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RISK MANAGEMENT AND VALUATION OF REAL OPTIONS IN IT PROJECTS: AN EXPLORATORY EXPERIMENT

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Abstract

IT project performance is influenced by the fit between the project's risks and how the IT project risk is managed (Barki et al. 2001). Recently researchers have emphasized the need to use concepts from real option theory for risk management purposes (Boehm 1989, Benaroch 2002, Kumar 2002, Miller et al. 2003). A project embeds real options when managers have the opportunity but not the obligation to adjust the future direction of the project in response to external or internal risks. Proactively embedding options in a risky IT project can represent a substantial portion of a project's value. From a risk management perspective, the specific risk one seeks to control dictates the choice of which specific options to use. Recently, Benaroch (2002) proposed an explicit normative option based risk management model suggesting the most effective risk-options combinations. This paper describes an exploratory experiment that was conducted to determine whether IT professionals explicitly recognize that the value of flexibility, related to different types of options, is driven by the presence of specific risks. The results partially indicate support for the risk-options relations as proposed by Benaroch (2002).

Keywords: decision making, IT projects, risk management, real options, experiment

1 INTRODUCTION

In an attempt to deal with the continuing problem of IT project failures, researchers have tried to identify critical risk factors in IT projects (Barki et al. 2001, Keil et al. 1998). A risk factor is a property of an IT project or its contextual environment that affects the degree of variation in expected project performance. IT project performance is influenced by the fit between the project's risk and how the project risk is managed (Barki et al. 2001). From a risk management perspective, flexibility is a crucial success factor in IT projects as it enables deployment of risk countermeasures as a response to risk (Avison et al. 1995). Flexibility in IT project concerns the processes by which IT systems are delivered. IT is particularly well suited to the use of simulations, prototypes, pilots, and various forms of staged implementation—all of which generate a wide variety of opportunities for incremental project commitment. Recognizing and promoting this flexibility in a project can be conceptualised as real options (Fichman et al, 2005). A project embeds real options when managers have the opportunity (but not the obligation) to adjust the future direction of the project in response to external or internal events. Since real options are not inherent in any IT project, they usually must be planned and intentionally embedded in an IT project in order to control specific risk factors (Benaroch, 2002). Proactively embedding options in risky IT projects can represent a substantial portion of a project's

value. Since different risk factors and multiple types of options can be embedded in IT projects, the valuation of complex options remains difficult and open for further research

Benaroch et al. (2006) and Tiwana et al. (2006) have investigated the intuitive logic behind the relationship between risk and the forms of flexibility offered by real options. In our research we extend the findings of their research by investigating whether and how the value that IT professionals assign to different types of real options (flexibility) in IT projects is influenced by various IT risk factors. The research question in this study is: how do risk factors differentially influence the value that professionals ascribe to real options embedded in an IT project? We assume that the valuation of real options (as perceived by IT-professionals) is differentially influenced by the particular type of risk a project faces. Our aim is to provide an empirical evidence of the link between IT risks, flexibility in IT projects and IT project value assessment.

In this paper we first introduce a theoretical model that relates risk factors, real options, and perceived value of IT projects. The relations in the model were empirically tested using an exploratory field experiment, as described in the second part of the paper.

2 IT RISK MANAGEMENT AND REAL OPTIONS

2.1 IT risks

Many IS researchers examining IT projects identified the concept of project risk as a key construct that needs to be taken into account when managing a project (Barki et al. 2001, Keil et al. 1998). IT project risk can be categorised by distinguishing between market risk and firm-specific risk. Market risks are due to exogenous (in the business environment) uncertainties caused by the randomness or unpredictability of the environment. Market risks like demand uncertainty and technical uncertainty, can significantly influence the returns of a firm or project. Firm-specific risks are caused by endogenous (within the firm) uncertainties. Firm-specific risks can be categorised in:

- Monetary risk, caused by uncertainty about expected project costs or unclear, validated or credibly projected benefits, and about whether they are linked to adequate realization plans.
- Project risk, caused by uncertainty about the project being too large or too complex, the IS staff's technical skills being adequate or lacking experience with a target IT, or about the adequacy of the firm's existing IT infrastructure.
- Functionality risk, caused by uncertainty whether the firm builds the application right according to the required specifications, or the requirements are clear or unproblematic.
- Organisational risk, caused by uncertainty whether the IT application can be undermined or adopted too slowly by people in the firm.

