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Information & Management 42 (2004) 115–125
INFORMATION & MANAGEMENT
www.elsevier.com/locate/dsw

Understanding software project risk: a cluster analysis

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Accepted 31 December 2003

Available online 19 March 2004

Abstract

Understanding software project risk can help in reducing the incidence of failure. Building on prior work, software project risk was conceptualized along six dimensions. A questionnaire was built and 507 software project managers were surveyed. A cluster analysis was then performed to identify aspects of low, medium, and high risk projects. An examination of risk dimensions across the levels revealed that even low risk projects have a high level of complexity risk. For high risk projects, the risks associated with requirements, planning and control, and the organization become more obvious. The influence of project scope, sourcing practices, and strategic orientation on project risk dimensions was also examined. Results suggested that project scope affects all dimensions of risk, whereas sourcing practices and strategic orientation had a more limited impact. A conceptual model of project risk and performance was presented.

Keywords: Software project risk; Cluster analysis; Project management; Outsourcing; Scope

1. Introduction

Failing to understand and manage software project risk can lead to a variety of problems including cost and schedule overruns, unmet user requirements, and the production of systems that are not used or do not deliver business value. Being able to complete software projects successfully becomes even more important as organizations embrace the Internet and strive to operate in the twin worlds of the physical marketplace and the cyber world of the marketspace [49,56]. As organizations continue to invest time and resources in strategically important software projects, managing the *risk* associated with them becomes a critical area of concern [33,45].

Advocates of IS risk management argue that identifying and analyzing threats to success allows actions to be taken to reduce the chance of failure. Articles have stressed the importance of empirically categorizing the sources and types of risks associated with software development projects (e.g. [51]). Unfortunately, despite these recommendations there are relatively few tools available to help project managers identify and categorize risk factors in order to develop effective strategies.

While various risk checklists (e.g., the ‘‘top-10’’ list of risk factors described by [5]) and frameworks (e.g. [29]) have been proposed, the underlying dimensions of the software project risk construct and their influence on a project remain largely unexplored. A better

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0378-7206/$ – see front matter
doi:10.1016/j.im.2003.12.007

understanding of the dimensions of software project risk and the trends or patterns that they are likely to follow in different types of projects could help project managers formulate more specific risk management strategies by allowing them to focus on areas that are at potentially high risk. The purpose of this study was: (1) to explore trends in risk dimensions across low, medium and high risk projects and (2) to determine how project characteristics, such as project scope, sourcing practices, and the strategic orientation of a project affect the risk.

2. Background

When managers deal with risk, they seek to influence their environment so as to reduce negative outcomes [35,36]. Consistent with this view, we define *software project risk* as a set of factors or conditions that can pose a serious threat to the successful completion of a software project. Advocates of software project risk management suggest that project managers should identify and control these factors to reduce the chance of project failure.

Though several lists of risk factors have been published (e.g. [2,17,41,54]), until relatively recently there has been little attempt to move beyond checklists and frameworks. There are two notable exceptions. First, Barki et al. [4] compiled a list of 35 risk variables which were operationalized in the form of a questionnaire consisting of 144 items. The questionnaire was administered and factor analysis of the results yielded five factors or risk dimensions: technological newness, application size, lack of expertise, application complexity, and organizational environment. The final instrument contained 23 uncertainty variables that were measured with a range of single- and multi-item binary scales, ratio scales, interval scales, and semantic differential scales. This instrument represented a significant advance in software risk measurement. However, because it employed a variety of different types of measurement scales, analysis at the risk dimension level was not possible, and cumbersome transformations were required in order to compute a score for the overall measure of project risk.

Second, building upon this, Wallace [60] conducted interviews with software project managers in order to develop a definition that was grounded both in previous literature and input from practitioners. Several rounds of sorting and interviewing were used to differentiate between types of software project risk factors. This effort resulted in six categories or dimensions of risk: team, organizational environment, requirements, planning and control, user, and project complexity. Multiple measurement items (using seven-point Likert-type scales) were created to assess each risk dimension (see Appendix A for a list of the items). Following an iterative approach that involved multiple sorting exercises, pre-testing, and the administration of a large-scale survey, these measurement scales were refined and structural equation modeling was used to verify the reliability and validity of each dimension's measure. Table 1 lists the six dimensions and representative references for each.

