The effects of project uncertainty and risk management on IS development project performance: A vendor perspective

Liu Jun [a,1], Wang Qiuzhen [b,*], Ma Qingguo [b,2]

[a] *Dept. of Information Management & Information Systems, Zhejiang University City College, Hangzhou, 310015, PR China*
[b] *Dept. of Management Science and Engineering, School of Management, Zhejiang University, Hangzhou 310058, PR China*

Abstract

The structural contingency perspective has been widely used in information systems development (ISD) project risk management research. This paper develops an integrative model to explore the moderating effects of uncertainty on the relationship between risk management and IS development project performance from a vendor perspective, rather than the client perspective that is mainly employed in the literature. A survey-based research design is used to collect data to test the proposed model. The results reveal that project uncertainty can moderate the effects of project planning and control on process performance and the effects of user participation on product performance. More specifically, the results indicate that project planning and control makes a greater contribution to process performance when there is a low level of inherent uncertainty and that user participation makes a greater contribution to product performance when there is a high level of inherent uncertainty. The results of this study contribute to a more acute understanding of the contingency approach to ISD project risk management.
© 2010 Elsevier Ltd. and IPMA. All rights reserved.

Keywords: Contingency approach; Outsourced IS development projects; Project uncertainty; Risk management; Moderating effects; Project performance; Partial Least Square (PLS)

1. Introduction

With information technology playing an increasing role in the economy, companies have grown more heavily dependent on the successful delivery of information systems (IS). However, information systems development (ISD) project failures are common. The Standish Group Chaos Report for 2009 indicated that 44% of software projects were unable to be delivered on schedule, within budget, or with the required functions, and that 24% of all software projects were cancelled (Standish Group International, 2009).

Effective ISD project management has received considerable attention from academics and practitioners. A key question for researchers is how to deal with the uncertainties of software development (Zmud, 1980; McFarlan, 1981; Wallace et al., 2004) or, in other words, risk identification and management. One branch of IS research discusses risk management, project success, and the relationships between the two from a contingency perspective (e.g., Nidumolu, 1995; Barki et al., 2001; Jiang et al., 2006). The contingency approach considers project success to be dependent on how well the project as a whole is able to deal with uncertainties in the project environment. With the exception of Barki et al. (2001), contingency studies of software project risk management do not consider uncertainty profiles or risk management profiles from an integrated perspective. Moreover, most of these studies focus on in-house development projects, where developers and users are members of the same organization. However, companies are increasingly outsourcing all or part of their IS activities to external vendors (Lacity and Willcocks, 1998), including IS development. Outsourcing may give rise to additional or different risks from the perspectives of both the client and the vendor (Taylor, 2007). In this situation, client and

* Corresponding author. Tel.: +86 571 88363233; fax: +86 571 88206827.
 E-mail addresses: liuj@zucc.edu.cn (L. Jun), wqz@zju.edu.cn (W. Qiuzhen), Maqingguo3669@zju.edu.cn (M. Qingguo).
[1] Tel.: +86 571 88284310; fax: +86 571 88018449.
[2] Tel./fax: +86 571 88206827.

vendor share the responsibilities for managing outsourced IS projects. As system vendors absorb considerable amounts of risk, an integrated framework is needed for managing the risk in software development from a vendor perspective (Dey et al., 2007). However, prior research on risk management in outsourced ISD projects has paid little attention to the vendor's perspective (Taylor, 2007). The two parties involved in outsourcing may have different perceptions of risk, risk management and project success because of the differences in their goals and structures. Accordingly, the contingency relationships found in prior research need to be examined to determine whether they also apply to the study of the outsourced projects from a vendor perspective.

Thus, this paper attempts to develop an integrative contingency framework to describe the effects of project uncertainty, risk management and their interaction on project performance from the vendor's perspective. This paper is expected to advance our understanding of the risk management of outsourced IS development projects and to provide system vendors with a set of guidelines that may be helpful for the effective risk management of outsourced ISD projects.

The remainder of this paper is organized as follows. The next section discusses the theoretical background to ISD project management and reviews the existing literature. Section 3 describes the research model and the resulting hypotheses. The research methodology and the results of our model test are reported in Sections 4 and 5. Section 6 discusses the results and the implications of the study. The final section outlines the limitations to the study and the opportunities for further research.

2. Literature review

IS research employing the contingency approach to software project risk management has been strongly influenced by research in organizational contingency theory. From this perspective, software development projects that are managed with approaches that fit the demands imposed by the degree of risk or uncertainty related to the project environment will be more successful than projects that do not (Barki et al., 2001). Table 1 summarizes the past IS research that has adopted such a contingency approach to software project risk management. In these studies, risk management is not considered to be a separate management

Table 1
Contingency approaches to software project risk management.

