# A Temporal Model of Information Technology Project Performance

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*Journal of Management Information Systems* / Winter 2007–8, Vol. 24, No. 3, pp. 9–44.

0742–1222 / 2008 $9.50 + 0.00.
DOI 10.2753/MIS0742-1222240301

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Abstract: Efficiently delivering expected performance from information technology projects remains a critical challenge for many organizations. Improving our understanding of how various factors influence project performance is therefore an important research objective. This study proposes and tests a temporal model of information technology project performance (TMPP). It shows that performance can be better understood by separating risk factors into earlier (a priori) risk factors and later (emergent) risk factors, and modeling the influence of the former on the latter. Project performance, the dependent variable, is measured by considering both process (budget and schedule) and product (outcome) components. The model includes interactions between risk factors, project management practices, and project performance components. The model is tested using partial least squares analysis with data from a survey of 194 project managers. Our results indicate that the TMPP increases explanatory power when compared with models that link risk factors directly to project performance. The results show the importance for active risk management of recognizing, planning for, and managing a priori and emergent risk factors. The finding of a strong relationship between structural risk factors and subsequent volatility shows the need for risk management practice to recognize the interaction of a priori and emergent risk factors. The results confirm the importance of knowledge resources, organizational support, and project management practices, and demonstrate the ways in which they reinforce each other.

Key words and phrases: information technology project management, knowledge management, project performance, software project risk.

Efficiently delivering expected benefits from information technology (IT) projects remains a challenge for many organizations [22]. Industry studies [29] and government reports [14, 33] continue to call for improved performance in IT projects. The combination of increasing dependency on information systems and the increasing costs of delivering such projects suggests that IT project performance is a critical organizational issue. Indeed, the ability to conceive of strategic systems may be of less importance to organizations today than the ability to execute and deliver planned project benefits.

Projects are complex, multidimensional phenomena. Many factors interact in their execution. Understanding project performance therefore requires complex, interactive, multivariate modeling. Prior research has drawn attention to the multivariate nature of project risk [2, 19, 36]; it has modeled the role of specific project management interventions [12, 25, 26]; and it has developed prescriptions for managing specific risks [2, 5, 6, 19, 35]. Relatively few studies have systematically modeled performance as a function of the complex interaction of a wide range of risk and project management factors [11, 37]. Understanding the impact of project management practice in project execution requires this more integrated modeling.

This paper suggests that there is value in further considering the factors influencing IT project performance. The difference between this model and previous research is that it models (1) temporal differences in risks, (2) the influence of initial (a priori) risks on later (emergent) risks, (3) the interaction between project management practices and different risk categories, and (4) the direct effects of emergent risks on performance. The proposed temporal model of IT project performance (TMPP) is tested using data from a survey of 194 project managers using a partial least squares (PLS) approach. Results indicate that the TMPP offers encouraging gains in explanatory power and provides support for the separation of initial risk from emergent actions and events.

## Prior Research in IT Project Performance

Practitioners and researchers continue to be concerned with how to properly identify risk and manage projects for success. Some researchers have focused on identifying risk [19, 31, 34]; others have focused on theory development to understand risk management [3, 25]; still others have focused on the relationship between risk exposure and performance [12, 28, 35, 36, 37]. This section surveys previous work to develop a model relating risk, project management, and project performance.

In developing this discussion, we take a broad temporal view of risks and IT projects. Projects are often separated from operational work because projects have a defined beginning and end. While we recognize that the beginning and end of projects can be difficult to establish, it is useful to consider that projects begin, people engage in project activities, and at some time the project ends. Although simple, the concept of a start, middle (i.e., what happens during a project), and end (i.e., the outcomes) provides a useful way of organizing our discussion of project risk and performance. We start by reviewing established approaches to defining, identifying, and categorizing IT risks. We then apply our temporal perspective.

## Defining, Identifying, and Categorizing IT Risks

The "risk" construct has been modeled in a variety of ways in IT research. Broadly speaking, it is either modeled as a single construct (e.g., overall risk or risk exposure) or as separate risk factors. When modeled as a single construct, risk is often developed by creating quantitative estimates of event probabilities and expected effects arising from a number of risk factors. Such a construct is challenging to estimate as event probabilities are often difficult to ascertain and the subjective assessments of effects often vary widely. Boehm [5] suggested the use of approximation techniques and prioritized checklists designed to address some of these estimation challenges.