However, earlier efforts did not attempt to examine the ways in which the dimensions of risk vary across different types of projects. While the specification of risk and measures allows managers to audit risk levels, it does not provide them with information to help formulate a tailored strategy for countering the risks on a specific project.

Exploring the differences between low, medium, and high risk projects focuses managerial attention on recurring patterns. Insight into the relative trends in risk dimensions could enhance managerial understanding of the nature of vulnerability. Our research addressed these issues by using the Wallace instrument to collect data from a large number of software development projects, identified whether they exhibited low, medium, or high risk, and then examined them to determine if there were patterns among the dimensions and across the project risk categories.

Project characteristics also impact the risk level. In our study, we investigated three of them: project scope, the degree to which it is strategic, and whether it is outsourced. We chose these three because they have been proposed in the literature as factors that may affect the riskiness of a project, though there is a lack of empirical studies to support this claim.

The first characteristic which we examined was *project duration* (elapsed time), one of the indicators of project scope. McFarlan [38] has suggested that the larger a project, "in dollar expense, staffing levels, elapsed time, and number of departments affected by the project, the greater the risk." Although support for this claim has been widely acknowledged with

Table 1
Six dimensions of risk

Dimension	Description	Representative references
Team risk	Team risk refers to issues associated with the project team members that can increase the uncertainty of a project's outcome, such as team member turnover, staffing buildup, insufficient knowledge among team members, cooperation, motivation, and team communication issues	[1,7,13,24]
Organizational environment risk	The risk or uncertainty surrounding the organizational environment in which a software project takes place was identified as a second major area of project risk. Factors such as organizational politics, the stability of the organization environment, and organizational support for a project have been shown to impact project performance	[16,21,25,46]
Requirements risk	Uncertainty surrounding system requirements is another major factor that can impact project performance. Frequently changing requirements are not the only possible requirements-related problem associated with system development projects. Incorrect, unclear, inadequate, ambiguous or unusable requirements may also increase the problems, or risks, associated with a software development project	[8,11,53,58]
Planning and control risk	The planning and control of the software development process adds another dimension to the riskiness of a project. Poor planning and control often leads to unrealistic schedules and budgets and a lack of visible milestones to assess whether the project is producing the intended deliverables. Without accurate duration estimates, managers do not know what resources to commit to a development effort. The net result is often excessive schedule pressure or unrealistic schedules that can increase project risk	[26,28,39,40,59]
User risk	The lack of user involvement during system development is one of the most often cited risk factors in the literature. If the attitudes of users towards a new system are unfavorable, then it is likely that they will not cooperate during a development effort, leading to an increased risk of project failure	[12,20,23,37,50,55]
Complexity risk	The inherent complexity of a software project, in terms of the difficulty of the project being undertaken, represents another dimension of software project risk. There are several attributes of a project that can indicate how complex it is, such as whether new technology is used, if the processes being automated are complex, and if there are a large number of required links to existing systems and external entities	[30,34,42,52]

anecdotal evidence, e.g. [6,61], it has not been operationalized and empirically tested. We selected project duration as the measure for scope because we believe that duration information is tracked for most projects and this type of information can be easily collected using a survey-based data collection procedure.

The second project characteristic relates to whether the project is performed *in-house* or *outsourced*. It has been suggested that outsourcing is risky, especially when compared to in-house sourcing [14,19,32,48]. However, there has been no empirical effort to examine the implications of outsourcing on project risk [18]. Using measures of the six dimensions of risk, along with an indicator of in-house and outsourced projects, we explored and highlighted the key areas of a project that became more or less risky when an outsourced development strategy was selected.

The third characteristic is the *strategic orientation* of the project. Clemons [9] suggested that developing a strategic application was fundamentally different from developing an application to automate transactions or aid in decision-making. While it seemed likely that projects of a strategic nature within the company differed from non-strategic projects in terms of risks, this has not been studied empirically.

Therefore, risk management could be enhanced by contrasting the nature and types of risk faced by different types of software projects. Better strategies can be developed by being aware of the characteristics that may affect exposure to risk, as well as common patterns revealed through the examination of risk dimensions and risk levels. Here, we used the dimensions of Table 1 with the instrumentation previously validated by Wallace to address the following research questions:

(1) What trends in risk dimensions can be observed across low, medium, and high risk projects?
(2) How do project scope, sourcing practices, and strategic orientation affect project risks?