Author (year)	Key construct studied	Recommended course of action	Support provided
Zmud (1980)	Project coordination mode	Use impersonal mode of coordination for low project risk or uncertainty, a personal mode of coordination is advocated for moderate uncertainty levels, and use group mode of coordination for high project uncertainty.	Conceptual
McFarlan (1981)	External integration, internal integration, formal planning and formal control	Different types of projects need different management tools and provide the risk management countermeasures given a project's inherent risk influenced by project size, experience with the technology and project structure.	Conceptual
Beath (1987)	Relationship between parties concerned	Use arm's length relationships for low project risk or uncertainty, whereas use clan relationship.	Case study
Nidumolu (1995, 1996a)	Coordination structure	Use vertical coordination for high project uncertainty.	Cross-sectional data from 64 projects
McKeen and Guimaraes (1997)	User participation	Use low levels of user participation when project uncertainty is low, whereas enhance user participation.	Cross-sectional data from 151 projects
Barki et al. (2001)	Formal planning, internal integration, and user participation	When meeting project budgets is the performance criterion, successful high-risk projects have high levels of internal integration, as well as high levels of formal planning. When quality is the performance criterion, successful high-risk projects have high levels of user participation.	Cross-sectional data from 75 projects
Jiang et al.(2006)	User partnering	Apply user partnering techniques for high project user non-support risk.	Cross-sectional data from 170 projects
Sauer et al.(2007)	Project size, process volatility	Project size affects project performance, but risk does not rise smoothly against every dimension of size. Volatility is associated with project variances. In particular, changes in the project manager have shown strongly adverse effects.	Cross-sectional data from 412 projects

process. Instead, it is seen as embedded in the various processes and procedures of the project (Bakker et al., 2010).

As shown in Table 1, most IS research has been based on empirical evidence, except for the early studies (Zmud, 1980; McFarlan, 1981). Yet, most of the empirical studies are limited to single management factors, such as the relationship between parties concerned (Beath, 1987), user participation (McKeen and Guimaraes, 1997), coordination mechanisms (Nidumolu, 1995, 1996a), and user partnering (Jiang et al., 2006), or to specific drivers of uncertainty, such as project size and process volatility (Sauer et al., 2007), and user non-support risk (Jiang et al., 2006). The research of Barki et al. (2001) represents a significant advance in that it adopts the contingency approach to software project risk management from an integrated perspective. Nonetheless, there are some limitations to this research, such as an insufficient sample size, no organizing framework for risk factors and no distinction is made between initial and emergent risks. Distinguishing between risks that exist prior to a phase and those that emerge during a phase is important for risk management, because factors that exist prior to a particular project or operational phase may need to be managed differently than those that emerge during that phase (Alter and Sherer, 2004).

Moreover, the empirical results of studies based on the structural contingency perspective have been conflicting and disputed in IS project risk management. For example, the results of Nidumolu (1996a) suggest a lack of support for the mediation, interaction (moderation) and profile deviation approaches to the structural contingency perspective in regard to the effects project coordination and requirements uncertainty have on project performance. Therefore, the effects of the interaction between project uncertainty and risk management factors need to be further examined.

In addition, prior research has been largely focused on in-house IS development projects. Over the last decade, firms have shown an increasing tendency towards outsourcing their IS activities (Lacity and Willcocks, 1998). Compared with in-house development projects, outsourcing may give rise to additional or different risks from the perspectives of both the client and the vendor (Taylor, 2007). However, although interest in the client perspective on the risks related to software projects is increasing, the vendor perspective has received less attention (Taylor, 2007). The results of a number of studies suggest that the two sides may have different perceptions of risk, management mechanisms and project success, because of their different goals (Sabherwal, 2003; Taylor, 2007). For example, in a case study, Sabherwal (2003) revealed that the vendor and the client had different perspectives on the coordination of outsourced software development projects. In a study based on semi-structured interviews, Taylor (2007) indicated that the vendors involved in outsourced projects had different perspectives on the risk than the clients. Therefore, the relationships between uncertainty, risk management and project performance need to be empirically examined from the vendor's perspective.

3. Research model and hypotheses

The literature on software project management has identified project uncertainty or risk as a key construct influencing project success. A software project's overall level of risk or uncertainty can be obtained by assessing specific risk factors (Barki et al., 2001; Jiang et al., 2002). Researchers have identified various risk or uncertainty factors that can threaten the successful completion of a software development project (Alter and Ginzberg, 1978; Barki et al., 1993; Schmidt et al., 2001; Lihong et al., 2008; Nakatsu and Iacovou, 2009). Taking into consideration project type and the research perspective of this study, relative project size, technical complexity, development team skill and client/user experience are chosen as risk factors. These are project-specific characteristics that initially exist in a project rather than emerge during the course of its implementation. Furthermore, there is little change in the perceived nature of these characteristics as the project is being completed. For example, the project doesn't become more or less complex over time, nor does it become smaller or larger in size. Together, the four factors constitute the construct of project inherent uncertainty.

This paper focuses on process and product performance as two key dimensions of project performance (Nidumolu, 1996b; Wallace et al., 2004). Process performance refers to the extent to which a project is delivered on schedule and within budget. Product performance refers to the quality of resulting system. It is important to study both aspects of project performance, because there is a potential conflict between the efficiency of the process and its quality.

Project uncertainty has been demonstrated to be negatively associated with project success (Jiang et al., 2002). The absence of client knowledge and understanding of requirements or the absence of development experience and expertise within a specific application area of the development team make it difficult to define complete, unambiguous or consistent requirements, which can lead to a software product that cannot meet the client's needs, and decreasing process performance. The use of unfamiliar technologies can also lead to software problems that reduce the performance of the software product (Nidumolu, 1995) and delay the project. Empirical evidence reveals that project size can affect project performance (Sauer et al., 2007). Thus, the following hypotheses can be derived:

H1. The level of project inherent uncertainty is negatively associated with process performance.

H2. The level of project inherent uncertainty is negatively associated with product performance.

Based on prior research (McFarlan, 1981; Barki et al., 2001; Kim and Park, 2007), we focus on three key constructs reflecting software project risk management practice: project planning and control, internal integration and user participation. The subsequent coordination costs and information processing capabilities differ with respect to different combinations of the three risk management strategies.