2.2 Real options theory and IT project value

An IT project possesses a real option when it offers management the opportunity, but not the obligation, to take some action in the future in response to endogenous (within the firm) or exogenous (in the business environment) events (Benaroch & Kauffman, 1999). Although real options can represent a substantial portion of a project's value, they rarely enter into a project's formal justification process in the traditional quantitative discounted cash-flow-based project valuation techniques. The goal of a real options analysis is to determine the active net present value (NPV) of a project. The traditional NPV estimates do not consider the value of the opportunity for managers to intervene across the project's trajectory. Therefore traditional NPV represent the lower bound of a project's actual value to the firm (Taudes et al. 2000). The active NPV is equal to the traditional, or passive NPV plus the value of the embedded real options (flexibility). Thus,

$$NPV_{Active} = NPV_{Passive} + f(\text{value of the bundle of real options embedded in the project}) \quad (1)$$

IT projects offer various opportunities to embed real options. Different types of real options that can be embedded in IT projects are:

1. Option to defer: this option exists when a project can be postponed in order to learn about the potential investment outcomes before committing to the entire project.
2. Option to prototype: exists when management creates flexibility to partially invest in a prototype effort. Building parts of an application using prototyping can be used to conduct performance tests, technical feasibility studies, or study technology issues.
3. Option to stage: this exists when a project can be divided into distinct stages where pursuit of each stage is contingent on a reassessment of costs and benefits at the time the preceding stage is completed.
4. Option to abandon: the option exists when a project can be terminated midstream and remaining project resources relatively easily redeployed.
5. Option to scale up or down: an option to change scale exists when allocated project resources can be contracted or expanded in response to future conditions, or when the delivered application can be scaled up or scaled down with comparative ease.
6. Option to grow: this option exists when an initial baseline project opens the door to pursue a variety of potential follow-on opportunities.

A theoretical distinction can be made between operating options (options 1 to 5) and strategic growth options (option 6). Operating options allow managers to reconfigure such elements as the timing and scope of an investment. Strategic growth options open new investment opportunities by giving management the ability to make follow-on investments (Trigeorgis 1993).

Using a field experiment, Tiwana et al. (2006) recently provided evidence that the presence of real options in an IT project leads to a tendency toward continuing projects, and this tendency increases with the number of real options that are present in a project. Some options, such as the option to abandon, are given very little comparative value. Benaroch (2002) developed a framework that explores the most effective combination of options to embed in an IT project in order to optimise the control of risk and maximise IT project value (see Table 1). Although Benaroch et al. (2006) tested this framework in a single case study, there remains the need for a solid validation of how different types of risk influence the valuation of real options by IT professionals. Recognizing which type of risk should be mitigated by which type of flexibility as offered by real options concepts, is a crucial step in optimally configuring an IT project in such a way that risk can be adequately managed and investment value can be maximized. Our research may also give insights into possible biases in how managers respond to different types of risk.

Risk category	Risk factors	Defer	Prototype	Stage	Abandon	Scale up
Monetary	1. Unclear project benefits	√	√			
Project	2. Team lacks needed skills	√	√	√		
	3. Project is too large		√	√		
	4. Inadequate infrastructure	√	√	√		
Functionality	5. Inadequate design (e.g. performance)		√	√		
	6. Problematic requirements	√	√	√		
Organisational	7. Insufficient management support	√	√	√	√	
	8. Ability of units to handle change		√	√	√	
Environmental	9. Demand exceeds expectations	√				√
Technological	10. Introduction of new superior technology	√			√	

Table 1. IT project risk factors mapped to operating options that could mitigate them (extracted from Benaroch 2002 and Benaroch et al. 2006)

3 RESEARCH MODEL AND PROPOSITIONS

In our research we combine the above findings on the relationship between the qualitative valuation of real options in IT projects, and the relationship between risk and real options. We first present our model of IT project decision making behaviour that assesses whether and how the various types of IT risk influence the valuation of different types of real options in IT projects (see Figure 1).