3. Research approach

In order to address our research questions, a cross-sectional survey was used to collect information on a broad sample of projects. Because of their role in managing software projects, software project managers are in a good position to respond to questions dealing with project risk and thus they were ideal subjects for our study. The subjects were members of the Information Systems Special Interest Group (ISSIG) of the Project Management Institute (PMI).

PMI–ISSIG members were invited to participate through an electronic newsletter distributed to approximately 3800 members (for whom email addresses were available) and through a newsletter distributed to the entire PMI–ISSIG membership (approximately 7200 members). These asked project managers to complete a web-based survey containing the risk items and measures to assess project performance, project scope, sourcing practices, and the strategic orientation of the project. Subjects were asked to complete the survey as it related to their most recently completed project. The project managers (507) who responded, ranged in age from 24 to 62 years, with an average age of 40.5 years. Their previous software project management experience ranged from 1 to 38 years, with an average of 6.6 years.

3.1. Constructs and measures

The survey included multiple-item measures for each of the six dimensions of software project risk in Appendix A. The final instrument also included measures of project performance. The performance measures included seven items to measure product performance, and two to measure process performance. *Product performance* is a measure of the success of the system developed during the development project, whereas *process performance* refers to success of the development process itself (i.e., the extent to which the project was delivered on schedule and within budget). These measures were adapted from Rai and Al-Hindi [47] and Nidumolu [43] and are shown in Appendix B.

Table 2
Constructs and measurement properties

Construct	Number of measurement items	Cronbach's alpha	AGFI
User risk	6	0.88	0.84
Team risk	7	0.81	0.89
Requirements risk	8	0.89	0.93
Planning and control risk	9	0.92	0.91
Complexity risk	8	0.76	0.88
Organizational environment risk	6	0.79	0.89
Product performance	7	0.90	0.90
Process performance	2	0.84	0.84

Table 2 shows the multiple-item constructs, the number of measures used to assess each, and their measurement properties. Reliability of the risk dimension and performance constructs was assessed using Cronbach alphas and the scales were judged to exhibit adequate reliability [44]. Reliability and validity was further assessed by running LISREL measurement models for each scale [27]. The adjusted goodness-of-fit index (AGFI) was used to determine if there was a good fit between the measurement model and the observed data. All its values were greater than 0.80, indicating good model fit [57]. Tests of discriminant validity between the six risk dimensions indicated that each scale was measuring a construct that was significantly different from the others.

As discussed earlier, scope was assessed through a measure of project duration. Specifically, the respondent was asked to indicate if the duration of the project fell within 1–6, 7–12, 13–18, 19–24, 25–30, 31–36 months, or more. In order to measure sourcing practice, the subjects were asked to respond Yes or No to a single-item indicating whether the project involved a system that was being developed internally. Finally, the strategic nature of the system was measured by asking the respondent to classify the project as either strategic (primarily to provide competitive advantage), transactional (primarily to capture and process data related to routine transactions of the organization), or

Table 3
Cluster means for the six risk dimensions

Cluster	Team	Planning and control	User	Requirements	Complexity	Organization
Cluster 1 (low risk)	2.05	2.01	2.37	2.37	3.58	2.75
Cluster 2 (medium risk)	3.39	3.50	3.56	3.93	4.11	3.99
Cluster 3 (high risk)	4.40	5.13	4.73	5.36	4.84	5.04

informational (to provide information for planning and decision-making) [3].

3.2. Cluster analysis

Using aggregate measures of the six risk dimensions, *k*-means cluster analysis was performed. This resulted in three clusters representing low ($n = 140$), medium ($n = 227$), and high ($n = 140$) risk projects.

4. Results

4.1. Trends in risk dimensions across risk levels

Table 3 shows the cluster means obtained for the six risk dimensions. Higher cluster means for a given dimension imply a greater level of risk.

The risk profiles for low, medium, and high risk projects can be better visualized in the form of a star chart (see Fig. 1).

From these results, certain trends in risk dimensions can be readily observed. First, the mean level of risk associated with each dimension increases significantly as we move from the low to the medium to the high risk cluster. This makes intuitive sense and provides some additional empirical validation of the risk dimensions identified by Wallace.