The construct of project planning and control is defined as the extent to which planning and control practices are used in a project. Previous research has demonstrated a positive relationship between planning and process performance (Deephouse et al., 1996; Yetton et al., 2000). Poor planning is likely to be

associated with inefficiencies in development and, thus, lead to large budget and time variances. Rigorously tracking and monitoring a project according to a project plan can ensure that the final product is delivered within budget and on schedule. The empirical results of Wallace et al. (2004) confirm the negative relationship between planning & control risk and project performance. Thus, the following hypothesis can be derived:

H3. Project planning and control is positively associated with process performance.

Internal integration refers to management practices that increase communication and cohesion among development team members. Internal integration can enhance the levels of communication and collaboration between the members of the project team, decrease the amount of team conflict and keep the team stable. Yetton et al. (2000) demonstrated that project team conflict can lead to instability in a project team and, thus, result in a project being delayed and over budget. In addition, software development is a knowledge-intensive and human-intensive activity that requires collaboration between team members with diverse skills and specialties. A lack of collaboration between team members or instability in a project team can affect the quality of the product delivered. Thus, the following hypotheses can be derived:

H4. Internal integration is positively associated with process performance.

H5. Internal integration is positively associated with product performance.

The construct of user participation is defined as the behaviors and activities of the user in relation to product development. It is a common wisdom in the IS literature that user participation can improve the chances of successful system implementation, which can be traced to the theory of "participative decision-making (PDM)" and "planned organizational change (POC)" (Ives and Olson, 1984). Some studies have provided data to support the positive relationship between user participation and systems quality (Boland, 1978; Gallagher, 1974; Nidumolu, 1995). It could be argued that user participation tends to increase budget variance by encouraging suggestions for changes to specification, but also tends to decrease budget variance by managing expectations and quickly resolving potential problems (Yetton et al., 2000). Empirical evidence provided by Subramanyam et al. (2010) supports the argument that potential conflicts arising from greater user participation may play a vital role in the perceived satisfaction of software developers and users. We will assume that user participation is positively related with process performance. Thus, the following hypotheses can be derived:

H6. User participation is positively associated with process performance.

H7. User participation is positively associated with product performance.

Organizational contingency theory proposes that decision makers must process an increasing amount of information to achieve a given level of performance, as the uncertainty facing an organization unit increases (Galbraith, 1974). Underlying the structural contingency perspective is an information processing viewpoint of organizations. Organizational designs thus must provide information processing capabilities that are appropriate to the level of uncertainty confronting each organization unit (Galbraith, 1974). IS researchers have adopted the contingency approach to software project risk management. From this perspective, software development projects that are managed with approaches that fit the demands imposed by the degree of risk or uncertainty associated with the project environment will be more successful than projects that do not (Barki et al., 2001). Project planning and control has often been cited as a low information processing capability approach to project management (Alter and Ginzberg, 1978; Zmud, 1980) and, to a certain extent, as reducing the amount of information to be processed (Nidumolu, 1995). Internal integration is a high information processing capability approach. User participation comprises all those activities that increase the levels of communication and information exchanged with the users and is also a high information processing capability approach. Thus, project planning and control, internal integration and user participation capture the high and low information processing capability approaches to managing software project uncertainty. The interaction relationships were proposed to show the impact of inherent uncertainty on the relationships between risk management and project performance. Thus, the following hypotheses can be derived:

H8. Project planning and control makes a greater contribution to process performance at low levels of inherent uncertainty than at high levels.

H9. Internal integration makes a greater contribution to process performance at high levels of inherent uncertainty than at low levels.

H10. Internal integration makes a greater contribution to product performance at high levels of inherent uncertainty than at low levels.

H11. User participation makes a greater contribution to process performance at high levels of inherent uncertainty than at low levels.

H12. User participation makes a greater contribution to product performance at high levels of inherent uncertainty than at low levels.

Based on the previous analysis, the research model is illustrated in Fig. 1.

4. Research method

4.1. Data collecting and sample

A survey design was selected for testing the research model. The questionnaire developed for the study was subject to a pretest
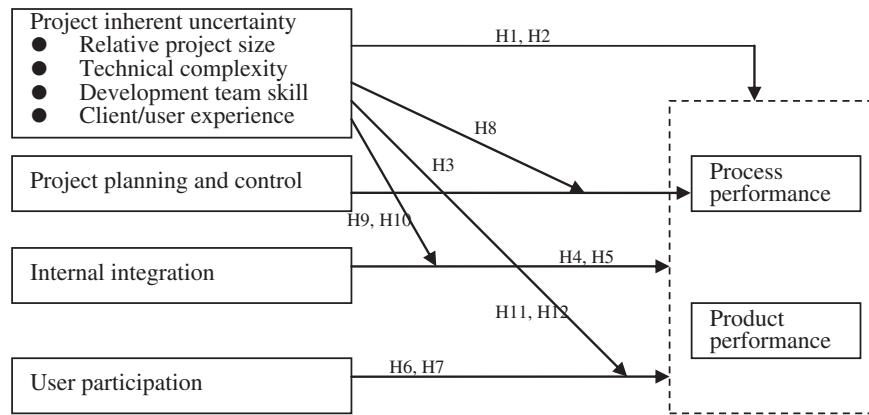
Fig. 1. Research model.

Table 2
Respondent demographics.