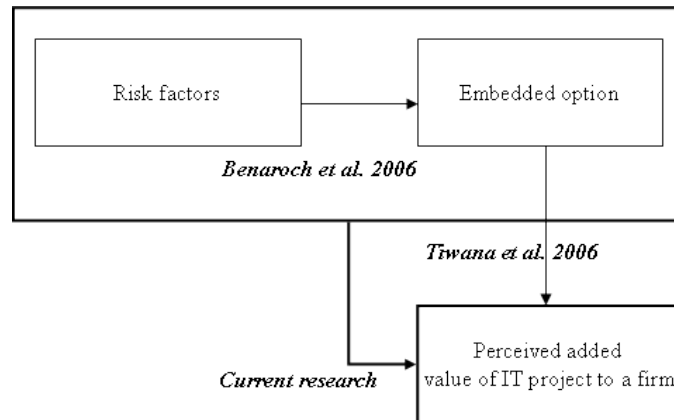


Figure 1. Research model (adapted from Benaroch et al. 2006 and Tiwana et al. 2006)

As in Tiwana et al. (2006), the value added associated with an IT project will be a function of the NPV_{Passive} (see equation (1)) plus the value of the embedded real options. When $NPV_{\text{Passive}} = 0$, the value added is equal to the value of the embedded real options. So the total perceived value that an IT project adds to the firm is a function of the proposed options to be embedded in the project. Since research shows that subjective option valuations increases with risk (Sirmans and Yavas 2001), while other do not (Howell and Jägle 1997), we keep risk in the projects a constant factor.

In order to empirically test the relations between risk factors, embedded options, and perceived added value, we selected ten risk factors (Table 1) ranging from different categories of firm-specific risks (risk factors 1-8) to market risks (risk factors 9 and 10). Also, we selected five option types, being the options to defer, prototype, stage, abandon and scale up. Based on the research model, we tested the propositions as shown in table 1 and described in section 3.1 (effects of firm-specific risks and embedded options on project value) and section 3.2 (effects of market-specific risks and real options on project value).

3.1 Effects of Firm-Specific Risks on Project Value

3.1.1 Monetary Risk

Monetary risk can be caused by uncertainty over the expected project costs and benefits. One aspect of monetary risk is benefits risk. Benefits risk can be caused by uncertainty over whether the expected project benefits are clear or validated, for example due to poor benefit estimation. To learn about benefits risk facing an IT project, management can decide to acquire information to adjust the course of the IT project. In an economically rational approach, buying information can be obtained by the flexibility afforded by the option to defer or the option to prototype (Benaroch et al. 2006). The option to defer and prototype can give the flexibility to wait for new information to arrive over time (Boehm 1989), for example by waiting for regulatory changes or new technology standards, or it could be

obtained proactively through, for example, conducting a better benefits analyses to find out whether an early version can give insight in the expected project payoffs.

Proposition 1: In case of risk of unclear project benefits, the option to defer (resp. prototype) an IT project will be more highly valued than the option to stage, abandon or scale up.

3.1.2 Project Risk

Project risk can be caused by (1) uncertainty over whether the project staff (technical) skills are adequate (Barki et al. 2001, Wallace et al. 2004, Benaroch et al. 2006), (2) the project is too large or too complex (McFarlan 1981, Barki et al. 2001, Wallace et al. 2004, Applegate 2005, Benaroch et al. 2006, Du et al. 2007) or whether (3) the firm's IT infrastructure is adequate (Benaroch et al. 2006). Project risk facing an IT project can be mitigated by transferring risk from one part of a project to another, using the option to stage, or by acquiring information, using the option to defer or prototype. Risk of a lack of project team skills can be mitigated by deferring, prototyping or staging the project. Risky parts of the project needing specific skills can be planned at the end of the project as to gain time to invest in overcoming a lack of knowledge. Also, a prototype can be an effective way to conduct feasibility studies or make a knowledge and task analysis to reveal and repair a lack of skills.

Proposition 2a (resp. 2b, resp. 2c): In case of risk of inadequate project staff skills, the option to defer (resp. the option to prototype, resp. the option to stage) an IT project will be more highly valued than the option to abandon or scale up.