We can also see that the low risk cluster consisted of projects that have, on average, low risk (between 2.01 and 2.75) along five of the six risk dimensions, based on the seven-point scale used to express the aggregate risk level of each dimension. Interestingly, however, even low risk projects have a moderate level of complexity risk, exhibiting a value (3.58) that is near the midpoint of the seven-point scale. The complexity risk

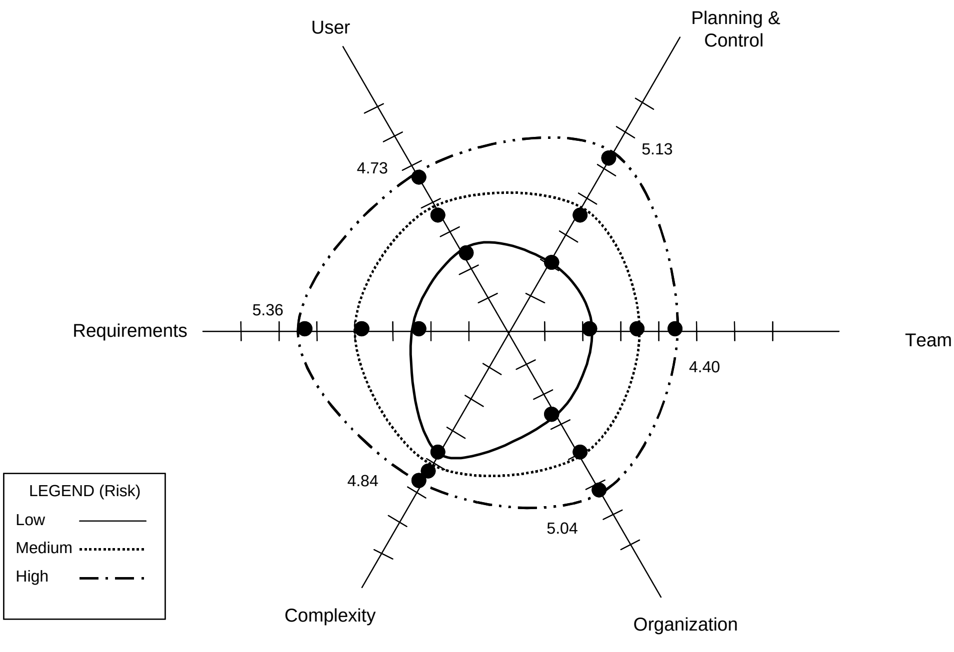

Fig. 1. Risk star chart.

Table 4
Relationship between risk and performance

Cluster	Process performance	Product performance
Cluster 1 (low risk)	5.18	5.88
Cluster 2 (medium risk)	3.82	5.27
Cluster 3 (high risk)	2.55	4.48

for the medium risk cluster is also somewhat higher (value of 4.11) relative to the other dimensions (values ranging from 3.39 to 3.99). Requirements risk and organizational risk are next highest in terms of describing the risk profile for medium risk projects.

For the high risk cluster, requirements risk, planning and control risk, and organizational risk come to the fore, outstripping complexity risk as the most prominent. These results suggest that for low and medium risk projects managing the complexity is key, while for high risk projects managing some of the other risk dimensions, such as requirements risk, become more important.

Another trend that can be observed is the relationship between project risk levels and project performance. Table 4 shows this relationship rather clearly.

As one would expect, there is significant degradation in both process and product performance as we move from low to high risk projects. This is particularly sharp for process performance; however, the differences are statistically significant for both performance measures. Both medium and high risk projects exhibit a mean process performance below four on a seven-point scale. Interestingly, however, product performance never falls below four on a seven-point scale, suggesting that product performance is not as seriously impacted as is process performance.

4.2. Impact of project scope, sourcing practices, and strategic orientation on project risks

Our second research question concerned the impact of project scope, sourcing practices, and strategic orientation on project risks. The mean values for project scope (as measured by project duration) for the low, medium, and high risk clusters were 2.11, 2.63, and 3.26, respectively. These differences were found to be statistically significant, with project duration increasing as the projects move from low to high risk. We used a MANOVA to examine the relationship between project duration and the six dimensions of risk. The MANOVA was significant ($P = 0.000$ for Hotelling's Trace and Pillai's statistics) and individual ANOVA's revealed that longer duration projects tended to carry greater risks along all six dimensions.