Barki et al.'s [2] alternative definition suggested that development risk should be estimated using the uncertainty surrounding the entire project and the potential loss associated with project failure. Software development risk was defined as the project uncertainty multiplied by the potential loss due to project failure. This narrowed the estimate of effects to a single item—project failure.

Nidumolu [25] extended the definition of software development risk in two ways. He suggested that project performance was multidimensional and that performance risk changes over time. For example, performance risk decreases near the closing of the project as actual performance becomes more evident. The definition of risk exposure, later defined by Barki et al. [3], largely captures these extensions.

In this study, our focus is placed on the risk factors associated with projects. Risk exposure and overall project risk will not be considered. The objective of this research is to better understand how risk factors are associated with project performance.

Previous research has provided an extensive list of risk factors affecting IT projects. Zmud [38] suggested that technological complexity, the degree of novelty or technological change, and project size were important risk considerations. McFarlan [24] added experience with the technology and project structure. Boehm [5] provided a top-ten checklist associated with projects that was later used by Ropponen and Lyytinen [28] to develop six risk components. These risk components included (1) scheduling and timing risks, (2) system functionality risks, (3) subcontracting risks, (4) requirement management risks, (5) resource usage and performance risks, and (6) personnel management risks. In a similar fashion, Barki et al. [2] identified five risk categories, including (1) novelty, (2) application size, (3) lack of expertise, (4) application complexity, and (5) organizational environment (lack of resources and support).

Keil et al. [19] and Schmidt et al. [31] used results from a Delphi procedure to further detail IT risk factors. These analyses resulted in the development of two dimensions of risk—relative importance and controllability. These dimensions create a $2 \times 2$ matrix that establishes four risk categories, including (1) customer mandate (uncontrollable and of high importance), (2) scope and requirements (controllable with high importance), (3) execution risk (controllable with moderate importance), and (4) environment risks (uncontrollable with moderate importance). Specific elements of these risks are detailed in the 53 project risks provided in Wallace and Keil [35, p. 72].

The various categorizations of risk factors have provided insights (e.g., [35]) and have helped to improve our understanding of the nature of the risks associated with IT projects. Below, we propose an alternative categorization based on a temporal perspective.

## The Start: A Priori Risk Categories

The temporal nature of projects (conceived as the transition from the starting conditions to what happens during the project to its outcomes) can be used to suggest a different categorization of IT project risk factors. Previous studies have not acknowledged the difference between risk factors that are present when a project is defined and risk factors that either emerge or are revealed as the project is executed.

### A Priori Risks: Structural and Knowledge Factors

In general, we argue that some characteristics of the project, such as the budget, duration, technical complexity, requirements certainty, inexperience of the team, and lack of project sponsor knowledge, can be estimated before a project begins. We refer to these as a priori risk factors.

Two categories of a priori risk factors can be identified:

1. risk factors associated with structural elements of the project (e.g., duration, budget, effort, technical complexity) and
2. risk factors inherent in the knowledge available to the team (e.g., competence of project manager, sponsor, team members).

Structural elements, such as project size and technical complexity, have been recognized as important risk factors [24, 38]. Our assumption is that these are known or at least potentially knowable at the start of a project. Managing them requires the use of traditional "hard" project management techniques such as work breakdown, estimation, scheduling, and budgeting.

The lack of knowledge resources (e.g., inexperienced project manager or team) has also been recognized as an important category of risk factors in IT projects [2, 24]. These risk factors require management techniques that are often referred to as "soft skills," such as communication, team building, learning, and expertise coordination. The difference in hard and soft skill approaches suggests that separating knowledge resources from structural risk factors should provide useful insights.

Before the project begins, the project manager will have formed expectations about the level of top management support and user participation he or she will receive. One might suggest that these expectations are a priori risk factors. However, we argue that expected levels of support or participation do not directly affect performance. Instead, it is the actual levels of support that are revealed through behaviors of top managers and users that most directly affect performance. For example, while a project manager may believe that he or she will receive a high level of user participation, the actual level of participation is revealed only through behaviors of users during the project. An executive might promise a high level of support, but actually deliver something less. We therefore refer to these risk factors that are revealed during the project as *emergent* risk factors. These emergent risk factors are discussed below.