Position			Age		
Position	Number	Ratio (%)	Age	Number	Ratio (%)
Top management	29	31.2	25 or below	2	2.2
Project manager	41	44.1	26–30	28	30.1
Technical Team leader	14	15.1	31–35	36	38.7
Developer	4	4.3	36–40	15	16.1
Other professional	5	5.4	41–50	12	12.9
	93	100		93	100
Management experience			Development experience		
Management experience (years)	Number	Ratio (%)	Development experience (years)	Number	Ratio (%)
0–3	20	21.5	0–3	12	12.9
3–5	31	33.3	3–5	28	30.1
5–10	35	37.6	5–10	32	34.4
10 or above	7	7.5	10 or above	21	22.6
	93	100		93	100

and a pilot test prior to usage. The questionnaire was administered to a large sample of software project managers and other key informants from software houses in Hangzhou City, China, by mail and email. The respondents were requested to provide information with respect to one or more recently completed outsourced IS development projects. Of the 600 questionnaires administered, 181 usable responses from 93 respondents were obtained from the survey, a response rate of approximately 30.2%, which compares well with most other IS surveys (e.g., Rai and Hindi, 2000; Aladwani, 2002; Wallace et al., 2004).[3] The industry profile of the client organizations was mainly distributed over industry sectors such as government, manufacturing, communications, retail and distribution. The 93 respondents were from 58 software firms. Approximately 81% of the software firms have less than 100 employees, while 6.9% of the software firms have more than 1000 employees. The large number of relatively small firms in the sample reflects the preponderance of

small firms in the software industry as a whole. A summary of the demographic characteristics of the respondents is presented in Table 2. A profile of the projects investigated is given in Table 3.

Self-evaluation of performance was adopted in this study. As it is possible for self-reported project performance measures to be biased, we collected an additional small sample from 20 corresponding projects, which included performance assessments by project leaders from the client organizations, with which to conduct a paired-sample *T*-test. The performance assessments from the clients excluded the measure item "the project was completed within budget," because the clients were not likely to know the vendors' project budget.

4.2. Measurement of variables

Each construct in the research model was measured using a seven-point scale to indicate the extent of presence in the project. All constructs were measured by using or adapting previously developed and validated scales. The measurement items contained in the questionnaire are shown in Table 4.

---

[3] Rai and Hindi (2000), Aladwani (2002) and Wallace et al. (2004) reported response rates of 12.4%, 17.3% and 13.34%, respectively.

Table 3
Profile of projects ($N=181$).

Attribute	Mean	Std. dev.	Minimum	Maximum
Number of team member	7.6796	7.22627	3	60
Project duration (months)	12.0279	9.88071	1	60
Effort (person months)	93.2235	151.50038	3	1200

4.3. PLS method

The research model in Fig. 1 was tested using the Partial Least Square (PLS) method of structural modeling. This paper tests the interaction effects between inherent uncertainty and risk management factors. The sample is not sufficient to test interaction effects using other structural modeling methods, such as LISREL. PLS is suitable for analyzing small samples, whereas LISREL requires substantially larger samples as the number of indicators grows. In addition, the respondents in this study tend to select projects that perform well, which likely leads to non-normal data distributions. PLS does not require multivariate normal data as does LISREL maximum likelihood estimation.

A significant amount of IS research has been devoted to examining the moderating variables that create interaction

Table 4
Measurement items.

Constructs and items	Source
Relative project size	Barki et al. (1993)
size1: compared to other information systems projects developed in your organization, the scheduled number of person-days for completing this project is much higher.	
size2: compared to other information systems projects developed in your organization, the scheduled number of months for completing this project is much higher.	
size3: compared to other information systems projects developed in your organization, the dollar budget allocated to this project is much higher.	
Technical complexity	Barki et al. (1993) Wallace et al. (2004)
comp1: project involves the use of new technology	
comp2: project has high level of technical complexity	
comp3: project involves the use of technology that has not been used in prior projects	
Client/user experience	Moynihan, (1996)
cexp1: client is not familiar with this type of application	
cexp2: client doesn't know what they want	
cexp3: client doesn't have a good understanding of the problems they want solved	
cexp4: users are not familiar with data processing as a work tool	
Development team skill	Barki et al. (1993)
skill1: development team's lack of experience with development platform/environment used in this project	
skill2: development team is very unfamiliar with this type of application	
skill3: development team's lack of knowledge of application domain involved in this project	
Project planning and control	Barki et al. (2001) McFarlan (1981) Wallace et al. (2004)
ppc1: special attention is paid to project planning	
ppc2: project milestones are clearly defined	
ppc3: project progress is monitored closely using PERT or CPM tools	
ppc4: periodic formal status reports versus plan	
ppc5: strictly audit at milestone	
Internal integration	Barki et al. (2001)
inte1: the project team meets frequently	
inte2: project team members are kept informed about major decisions concerning the project	
inte3: every efforts is made to keep project team turnover at a minimum	
inte4: project team members actively participate in the definition of project goals and schedules	
User participation	Barki et al. (2001)
upar1: users actively participated in requirements definition	
upar2: the project team kept users informed concerning project progress and problems	
upar3: users formally evaluated the work done by the project team	
upar4: users formally affirmed the work done by the project team	
Process performance	Wallace et al. (2004)
proc1: the project was completed within budget	
proc2: the project was completed within schedule	
Product performance	Wallace et al. (2004) Rai and Hindi (2000)
prod1: the application developed is reliable	
prod2: the application developed is easy to use	
prod3: flexibility of the system is good	
prod4: the system meets user's intended functional requirements	
prod5: users are satisfied with the system delivered	
prod6: the overall quality of the developed application is high	

effects, often under the general umbrella of contingency theory. Yet the majority of past IS studies have either failed to detect a moderating influence or have failed to provide an estimate of the size of the interaction effect (Chin et al., 2003). Our current lack of understanding and development of contingent effects may be a byproduct of the analytic method (Chin et al., 2003). While ANOVA and regression both are commonly used for interaction effects, they both make the assumption that variable have been measured free of errors, an assumption that in the social sciences is often questionable and these methods fail to analyze the whole model, as they examine each linkage in model separately. The PLS product-indicator approach was found to be a robust way to handle interaction effects in latent variable modeling (Chin et al., 2003).