When the project is too large or too complex, staging can give insight in the possibility of simplifying system requirements. The project can be divided into incremental units of functionality, each of which can be implemented separately. Risky parts of the project can be planned early in the project to reveal the seriousness of the risk, or at the end of the project as to gather more information about the risk. Building parts of a system using a prototype is also an effective way to learn about the system realisation success.

Proposition 3a (resp. 3b): In case of risk of a large project, the option to prototype (resp. the option to stage) an IT project will be more highly valued than the option to defer, abandon or scale up.

Inadequate infrastructure risk refers to uncertainty of the organisation's infrastructure to support the project's system (Benaroch et al. 2006). It can affect the entire system implementation, without leaving the possibility for implementing parts of the system or enabling a system expansion. For example, when implementing a large organisation-wide application, an organisation's network architecture may be inadequate to support the extensive use of the system, which may lead to performance problems. Therefore, transferring risk is perceived a less adequate mitigation strategy when facing infrastructure risk. By acquiring information through running simulations or performance tests, initiate technology feasibility or compatibility, management can learn about infrastructure risk facing an IT project.

Proposition 4a (resp. 4b, resp. 4c): In case of inadequate infrastructure risk, the option to defer (resp. the option to prototype, resp. the option to stage) an IT project will be more highly valued than the option to abandon or scale up.

3.1.3 Functionality risk

Functionality risk may be caused by (1) an inadequate system design (e.g., inadequate interfaces, performance or availability shortfall) (Barki et al. 2001, Wallace et al. 2004, Benaroch et al. 2006) or (2) by problematic, unstable or unclear requirements, also referred to as requirements volatility (Barki et al. 2001, Wallace et al. 2004, Applegate 2005, Benaroch et al. 2006). Functionality risk can be mitigated by transferring risk from one part of a project to another, which can be created using the

option to stage, or by acquiring information, which can be created using the option to defer or prototype. Risk of an inadequate system design or problematic or unclear requirements can be mitigated by prototyping or staging the project. An early project stage or prototype can be an effective way to reveal information about the system implementation success.

Proposition 5a (resp. 5b): In case of inadequate system design risk, the option to prototype (resp. the option to stage) an IT project will be more highly valued than the option to defer, abandon or scale up.

The option to defer can also be an effective risk mitigation strategy in the case of unstable or unclear requirements by giving the opportunity to solve the lack of clarity, for example due to changing business requirements or the course of competitive actions.

Proposition 6a (resp. 6b, resp. 6c): In case of unclear requirements risk, the option to defer (resp. the option to prototype, resp. the option to stage) an IT project will be more highly valued than the option to abandon or scale up.

3.1.4 Organisational risk

Organisational risk can be caused by uncertainty over (1) the ability of the organisation to handle change (Barki et al. 2001, Wallace et al. 2004) or (2) through insufficient management support. (Kumar 2002, Wallace et al. 2004, Applegate 2005).

Risk of insufficient management support can be mitigated by deferring a project. By waiting to invest, business conditions can change giving management a reason to support the project. Also, the project can be staged to slowly persuade management to support the project and participate. In the case of insufficient management support, the decision makers can realise that it might be preferable to terminate the project rather than continue (Kumar, 2002).

Proposition 7a (resp. 7b, resp. 7c, resp. 7d): In case of risk of insufficient management support, the option to defer (resp. the option to prototype, resp. the option to stage, resp. the option to abandon) an IT project will be more highly valued than the option to scale up.

Risk of the disability of the organisation to handle change can be caused for example by the restructuring of the organization during the project or corporate politics with negative effect on project (Wallace et al. 2004). A relevant risk mitigation strategy can be to stage the project, so that the organisation can learn about the organisational effects of a first implementation. Specifically, the option to abandon becomes relevant. The option to *abandon* (disinvest) allows killing a project and redirecting its resources to alternate uses if organizational risks materialize.

Proposition 8a (resp. 8b): In case of risk of inability of business units to handle change, the option to stage (resp. the option to prototype, resp. the option to abandon) an IT project will be more highly valued than the option to defer or scale up.