## During the Project: Emergent Risks and Project Management Practices

During the course of a project, not only do new risks emerge but also the project manager takes action to deal with the risk and progress of the project (we refer to these actions as project management practices). In this section, we examine how previous research has conceptualized this period of time.

### Emergent Risks

Two categories of emergent risk factors can be identified:

1. risk factors associated with deficiencies in organizational support (e.g., lack of sponsor, client, or user support) and
2. risk factors relating to changes that occur (e.g., changes to targets, team members, and the wider environment).

The first of these categories we call *organizational support risk.* Previous research suggests there are three important areas of organizational support—executive sponsor support, client manager involvement, and user participation. Organizational support risk can be loosely connected to the "customer mandate" risk category identified in Keil et al. [19]. Organizational support is actively sought after and managed by members of the project team and is often considered essential for project success [32, 37]. When the degree of organizational support demonstrated is below an expected level, it is often referred to as a risk factor (e.g., lack of management support). When the organizational support meets or exceeds expectations, it is often referred to as an important resource for project managers.

The second category of emergent risk factors comprises the changes that affect projects including changes in project targets, key personnel, and external conditions experienced by the project. We refer to these as *project volatility risk* [30]. Elements of this risk category are similar to the "environment" risk category identified in Keil et al. [19], the environmental contingencies proposed by Ropponen and Lyytinen [27, 28], and the instability factor in Yetton et al. [37]. This volatility is often outside the control of members of the project team but can have significant effects on project performance. The two categories of emergent risk factors—organizational support risk and volatility risk—are considered separately in our model of project performance.

The separation of risk categories and their relation to previous research is summarized in Table 1. The utility of our proposed categorization is an empirical question that is tested and discussed later in the paper.

### Project Management Practices

Some IT project risk literature assumes a direct link between identified risk factors and project performance. The majority of research, however, suggests that risk factors are managed and modified through project management practices.

Several studies have provided suggestions for managers of risk factors in software development projects [3, 11, 12, 19, 25, 28, 34]. Nidumolu [25] suggested vertical and horizontal coordination for effective management of risk factors. Vertical coordination is similar to administrative controls defined earlier in Barki et al. [2] and includes formalized, hierarchical communication between the development team and project stakeholders. Horizontal coordination recognizes the importance of integrating users into the discussion and describes communication undertaken through mutual and lateral means at both personal and group levels.

Faraj and Sproull [12] extended this discussion of coordination by suggesting the inclusion of expertise coordination in managing risk factors associated with knowledge. Expertise coordination includes three elements: (1) expertise identification (knowing what knowledge is required), (2) expertise location (knowing where the experts are), and (3) expertise application (bringing the expertise to bear on important problems). Faraj and Sproull [12] showed that expertise coordination is a significant contributor to performance above and beyond the management methods identified by Barki [2, 3] and Nidumolu [25].

Table 1. Summarizing Categories of Risk Factors

| | Proposed risk factor categories | | | |
|---|---|---|---|---|
| | A priori risks | | Emergent risks | |
| | Knowledge | Structure | Organizational support | Volatility |
| Zmud [38] | Degree of novelty | Technological complexity, project size | User involvement | Personnel changes |
| McFarlan [24] | Experience with the technology | Project size | | Project structure |
| Barki et al. [2] | Expertise (lack of knowledge), technological newness (need for new software and hardware) | Application size, technical complexity | Organizational environment, expertise (user support) | Technological newness (software and hardware suppliers) |
| Keil et al. [19] | Misunderstanding requirements, managing user expectations, lack of knowledge, changing requirements | | Top management support, user commitment, lack of user involvement, inappropriate staffing | Conflict between departments, changing scope, changing requirements |