Zmud [62] has suggested that larger projects experience greater uncertainties because of the interdependencies among project tasks and the greater levels of coordination that must be used to manage the people, requirements, and complexity involved. One company has even classified all large projects as high risk and will only take on such a project if the benefits are unusually high [10]. Based on our research, they may be following a wise approach and other companies may consider similar strategies. Large projects may also be able to be broken down into several shorter duration, lower risk projects.

To examine the relationship between sourcing practices and project risk dimensions, a MANOVA was conducted. The overall model was significant ($P = 0.032$ for Hotelling's Trace and Pillai's statistics), providing statistical evidence of a difference in risk levels across outsourced and insourced projects. A drill-down into the specific differences in risk levels across insourced and outsourced projects was conducted by using six ANOVA tests. The results indicated that outsourced projects had significantly higher levels of team risk ($P = 0.014$) and planning and control risk ($P = 0.001$) than did insourced projects. No statistically significant differences were observed for the other four dimensions of risk. One explanation of these findings is that outsourced projects tend to pose greater challenges in terms of team communication and coordination, since they involve at least two organizations. Thus, team and planning and control risks could be elevated for outsourced projects.

Finally, MANOVA analysis revealed a relationship between strategic orientation and risk. The overall model was significant ($P = 0.012$ for Hotelling's Trace and Pillai's statistics), providing evidence of a difference in risk levels across strategic, informational, and transactional projects. A drill-down into the specific differences across the strategic orientation of the projects was conducted by using six ANOVA tests. Strategic applications were found to involve greater

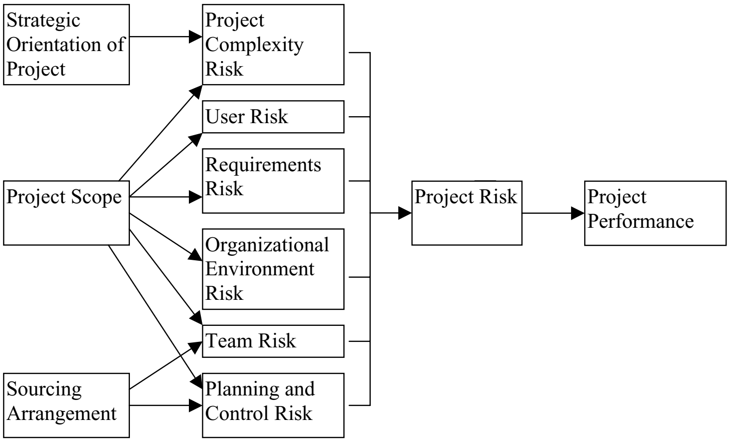

Fig. 2. Model of project risk and performance.

complexity risk than either informational or transactional applications ($P = 0.001$).

4.3. Toward a theoretical model of project risk and performance

Based on the results, one can start to define a model of project risk and performance. Fig. 2 proposes such a model.

The results suggest some support for the basic structure of this model. The cluster analysis clearly revealed a pattern in which all six dimensions of risk moved in the same direction as the risk went from low to high. The same analysis revealed an inverse relationship between project risk and project performance, particularly pronounced for process as opposed to product performance. Subsequent analyses revealed that both the strategic orientation and the sourcing arrangement influenced specific dimensions of project risk, while project scope appeared to impact all six risk dimensions.

5. Discussion and implications

Before discussing the implications, it is important to understand potential limitations. Risk is a complex construct and our research may not have captured all major aspects of software project risk. Also, we selected three project characteristics that had been identified in earlier research as possible influences on project risk levels, but there are other variables that may also affect the dimensions. Finally, convenience samples were used, with responders self selected. Thus the external validity and generalizability of our study may be limited. However, we believe that the study has important implications.

Strategic applications were found to involve greater complexity risk than either informational or transactional applications, so managers should focus on reducing or managing complexity in order to deliver these projects successfully. Strategic applications have a significant impact on a firm's performance and tend to span boundaries of systems, functions, processes, and firms. For example, strategic inventory applications must provide firms with the ability to detect patterns of supplier performance, over time, across established performance dimensions. Projects associated with these applications require technical capabilities, such as near real-time data warehousing and reporting, and management of conflicts, both organizational and technical, that are associated with the boundary-spanning orientation of strategic systems.