3.2 Effects of Market-Specific Risks on Perceived Project Value

3.2.1 Environmental Customer Demand Risk

Environmental risk may be caused by customer demand that exceeds expectations. We specifically test customer demand exceeding expectations since this will allow us to test a risk that can have positive consequences. A customer acceptance rate exceeding expectations can present follow-up investment opportunities, and therefore this type of risk can have positive consequences. In this specific case management can either decide to wait since this may reveal additional information, or expand the project in activities or products that increase the value of future options.

Proposition 9a (resp. 9b): In case of risk of customer demand exceeding expectations, the option to defer (resp. the option to scale up) an IT project will be more highly valued than the option to prototype, stage or abandon.

3.2.2 Technological Risk

A specific case of environmental technological risk is the introduction of a new superior technology, which may render the initial system obsolete. For example, when investing in an older version of an operation system technology when a new improved operating system version can appear, project returns may be lower than when management decides to wait for the newer version. To mitigate this type of risk, management can decide to wait to invest or abandon the entire project.

Proposition 10a (resp. 10b): In case of risk of the introduction of a superior technology, the option to defer (resp. the option to abandon) an IT project will be more highly valued than the option to prototype, stage or scale up.

4 RESEARCH METHOD

An exploratory field experiment is used to test the proposed model. Since our research tries to test normative real options theory, an exploratory field experiment is considered appropriate for this goal. In the experiment, each respondent assesses eight IT project scenarios with different risk factors. As in Tiwana et al. (2006) we assume that the (passive) NPV of the IT project scenario is zero. When the NPV of the IT project is zero, according to equation (1), the perceived added value of the IT project to the firm is equal to the value of the options. The ten risk factors are assigned in a random order to each IT project scenario. In each scenario, given a specific IT risk factor and presented with five different types of options, for every risk-option relation subjects are asked to assess the value of the IT project to their firm. Respondents received the following instructions: "You are asked to assess eight IT projects in your organisation. Each project is a risky software development project. Despite the risk, the expected benefits for every project equal the expected expenses. Every presented project faces a different type of risk. For each presented risk, five investment options are presented to mitigate the risk. Indicate, based on the mentioned risk factor and the different investment options, the value of the IT project for your firm from 'Does not add value to my firm' to 'Adds value to my firm'. The project description is limited to: *"The project concerns the development of a software system. Assess the project based on the investment options mentioned below for the execution of the project in relation to the given type of risk. Also use your own knowledge and experience."* As in Tiwana et al. (2006) we use a scale from 1 to 7. So for each risk factor, subjects give five assessments of IT project value. The presented order of the different types of options in the experiment is randomly assigned per person, and remains constant during an individual session. The operationalisation of each risk and option attribute is based on existing descriptions of IT risk (see section two) and real options in IT projects (Benaroch 2002, Tiwana et al. 2007, Trigeorgis 1993). We pre-tested materials with five IT professionals to ensure the instrument was unambiguous and possessed face validity and that the project scenarios were realistic.

We contacted the subjects by mail, providing a URL for a web-based version of the experiment. We used a professional external institute to build and host the website and contacted the subjects using a personalised email. After filling in a pre-questionnaire (industry, years of experience,...), subjects were asked to assess the project scenarios. As in Tiwana et al. (2006) subjects were informed that, despite the risk facing the project, expected incoming cash flows of the projects equal the project costs.

We conducted the experiment in September 2008 and contacted 151 management consultants in a large global consultancy firm. The management consultants all work in the IT Effectiveness competence group, operating in various public and private industries. We sent out 151 invitations by email. Six emails were returned as undeliverable. We received 81 completed sets of responses (53%

response rate) for the eight different project scenarios, providing a total of 648 non-independent risk observations.

5 RESULTS

On average, the respondents had 8.9 years (standard deviation 7.023) years of IT experience and had previously been involved in making project assessments for 12.50 projects (standard deviation 28.34). Table 2 shows descriptive statistics of our findings. Means and standard deviations for each risk factor are given for each option type. Grey cells represent the proposed risk-options relations.

We find that for each risk factor, our respondents assign different values to an IT project for different real options. This is true for each type of project risk ($p < 0.001$, one-way repeated measures ANOVA). This shows that the valuation of real options in IT projects is differentially influenced by different types of risk factors. To test the propositions, we first performed a sign test to make a comparison between the valuations of the different option types per risk factor. Since this test offers us no significant results, we exploratory tested our propositions using a one-tailed t-test. The one-tailed t-test is used to make a paired comparison between the different option types. For each risk factor we make a paired comparison between the option types.