Due to the reasons mentioned previously, we tested our model using the PLS method, employing the VisualPLS 1.04 version. Following the two-step approach to structural equations proposed by Anderson and Gerbing (1988), the measurement models for the constructs were validated before the structural model was examined to test the hypothesized relationships between constructs.

5. Results

5.1. Measurement model test

Although all of the constructs in this study were measured using previously developed and validated scales, quality assess-

ment of the final data set can provide further verification of this. The measurement model in the PLS procedure can be defined as either a reflective or a formative mode. The reflective mode is used for constructs that are viewed as underlying factors that give rise to observable variables, such as attitude and personality. In contrast, the formative mode is used for constructs that are modeled as explanatory combinations of their indicators (Fornell and Booktein, 1982). In this study, all of the constructs, except for the construct "inherent uncertainty," are modeled in a reflective mode.

Confirmatory factor analysis (CFA) was conducted to refine the reflective measurement models. The results are presented in Table 5. All of the measurement items load on their respective factors with strong statistical significance ($p < 0.01$), indicating good convergent validity. The Cronbach alpha for each construct is higher than the recommended level of 0.70. The composite reliability of all the latent variables is higher than the recommended level of 0.60 (Bagozzi and Yi, 1988). The average variance-extracted (AVE) value for each construct is higher than the recommended level of 0.50 (Bagozzi and Yi, 1988). All of these results indicate good reliability.

In addition, the variance-extracted test was used to establish discriminant and convergent validity. Validity is demonstrated if the square root of the AVE of each construct is higher than the correlations between it and other constructs. The results (shown in Table 6) indicate good convergent and discriminant validity.

Project inherent uncertainty is composed of four constructs that are all measured with reflective indicators. The results of the CFA indicate that the four constructs have good convergent and discriminant validity and reliability (as shown in Tables 7 and 8). We then used the factor scores of the four latent variables obtained in PLS as formative indicators of the construct of inherent uncertainty. To ensure the validity of the formative measurement model, we adopted the analytic procedure recommended by Diamantopoulos and Winklhofer (2001) to test the formative measurement model from content specification, indicator specification, indicator collinearity and external validity.

Self-evaluation of performance was adopted in this study, which possibly led to biased performance measures. To validate the reliability of the performance assessments provided by the vendors, we collected an additional small sample of performance assessments of 20 corresponding projects by the project leaders from client organizations and conducted a paired-sample *T*-test. The results (shown in Table 9) indicate that there was no significant difference in the project performance assessments provided by the two parties ($p > 0.05$).

Table 5
Latent variable, measurement item, composite reliability, AVE and Cronbach alpha.

Construct and indicator	Factor loading	T	Composite reliability	AVE	Cronbach alpha
Project planning and control			0.90	0.65	0.87
ppc1	0.73	21.69			
ppc2	0.79	22.88			
ppc3	0.84	32.42			
ppc4	0.85	29.31			
ppc5	0.80	22.36			
Internal integration			0.95	0.83	0.93
inte1	0.91	50.48			
inte2	0.93	102.97			
inte3	0.87	33.08			
inte4	0.94	128.61			
User participation			0.91	0.72	0.87
upar1	0.86	43.37			
upar2	0.91	73.22			
upar3	0.89	44.68			
upar4	0.73	13.38			
Process performance			0.94	0.88	0.87
proc1	0.94	6.42			
proc2	0.94	6.42			
Product performance			0.96	0.79	0.95
prod1	0.92	80.81			
prod2	0.91	81.32			
prod3	0.82	29.45			
prod4	0.87	53.23			
prod5	0.91	64.37			
prod6	0.91	106.91			

Table 6
Correlation matrix and the square root of AVE.

	1	2	3	4	5
1. Project planning and control	**0.806**				
2. internal integration	0.504	**0.911**			
3. User participation	0.336	0.421	**0.849**		
4. Process performance	0.503	0.505	0.318	**0.938**	
5. Product performance	0.463	0.517	0.643	0.446	**0.889**

Note: The diagonal elements are the square root of AVE.

Table 7
Latent variable, measurement item, composite reliability, AVE and Cronbach alpha.

Construct and indicator	Factor loading	T	Composite reliability	AVE	Cronbach alpha
Relative project size			0.95	0.86	0.92
size1	0.91	46.40			
size2	0.93	58.14			
size3	0.93	75.72			
Technical complexity			0.90	0.75	0.83
comp1	0.86	31.58			
comp2	0.86	37.63			
comp3	0.87	52.47			
Client/user experience			0.88	0.64	0.81
cexp1	0.77	19.28			
cexp2	0.86	37.16			
cexp3	0.90	64.26			
cexp4	0.67	11.75			
Development team skill			0.89	0.74	0.82
skill1	0.79	21.03			
skill2	0.90	77.69			
skill3	0.88	44.19			

Table 8
Correlation matrix and the square root of AVE of uncertainty factors.