*(continues)*

Table 1. Continued

| | Proposed risk factor categories | | | |
|---|---|---|---|---|
| | A priori risks | | Emergent risks | |
| | Knowledge | Structure | Organizational support | Volatility |
| Ropponen and Lyytinen [28] | Requirement management risks | System functionality risks | Resource usage and performance risks, personnel management risks | Scheduling and timing risks, subcontracting risks, personnel management risks |
| Wallace et al. [35] | Team risk, requirements risk | Complexity risks, planning and control risks | Organizational environment risk (organizational support), user risks | Organizational environment risks (politics and stability) |
| Standish Group [17] | Experienced project manager, standard software infrastructure, firm requirements | Minimize scope, reliable estimates | Top management support, user involvement | |

This literature has established that involving users through the use of standard development methods, applying administrative controls, and coordinating expertise are important risk management practices. Yet few, if any, of these practices are solely targeted at risk factors. In addition to dealing with things that might get in the way of completing the task (risk management), they also help to plan, organize, and complete the task itself (project management). Ropponen and Lyytinen [27] found that specific risk management techniques were not instrumental in attacking specific risks and that risks were better managed with more general techniques such as traditional project management practices. We therefore use the term *project management practices* to describe the activities identified above because of their effect not only on risk but also on task completion.

## Project Outcomes: IT Project Performance

Researchers have largely converged on the importance of considering at least two elements of IT project performance—process performance and product performance [3, 12, 25, 28].

Process performance refers to the efficiency of the project and is often measured by considering how the project adhered to costs and time estimates [25, 35]. Product performance refers to the quality of the developed system—that is, the outcome of the project that includes considerations of product quality and realized benefits [3, 25]. In some instances, process performance may be traded against product performance (for example, higher quality may be achieved at the expense of schedule overrun). It is therefore necessary to conceptualize and measure product and process performance separately.

## Models of IT Project Performance

A traditional model of risk, risk management, and project performance would assume that projects have an overall risk exposure that is created from combining a large number of risk factors into a single estimate of risk. Management practices are adjusted, based on the risk exposure, with higher-risk projects receiving additional attention [11]. These management actions help to mediate the effects of risks and influence project performance. This type of model, summarized in Figure 1, incorporates the approach suggested in the project management body of knowledge (PMBOK).

There are several weaknesses with this traditional model. It does not consider:

1. the temporal nature of risks—that is, that some risks may exist ahead of others,
2. the influence of earlier (a priori) risks on later (emergent) risks,
3. the differential impact of project management practices on different risk categories,
4. the direct effects between emergent risks and performance.

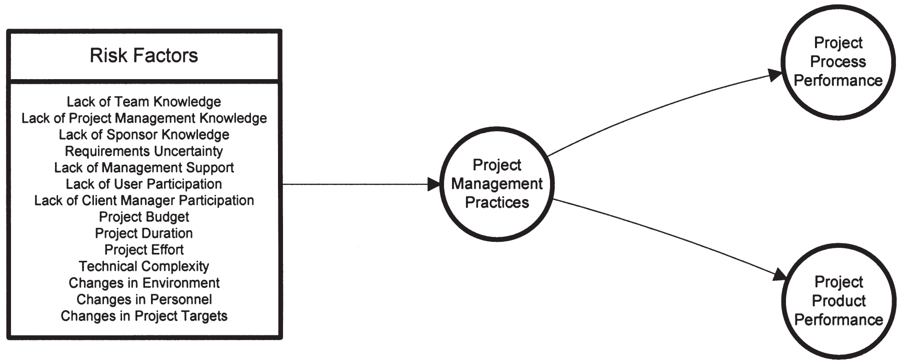


*Figure 1.* A Traditional Model of Risk Factors and Performance

We are able to address these shortcomings by dividing risks temporally into a priori and emergent. A priori risks are then divided into knowledge resource risks and structural risks (project size/technical complexity). Emergent risks are grouped into organizational support risks and volatility risks (Figure 2).

Separating these constructs allows us to posit temporal relationships between risk categories, project management practices, and project performance [11, 37]. In general, a priori risks are expected to influence emergent risks and project management practices. Emergent risks and project management practices are expected to be related to each other and to influence project and product performance. Figure 3 shows these relationships in a fully specified TMPP.

The direction of causality between emergent risk constructs (for example, organizational support risks and volatility) cannot be established in the absence of theory. For this reason, they are shown as bidirectional arcs connecting the constructs in Figure 3, suggesting that these factors likely interact and influence each other.

