 2009).

and Lopez, 2012; Liu et al., 2013; Kuo and Lu, 2013), while others use real options (Benaroch et al., 2007; Chen et al., 2009; Ho and Liao, 2011; Mao and Wu, 2011; Lin and Wesseh, 2013). These two approaches suit different needs. Fuzzy-based models aim to quantify the impact of risks on the success of a project, but do not provide economic analysis. On the other hand, models based on real options quantify the economic value of a project's flexibility towards risk, but lack an individual analysis on the impact of the identified risks.

Another alternative to assessing risk in projects is the use of stochastic simulation, as shown by Schmitz et al. (2006). However, the model proposed by Schmitz et al. (2006) underestimates a

Please cite this article as: Miorando, R.F., et al., An economic–probabilistic model for risk analysis in technological innovation projects. Technovation (2014), http://dx.doi.org/10.1016/j.technovation.2014.01.002