	1	2	3	4
1. Relative project size	**0.927**			
2. Technical complexity	0.231	**0.866**		
3. Client/user experience	0.246	0.004	**0.800**	
4. Development team skill	0.285	0.286	0.405	**0.860**

Note: The diagonal elements are the square root of AVE.

5.2. Hypothesis test

To test the hypotheses, the main effects model was run separately without interactions and then with the interactions, according to Chin et al. (2003). Bootstrapping procedures were performed to determine the path coefficients and the statistical significance of each hypothesized path, with the bootstrap resamplings set at 200.

5.2.1. Main effects
Fig. 2 shows the results of the main effects model without interactions. The only insignificant path ($p > 0.05$) was between user participation and process performance. All hypotheses, except for hypothesis H6 were supported. The percentages of variance explained by the model in relation to process performance and product performance were 43.8% and 51.4%, respectively.

5.2.2. Interaction effects
This section presents the application of the PLS product-indicator approach to detect the moderating effects of inherent uncertainty on the relationship between risk management and project performance. To test the moderating effects, we added the product terms based on the main effects model to create an interaction model. We did not examine the moderating effect of inherent uncertainty on user participation–process performance relationship (i.e. hypothesis H11) because of the insignificant impact of user participation on process performance in the main effects model. The summary of the path coefficients and the corresponding *t*-statistics for each hypothesized path in the full model with interactions is presented in Table 10. We found that the path of project planning and control-inherent uncertainty to process performance and the path of user participation-inherent uncertainty to product performance were significant.

The percentages of variance explained by the interactions model in relation to process performance and product performance were 46.2% and 53.5%, respectively. We can compute the overall effect size f^2 using the formula (Chin et al., 2003):

$$f^2 = [R^2(\text{interaction model}) - R^2(\text{main effects model})] / [1 - R^2(\text{main effects model})].$$

The overall effect sizes f^2 for the interaction of 0.02, 0.15, and 0.35 have been suggested to be small, moderate, and large effects, respectively (Chin et al., 2003). The two interaction constructs have an effect size f^2 of 0.04, which is comparatively small.

6. Discussion and implications

Our results showed that project inherent uncertainty had a direct negative effect on process performance and product performance, that project planning and control and internal integration had direct positive effects on process performance,

Table 9
Results of paired *t*-test for project performance assessments from two parties ($N=20$).

|	Vendor's assessments			Client's assessments			df	t	Sig. (2-tailed)
	Mean	Std. deviation	Std. error	Mean	Std. deviation	Std. error			
The project was completed within schedule	4.60	1.98	0.44	4.00	1.97	0.44	19	1.453	0.163
The application developed is reliable	5.00	1.21	0.27	4.95	1.47	0.32	19	0.134	0.895
The application developed is easy to use	5.25	1.52	0.34	4.95	1.47	0.33	19	0.825	0.419
Flexibility of the system is good	4.95	1.57	0.35	4.65	1.66	0.37	19	0.719	0.481
The system meets user's intended functional requirements	5.45	0.94	0.21	5.00	1.16	0.26	19	1.917	0.070
Users are satisfied with the system delivered	5.15	1.27	0.28	5.00	1.12	0.25	19	0.767	0.453
The overall quality of the developed application is high	5.05	1.36	0.30	5.05	1.19	0.27	19	0.000	1.000
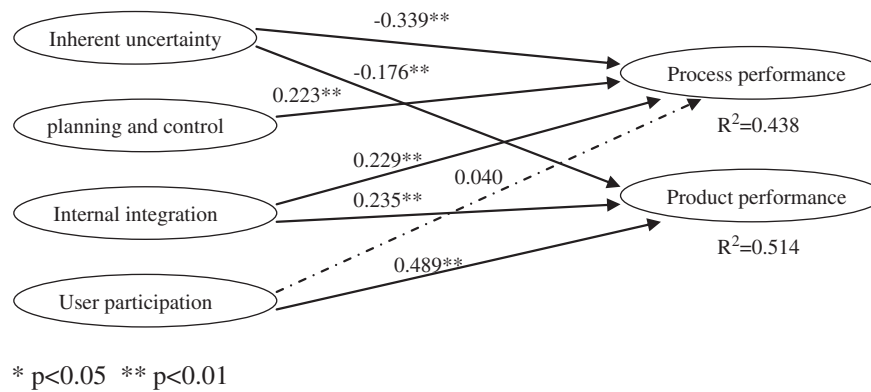
Fig. 2. The analysis results of main effects model.

and that user participation and internal integration had direct positive effects on product performance.

However, the direct relationship between user participation and process performance was not supported, which is consistent with the view of Yetton et al. (2000) that user participation tends to increase budget variance by encouraging suggestions for changes to specifications and the empirical finding of Nidumolu (1995) that increased interaction between users and IS staff does not necessarily lead to a project that converges well (i.e., improved process performance). User participation is necessary for project success and participation in the requirements analysis stage can decrease the risk of there being insufficient requirements. However, too much user participation may have a negative effect on project success and delivery time. Given the novelty of the technology involved and the corresponding uncertainty about requirements, clients/users will continually change their requirements, which can lead to conflict and the product being delivered late and over budget. Therefore, managers need to be aware of the potential trade-offs between too much, and extremely limited user participation.