	Risk factor (N)	Defer	Prototype	Stage	Abandon	Scale up
Firm	1. Unclear project benefits (71)	4.24/2.067	4.23/1.958	4.17/1.935	3.73/2.210	2.32/1.697
	2. Team lacks needed skills (63)	3.40/1.922	3.65/1.944	4.46/1.533	3.17/1.783	4.84/1.771
	3. Project is too large (76)	2.71/1.757	4.28/1.852	5.83/1.331	3.03/1.869	2.41/1.525
	4. Inadequate infrastructure (67)	3.25/1.980	4.72/1.968	3.85/2.009	2.90/1.970	3.60/1.939
	5. Inadequate design (e.g. performance) (71)	3.14/2.058	4.85/1.925	3.77/1.936	3.13/2.083	3.77/1.936
	6. Problematic requirements (76)	3.76/2.006	5.07/1.754	4.74/1.836	3.29/2.226	2.96/1.969
	7. Insufficient management support (74)	4.54/2.134	4.03/2.067	3.84/1.843	4.26/2.041	2.00/1.345
	8. Ability of units to handle change (66)	3.27/1.861	4.14/1.805	4.86/1.718	3.06/1.864	3.67/1.908
Market	9. Demand exceeds expectations (76)	1.83/1.215	4.05/2.065	4.46/1.907	1.92/1.354	4.43/1.864
	10. Introduction of superior technology (70)	4.20/2.237	3.07/1.868	3.70/2.010	3.73/2.078	2.20/1.557

Table 2. Main results (mean/variance) of perceived project value on a 1-7 Likert scale for five options and ten risk factors.

The first pair of propositions (1a and 1b) for risk factor ‘Unclear project benefits’ indicated that the option to defer, respectively the option to prototype, would more highly valued than the options to stage, abandon and scale up. However, we found no significant support for propositions 1a and 1b.

The second group of propositions (2a, 2b and 2c) for the risk factor ‘Team lacks skills’ indicated that participants would value the option to defer, respectively the option to prototype or stage, more highly than the options to abandon and scale up. Since the option to scale up is higher valued than all other options for this type of risk factor, there is no support for propositions 2a, 2b and 2c.

The third pair of propositions (3a and 3b) for the risk factor ‘Team lacks skills’ indicated that the option to prototype or the option to stage, would more highly valued than the options to defer, abandon and scale up. Propositions 3a and 3b are significantly ($p < 0.001$) supported.

The fourth group of propositions (4a, 4b and 4c) for the risk factor ‘Inadequate infrastructure risk’ indicated that participants would value the option to prototype, respectively the option to stage or the option to defer, more highly than the options to abandon and scale up. Only proposition 4a (option to prototype) is significantly supported.

The fifth pair of propositions (5a and 5b) for the risk factor 'Inadequate design' indicated that the option to prototype, respectively the option to stage, would more highly valued than the options to defer, abandon and scale up. Proposition 5a for the risk factor 'Inadequate design' is significantly ($p < 0.001$) supported for the option to prototype.

The sixth group of propositions (6a, 6b and 6c) for the risk factor 'Problematic requirements' indicated that the option to defer, respectively the option to prototype or stage, would more highly valued than the options to abandon and scale up. Propositions 6a, 6b and 6c on 'Problematic requirements' are significantly supported for the option to prototype and the option to stage ($p < 0.005$), and the option to defer ($p < 0.05$).

The seventh group of propositions (7a, 7b, 7c and 7d) for the risk factor 'Insufficient management support' indicated that participants would value the option to defer, respectively the option to prototype, stage, or abandon, more highly than the option to scale up. All propositions are significantly supported ($p < 0.001$).

The eighth group of propositions (8a, 8b and 8c) for the risk factor 'Ability of units to handle change' indicated that participants would value the option to prototype, respectively the option to stage or abandon, more highly than the option to defer or scale up. Proposition 8a (option to stage) is significantly ($p < 0.01$) supported.

The ninth pair of propositions (9a and 9b) for the risk factor 'Demand exceeds expectation' indicated that the option to defer, respectively the option to scale up would be more highly valued than the option to prototype, stage or abandon. Both propositions are not significantly supported.