Outsourced development projects exhibited significantly higher levels of team risk as well as higher levels of planning and control risk. Therefore, managers who choose to outsource development should pay more attention to them in order to mitigate against these risks. While Kirsch [31] studied the portfolios of control in traditional IS projects, less is known about how managers exercise control in outsourced projects. Most managers embarking on their first outsourced project may tend to assume that the outsourcer will take care of everything, perhaps resulting in an underestimate of the planning and control risks involved in such projects. Projects that are undertaken within the boundaries of an organization are likely to involve lower levels of coordination costs and inherently lower risk.

Agency theory would predict that involving external agents increases the risks of opportunistic behavior that the firm will face [15,22]. Firms can guard against opportunistic behavior of external agents by planning and controlling process and product performance from which the conduct of unobservable behavior of external agents can be inferred. In addition, they can establish structures and processes to observe, and even potentially influence, the behavior of agents on a somewhat more regular basis.

6. Conclusions

Previous studies have proposed that risk is a complex construct, consisting of many components, but no prior effort has apparently been undertaken to understand how projects with varying levels of risk differ in terms of the underlying dimensions that drive risk. Our study has provided empirical evidence that the most prominent risks associated with high risk projects differ from those of medium and low ones. For high risk projects, requirements risk, planning and control risk, and organizational risk are the most prominent risks, whereas for low risk projects complexity is the most prominent.

Acknowledgements

The authors would like to thank the Project Management Institute's Information Systems Special Interest Group for supporting this research. We would also like to thank Georgia State University for its financial support through the Ph.D. research grant program. The authors gratefully acknowledge Al Segars for his insightful comments and assistance at earlier stages in this project.

Appendix A

Risk dimension	Items[a]
Team	Frequent conflicts between development team members
	Frequent turnover within the project team
	Team members not familiar with the task(s) being automated
	Team members lack specialized skills required by the project
	Inadequately trained development team members
	Lack of commitment to the project among development team members
	Inexperienced team members
Organizational environment	Lack of top management support for the project
	Change in organizational management during the project
	Organization undergoing restructuring during the project
	Unstable organizational environment
	Corporate politics with negative effect on project
	Resources shifted away from the project because of changes in organizational priorities
Requirements	Incorrect system requirements
	Users lack understanding of system capabilities and limitations
	Undefined project success criteria
	Conflicting system requirements
	Difficulty in defining the inputs and outputs of the system
	Unclear system requirements

Appendix A. (*Continued*)

Risk dimension	Items[a]
	System requirements not adequately identified Continually changing system requirements
Planning and control	Project milestones not clearly defined Project progress not monitored closely enough Lack of an effective project management methodology Inexperienced project manager Poor project planning Lack of "people skills" in project leadership Ineffective communication Inadequate estimation of required resources Inadequate estimation of project schedule
User	Lack of cooperation from users Users resistant to change Users not committed to the project Lack of user participation Conflict between users Users with negative attitudes toward the project
Complexity	Project involves use of technology that has not been used in prior projects Large number of links to other systems required High level of technical complexity One of the largest projects attempted by the organization Project involved the use of new technology Many external suppliers involved in the development project Immature technology Highly complex task being automated

[a] Respondents were asked to indicate the extent to which each risk statement characterized their most recently completed project on a seven-point Likert-type scale that ranged from "strongly disagree" (1) to "strongly agree" (7).

Appendix B

Product Performance (items were measured on a 7 point Likert type scale with 1 representing "strongly disagree" and 7 representing "strongly agree").

1. The application developed is reliable.
2. The application developed is easy to maintain.
3. The users perceive that the system meets intended functional requirements.
4. The users are satisfied with the developed application.
5. The system meets user expectations with respect to response time.
6. The system meets user expectations with respect to ease of use.
7. The overall quality of the developed application is high.

Process Performance (items were measured on a 7 point Likert type scale with 1 representing "strongly disagree" and 7 representing "strongly agree").

1. The system was completed within budget.
2. The system was completed within schedule.

References

[1] T.K. Abdel-Hamid, A study of staff turnover, acquisition, and assimilation and their impact on software development cost and schedule, Journal of Management Information Systems 6 (1), 1989, pp. 21–39.