The results of the full model with the interaction effects revealed that inherent uncertainty can moderate the effect of project planning and control on process performance and the effect of user participation on product performance. However, interaction effects between inherent uncertainty and internal integration were not found. More specifically, the negative path

coefficient from the interaction term between project planning and control and inherent uncertainty to process performance indicated that project planning and control makes a smaller contribution to process performance when inherent uncertainty is at a high level, which is opposite to the finding of Barki et al. (2001). The positive path coefficient from the interaction term between user participation and inherent uncertainty to product performance indicated that user participation makes a greater contribution to product performance when inherent uncertainty is at a high level, which is consistent with the results of Barki et al. (2001) and Nidumolu (1995). Barki et al. (2001) focused on in-house development projects where developers and users are members of the same organization, rather than the vendor's perspective employed in this study. It is more convenient and effective for project leaders to use standards, plans and formal mutual adjustment through a hierarchical structure in in-house projects. However, it is difficult for vendors to implement formal plan and control mechanisms, as project uncertainty increases in outsourced projects where the developers and users belong to different organizations. Therefore, enhancing the communication and coordination between the development team and the clients/users through informal coordination mechanisms is more important for high-risk projects.

This study provided some support for the moderating role of project uncertainty using a PLS modeling method, which is not consistent with the results of Nidumolu (1996a), who used

Table 10
Standardized path coefficients and *t*-statistics of all hypothesized paths.

Path	Path coefficient	*t*-statistics	Supported
H1: inherent uncertainty to process performance	−0.324	−4.4105 **	Yes
H2: inherent uncertainty to product performance	−0.166	−2.7179 **	Yes
H3: project planning and control process performance	0.215	2.9894 **	Yes
H4: internal integration to process performance	0.242	3.6332 **	Yes
H5: internal integration to product performance	0.232	3.3797 **	Yes
H6: user participation to process performance	0.011	0.2944	No
H7: user participation to product performance	0.482	8.5938 **	Yes
H8: planning and control-uncertainty to process performance	−0.162	−2.2059 *	Yes
H9: internal integration-uncertainty to process performance	−0.009	−0.1270	No
H10: internal integration-uncertainty to product performance	0.041	0.8065	No
H12: user participation-uncertainty to product performance	0.135	1.9977 *	Yes

* $p<0.05$.
** $P<0.01$.

multiple regression analysis (MRA) to test moderating effects. Although the overall interaction effect size (f^2) is comparatively small, Chin et al. (2003) emphasized that a small f^2 does not necessary imply an unimportant effect. Even a small interaction effect can be meaningful under extreme moderating conditions and, if the resulting beta changes are meaningful, then it is important to take these conditions into account.

Barki et al. (2001) found that high-risk projects need higher levels of internal integration than low risk projects. However, this study did not find interaction effects between inherent uncertainty and internal integration. The software development process can be interpreted as a knowledge-intensive system, incorporating the expertise and skills of many different people over an extended period. Given the nature of the software development process, communication and coordination between development team members is necessary for project success and is viewed as a conventional mechanism by system vendors. Moreover, internal integration also includes the integration of technological and business process knowledge. Compared to the development teams in the in-house projects of client organizations, the vendor development teams have the advantage of understanding business processes because of their rich development experience. Due to the previous reasons, the project managers of vendor firms are likely to consider that a high level of internal integration does not play a very important role in high-risk projects.

The results of this study reveal that these risk management factors make different contributions to different dimensions of project performance for projects with different levels of inherent uncertainty, which has important implications for practitioners. It implies that proper management strategies should be applied according to project type and key performance criteria. When process performance is a key performance criterion, projects with high inherent uncertainty call for lower levels of formal planning and control. On the other hand, when product performance is a key performance criterion, projects with high inherent uncertainty call for higher levels of user participation. User participation is a client-related factor that cannot be controlled by the project manager, but it can be influenced. Project managers must take reasonable steps to ensure that they have the support and commitment needed to deliver a successful project. Accordingly, project managers require skills in relationship management, trust-building, and business politics. In addition, communication and coordination between development team members need to be strengthened, independent of the performance criterion and the level of project inherent uncertainty.

7. Limitations and future research directions

Although the results of this empirical study support the project level contingency perspective and provide a number of different conclusions in this specific context, more research is needed to overcome some of its limitations, as well as to further explore its findings. First, this study considered four key factors which composed the construct of project inherent uncertainty. Uncertainty is a complex construct and this study may not have captured every aspect of project inherent uncertainty. Other

facets of inherent uncertainty should be investigated in future research. Second, our study focused on initial risk factors and was unable to capture the dynamic nature of software projects. However, information gathering can lead to changes in the level of uncertainty (through learning) which can, in turn, lead to changes in risk management. Thus, other constructs (e.g., relationship quality) need to be included to develop a dynamic contingency model. Finally, this study empirically analyzed the relationships between uncertainty, risk management and project performance from a vendor perspective. More research is needed to examine whether the contingency relationships found here also apply from a client perspective and to analyze the differences between vendor and client perspectives.

Acknowledgements

References

Anderson, J.C., Gerbing, D.W., 1988. Structural equation modeling in practice: a review and recommended two-step approach. Psychological Bulletin 103 (3), 411–423.

Aladwani, A.M., 2002. An integrated performance model of information systems projects. Journal of Management Information Systems 19 (1), 185–210.

Alter, S., Ginzberg, M.J., 1978. Managing uncertainty in MIS implementation. Sloan Management Review 20 (1), 23–31.

Alter, S., Sherer, S.A., 2004. A general, but readily adaptable model of information system risk. Communications of the Association for Information Systems 14, 1–28.

Bagozzi, R.P., Yi, Y., 1988. On the evaluation of structural equation models. Journal of the Academy of Marketing Science 16 (1), 74–94.