The tenth pair of propositions (10 a and 10 b) for the risk factor 'Introduction of superior technology' indicated that the option to defer, respectively the option to abandon would be more highly valued than the option to prototype, stage or scale up. These propositions are not significantly supported.

In total 12 out of 26 propositions (46%) are significantly supported.

We also performed a t-test analysing results for more experienced IT professionals ($N = 51$), selecting a group having more than 4 years IT experience and having assessed at least five IT project. This did not influence the support of propositions as reported here. Overall, for all risk factors, the option to stage and the option to prototype are significantly higher valued than the option to defer, which is significantly higher valued than the option to abandon and scale up. Both for market risk (risk factors 9 and 10) as for firm risk (risk factors 1 to 8) the option to stage and the option to prototype are more highly valued than the other option types.

6 DISCUSSION AND CONCLUSION

In our research we presented and exploratory tested an IT project decision making model that investigates whether and how the value that IT professionals assign to different risk countermeasures as provided by different types of real options (flexibility) in IT projects is influenced by various IT risk factors. In relation to earlier research conducted by Tiwana et al. (2006), who show that IT professionals place a relative value on various real options in escalation decisions, our research indicates that this value is actually driven by the risk factors an IT project faces.

Different types of options can be used to properly reconfigure the timing, scale and scope of an IT project. Proactively embedding the *right* options in an IT project when facing risk can represent a substantial portion of a project's value. The main theoretical contribution of the research is thereby giving an empirical indication that the intuition of IT professionals is partly consistent with the risk management logic as proposed from a real options perspective, thereby partly supporting and extending the evidence found by Benaroch et al. (2006).

The evidence indicates that, for the risk factors presented in this research, professionals have an overall preference for the option to stage and the option to prototype, taking a proactive stance to risk.

This is in line with behavioural research, which shows that managers believe that risk is manageable and controllable. The option to abandon is the least preferred option.

A particular finding is that for three out of ten risk factors presented in our research, professionals prefer the option to scale up higher than or equally high as the normatively proposed options. This is the case for the risk factors 'Team lacks skills', 'Inadequate infrastructure' and 'Inadequate design'. In these situations we may assume that professionals will try to add team skills or add infrastructure to solve the risk. This would suggest that they expect to mitigate the risk by lowering the variance of the risk (by augmenting the quality of the resources, infrastructure or system). One possible explanation for this finding is we did not use a suitable operationalisation for the option to scale up. For the scale up option we used the operationalisation based on the 'expansion of resources initially allocated to the project to enlarge the scope or quality of the project'. In our research, the operationalisation of the scale up option may also lead to an interpretation of opening up the possibility to mitigate the risk in case of negative risk by adding resources. So the option to scale up may not be well operationalised for the particular application domain in this research.

The preference for the option to scale up in case of external risk indicates that professionals comprehend the positive nature of this type of risk. In relation to this particular risk the option to scale up is obviously interpreted as opening up the possibility to expand the scope of the project.

A practical implication of our results implies an enhancement of the importance of IT project risk management, asking for an active approach to relating different types of flexibility to different types of IT risk. Our results suggest that managers may be prone to undervalue the option to abandon that is exercisable in unfavourable circumstances. This may exist because professionals feel personal or organisational constraints to exercise this option, which may be caused by an aversion to loss (Shin and Ariely 2004). Although our research shows that managers place a different value on real options in response to particular risks, organisational mechanisms have to be put in place to actively exercise these options, such as effective governance practices, project planning mechanisms, valuation techniques to value the options.

The study has several limitations. First, the operationalisation of the option to scale up may be improved for the particular application domain. Second, given the experimental setting limitations to generalization apply. Findings found in an experiment do not always hold true for real-life situations. In practice, managers face very complex situations in which different types of options in IT projects are not per definition easily identifiable. Therefore in practice, the support we find between risk factors and the different types of options may not be as easily expanded to 'real life' situations. Third, experiments and surveys show that the economic valuation of real options and risk is not well estimated in practice (Busby and Pitts 1997, Howell and Jägle 1997). This suggests that assessment of real options cannot rely on intuition alone, since this may lead to non optimal decisions.

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