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

[3] L.M. Applegate, F.W. McFarlan, J.L. McKenney, Corporate Information Systems Management: Text and Cases, Irwin, Chicago, 1996.

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

[5] B.W. Boehm, Software risk management: principles and practices, IEEE Software 8 (1), 1991, pp. 32–41.

[6] F.P. Brooks, The Mythical Man–Month, Addison-Wesley, Reading, MA, 1975.

[7] F.P. Brooks, No silver bullet: essence and accidents of software engineering, Computer 22 (4), (April 1987) 10–19.

[8] R.N. Charette, Software Engineering Risk Analysis and Management, Intertext Publications, New York, 1989.

[9] E. Clemons, Evaluation of strategic investments in information technology, Communications of the ACM 34 (1), 1991, pp. 22–36.

[10] J. Cumming, IT portfolio management: balancing risks and rewards of projects yields significant returns, NetworkWorld 19 (13), 2002, pp. 48.

[11] B. Curtis, H. Krasner, N. Iscoe, Field study of the software design process for large systems, Communications of the ACM 31 (11), 1988, pp. 1268–1287.

[12] G.B. Davis, Strategies for information requirements determination, IBM Systems Journal 21 (1), 1982, pp. 4–30.

[13] M. Deutsch, An exploratory analysis relating the software project management process to project success, IEEE Transactions on Engineering Management 38 (4), 1991, pp. 365–375.

[14] M.J. Earl, The risks of outsourcing IT, Sloan Management Review 37 (3), (Spring 1996) 26–32.

[15] K.M. Eisenhardt, Agency theory: an assessment and review, Academy of Management Review 14 (1), 1989, pp. 57–74.

[16] K. Ewusi-Mensah, Z.H. Przasnyski, On information systems project abandonment: an exploratory study of organizational practices, MIS Quarterly 15 (1), 1991, pp. 67–85.

[17] F.J. Heemstra, R.J. Kusters, Dealing with risk: a practical approach, Journal of Information Technology 11 (4), 1996, pp. 333–346.

[18] R. Hirschheim, M. Lacity, The myths and realities of information technology insourcing, Communications of the ACM 43 (2), 2000, pp. 99–107.

[19] A.S. Horowitz, Extreme outsourcing: does it work?, Computerworld 33 (19), (May 1999) 50–51.

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

[21] S.L. Jarvenpaa, B. Ives, Executive involvement and participation in the management of information technology, MIS Quarterly 15 (2), 1991, pp. 205–277.

[22] M.C. Jensen, W.H. Meckling, Theory of the firm: managerial behavior, agency costs and ownership structure, Journal of Financial Economics 3, 1976, pp. 305–360.

[23] J.J. Jiang, G. Klein, Risks to different aspects of system success, Information and Management 36, 1999, pp. 264–272.

[24] J.J. Jiang, G. Klein, T. Means, Project risk impact on software development team performance, Project Management Journal 31 (4), (December 2000) 19–26.

[25] C. Jones, Assessment and Control of Software Risks, Yourdon Press, Englewood Cliffs, NJ, 1994.

[26] M.M. Jones, E.R. McLean, Management problems in large-scale software development projects, Industrial Management Review 11 (3), 1970, pp. 1–15.

[27] K.G. Joreskog, D. Sorbom, LISREL 7: a guide to the program and applications, SPSS Inc., Chicago, 1989.

[28] S.P. Keider, Why systems development projects fail, Journal of Information Systems Management 1 (3), 1984, pp. 33–38.

[29] M. Keil, P. Cule, K. Lyytinen, R. Schmidt, A framework for identifying software project risks, Communications of the ACM 41 (11), 1998, pp. 76–83.

[30] C.F. Kemerer, G.L. Sosa, Systems development risks in strategic information systems, Information and Software Technology 33 (3), 1991, pp. 212–223.

[31] L. Kirsch, Portfolios of control modes and is project management, Information Systems Research 8 (3), 1997, pp. 215–239.

[32] R. Kliem, Managing the risks of outsourcing agreements, Information Systems Management 16 (3), 1999, pp. 91–93.

[33] R. Kumar, Managing risks in IT projects: an options perspective, Information and Management 40, 2002, pp. 63–74.