Bakker, K.D., Boonstra, A., Wortmann, H., 2010. Does risk management contribute to IT project success? A meta-analysis of empirical evidence. International Journal of Project Management 28 (5), 493–503.

Barki, H., Rivard, S., Talbot, J., 1993. Toward an assessment of software development risk. Journal of Management Information Systems 10 (2), 203–225.

Barki, H., Rivard, S., Talbot, J., 2001. An integrative contingency model of software project risk management. Journal of Management Information Systems 17 (4), 37–69.

Beath, C.M., 1987. In managing the user relationship in information systems development projects: a transaction governance approach. Proceedings of the Eighth International Conference on Information Systems, Pittsburgh, PA, pp. 415–427.

Boland, R.J., 1978. The process and product of system design. Management Science 24 (9), 887–898.

Chin, W.W., Marcolin, B.L., Newsted, P.R., 2003. A partial least squares latent variable modeling approach for measuring interaction effects: results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study. Information Systems Research 14 (11), 189–217.

Deephouse, C., Mukhopadhyay, T., Goldenson, D.R., Kellner, M.I., 1996. Software process and project performance. Journal of Management Information Systems 12 (3), 187–205.

Dey, P.K., Kinch, J., Ogunlana, S.O., 2007. Managing risk in software development projects: a case study. Industrial Management & Data Systems 107 (2), 284–303.

Diamantopoulos, A., Winklhofer, H.K., 2001. Index construction with formative indicators: an alternative to scale development. Journal of Marketing Research 38 (2), 269–277.

Fornell, C.F., Booktein, F.L., 1982. Two structural equation models: LISREAL and PLS applied to consumer exit-voice theory. Journal of Marketing Research 19 (4), 440–452.

Galbraith, J.R., 1974. Organizational design: an information processing view. Interfaces 4 (3), 28–36.

Gallagher, C.A., 1974. Perceptions of the value of a management information system. Academy of Management Journal 17 (1), 46–55.

Ives, B., Olson, M., 1984. User involvement and MIS success: a review of research. Management Science 30 (5), 586–603.

Jiang, J.J., Klein, G., Ellis, T.S., 2002. A measure of software development risk. Project Management Journal 33 (3), 30–41.

Jiang, J.J., Klein, G., Chen, H.G., 2006. The effects of user partnering and user non-support on project performance. Journal of the Association for Information Systems 7 (2), 68–90.

Kim, E.H., Park, Y., 2007. Prediction of IS project escalation based on software development risk management. Journal of Information & Knowledge Management 6 (2), 153–163.

Subramanyam, R., Weisstein, F.L., Krishnan, M.S., 2010. User participation in software development projects. Communications of the ACM 53 (3), 137–141.

Lacity, M., Willcocks, L.P., 1998. An empirical investigation of information technology sourcing practices: lessons from experience. MIS Quarterly 22 (3), 363–408.

Lihong, Z., Casconcelos, A., Nunes, M., 2008. Supporting decision making in risk management through an evidence-based information systems project risk checklist. Information Management & Computer Security 16 (2), 166–186.

McFarlan, F.W., 1981. Portfolio approach to information systems. Harvard Business Review 59 (5), 142–150.

McKeen, J.D., Guimaraes, T., 1997. Sucessful strategies for user participation in systems development. Journal of Management Information Systems. 14 (2), 133–150.

Moynihan, T., 1996. An inventory of personal constructs for information systems project risk researchers. Journal of Information Technology 11 (4), 359–371.

Nakatsu, R.T., Iacovou, C.L., 2009. A comparative study of important risk factors involved in offshore and domestic outsourcing of software development projects: a two-panel Delphi study. Information Management 46 (1), 57–68.

Nidumolu, S.R., 1995. The effect of coordination and uncertainty on software project performance: residual performance risk as an intervening variable. Information Systems Research 6 (3), 191–219.

Nidumolu, S.R., 1996a. A comparison of the structural contingency and risk-based perspectives on coordination in software-development projects. Journal of Management Information Systems 13 (2), 77–113.

Nidumolu, S.R., 1996b. Standardization, requirements uncertainty and software project performance. Information & Management 31 (3), 135–150.

Rai, A., Hindi, A.H., 2000. The effects of development process modeling and task uncertainty on development quality performance. Information & Management 37 (6), 335–346.

Sabherwal, R., 2003. The evolution of coordination in outsourced software development projects: a comparison of client and vendor perspectives. Information and Organization 13 (3), 153–202.

Sauer, C., Gemino, A., Reich, B.H., 2007. The impact of size and volatility on IT project performance: studying the factors influencing project risk. Communications of the ACM 50 (11), 79–84.

Schmidt, R., Lyytinen, K., Keil, M., Cule, P., 2001. Identifying software project risks: an international Delphi study. Journal of Management Information Systems 17 (4), 5–36.

Standish Group International, Inc, 2009. CHAOS Summary 2009. report. from: http://www.standishgroup.com. retrieved May 20, 2010.

Taylor, H., 2007. Outsourced IT projects from the vendor perspective: different goals, different risks. Journal of Global Information Management 15 (2), 1–27.

Wallace, L., Keil, M., Rai, A., 2004. How software project risk affects project performance: an investigation of the dimensions of risk and exploratory model. Decision Sciences 35 (2), 289–321.

Yetton, P., Martin, A., Sharma, R., Johnston, K., 2000. A model of information systems development project performance. Information Systems Journal 10 (4), 263–289.

Zmud, R.Z., 1980. Management of large software development efforts. MIS Quarterly 45–55 (June).