[34] K. Lyytinen, R. Hirschheim, Information systems failures—a survey and classification of the empirical literature, Oxford Surveys in Information Technology 4, 1987, pp. 257–309.

[35] K.R. MacCrimmon, D.A. Wehrung, The risk in-basket, Journal of Business 57 (3), 1984, pp. 367–387.

[36] J.G. March, Z. Shapira, Managerial perspectives on risk and risk taking, Management Science 33 (11), 1987, pp. 1404–1418.

[37] D. McComb, J.Y. Smith, System project failure: the heuristics of risk, Journal of Information Systems Management 8 (1), 1991, pp. 25–34.

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

[39] P.W. Metzger, Managing a Programming Project, Prentice-Hall, Englewood Cliffs, NJ, 1981.

[40] J.H. Moore, A framework for MIS software development projects, MIS Quarterly 3 (1), 1979, pp. 29–38.

[41] T. Moynihan, How experienced project managers assess risk, IEEE Software 14 (3), 1997, pp. 35–41.

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

[43] S.R. Nidumolu, A comparison of the structural contingency and risk-based perspectives on coordination in software-development projects, Journal of Management Information Systems 13 (2), 1996, pp. 77–113.
[44] J.C. Nunnally, I.H. Bernstein, Psychometric Theory, McGraw-Hill, New York, 1994.
[45] J.S. Osmundson, J.B. Michael, M.J. Machniak, M.A. Grossman, Quality management metrics for software development, Information and Management 40, 2003, pp. 799–812.
[46] R.J.W. O'Toole, E.F. O'Toole, Top executive involvement in the EDP function, PMM & Co-Management Controls (June 1966) 125–127.
[47] A. Rai, H. Al-Hindi, The effects of development process modeling and task uncertainty on development quality performance, Information and Management 37, 2000, pp. 335–346.
[48] H.R. Rao, K. Nam, A. Chaudhury, Information systems outsourcing, Communications of the ACM 39 (7), 1996, pp. 27–28.
[49] J.F. Rayport, J.J. Sviokla, Managing in the marketspace, Harvard Business Review 72, 1994, pp. 141–150.
[50] D. Robey, D.L. Farrow, User involvement in information systems development: a conflict model and empirical test, Management Science 28 (1), 1982, pp. 73–85.
[51] J. Ropponen, K. Lyytinen, Can software risk management improve systems development: an exploratory study, European Journal of Information Systems 6 (6), 1996, pp. 41–50.
[52] Z.G. Ruthberg, B.T. Fisher, Work priority scheme for EDP audit and computer security review, National Bureau of Standards Technical Report, NBSIR 86-3386, March 1986, p. iii-B-14.
[53] T. Saarinen, System development methodology and project success, Information and Management 19 (3), 1990, pp. 183–193.
[54] R. Schmidt, K. Lyytinen, M. Keil, P. Cule, Identifying software project risks: an international Delphi study, Journal of Management Information Systems 17 (4), 2001, pp. 5–36.
[55] P. Tait, I. Vessey, The effect of user involvement on system success: a contingency approach, MIS Quarterly (March 1988) 91–110.
[56] D. Tapscott, D. Ticoll, A. Lowy, Digital Capital: Harnessing the Power of Business Webs, Harvard Business School Press, Boston, 2000.
[57] S. Taylor, P.A. Todd, Understanding information technology usage: a test of competing models, Information Systems Research 6 (2), 1995, pp. 144–176.
[58] R.H. Thayer, J.H. Lehman, Software engineering project management: a survey concerning US aerospace industry management of software development projects, in: D.J. Reifer (Ed.), Software Management, IEEE Computer Society Press, Washington, DC, 1979, pp. 337–354.
[59] R.H. Thayer, A. Pyster, R.C. Wood, The challenge of software engineering project management, IEEE Computer 13 (8), (August 1980) 51–59.
[60] L. Wallace, The development of an instrument to measure software project risk, unpublished Doctoral Dissertation, Georgia State University, 1999.
[61] S. Ward, Requirements for an effective project risk management process, Project Management Journal 30 (3), 1999, pp. 37–43.
[62] R.W. Zmud, Management of large software development efforts, MIS Quarterly 4 (2), 1980, pp. 45–55.

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