The models presented in Figures 1 and 3 present alternative descriptions for the relationships between factors important to IT project performance. Because arguments for both approaches can be constructed, the question of which model provides more explanatory power with respect to IT project performance can only be addressed empirically. We address this question by comparing the two models using a single set of data. The following section describes the instrument designed to collect the data with which to perform this comparison.

## Empirical Methods

An online survey instrument was created using SurveyMonkey.com to collect data for the model comparison. The survey underwent both a pretest and pilot phase. Members of the study team were used to test the online questionnaire in the pretest phase. In the pilot phase, seven project mangers were asked to fill in the survey and provide feedback through interviews. The pilot test provided additional information on usability, language ambiguity, and expected completion time. Final adjustments

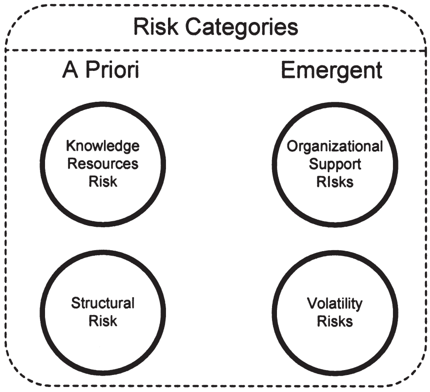


*Figure 2.* Proposed Categories of Risk Factors

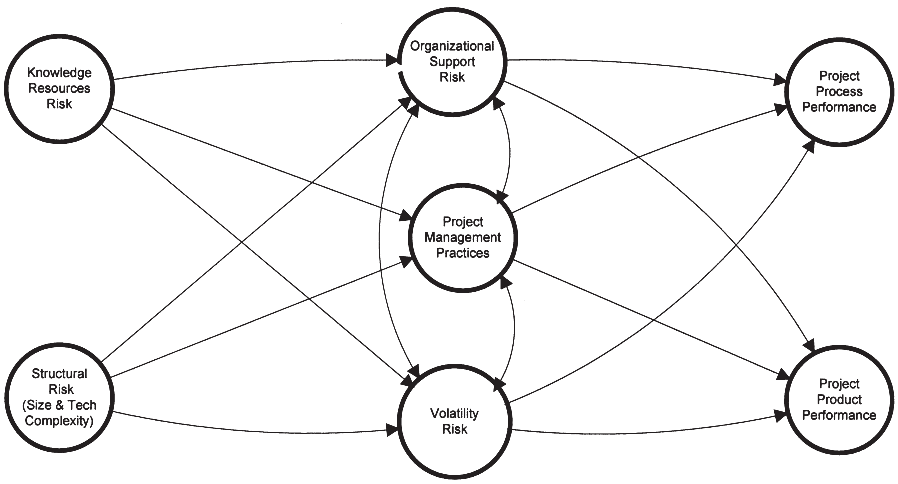


*Figure 3.* Temporal Model of IT Project Performance (TMPP)

were made to the online instrument as a result of the pilot phase. E-mail invitations and follow-up requests to participate were sent to project managers across three Project Management Institute (PMI) chapters in Ohio. The exact number of potential participants is difficult to estimate due to e-mail bounce back and the fact that PMI includes IT and non-IT project managers. The invitation requested that only IT project managers answer the survey. A total of 523 first-time visitors clicked onto the survey Web site through the invitation. From these, 223 responses were collected providing an effective response rate of 42.6 percent.

Our unit of analysis is the individual project. Respondents were asked to provide information about the most recent project they had completed (either implemented or cancelled). The most recently completed project was chosen to ensure that respondents were considering projects for which there was a defined outcome while maintaining reasonable recall of project details.

Of the 223 respondents, 204 participants provided complete information regarding project performance indicators. A *t*-test comparison of the incomplete responses showed no significant difference in project manager experience, project budget, or project duration. A subsequent review of respondents identified an additional 10 projects that were eliminated because of inconsistencies regarding project size and performance, giving a final sample size of 194. Considerations for these outliers included, for example, a large number of person months but a very small budget (for example, 350 person months for $150,000) or extremely large budgets with short project times (for example, $1.7 billion in less than eight months).

The respondents were experienced and knowledgeable project managers with an average age of 43, including an average of 15 years of industry experience and approximately 34 days of formal project management training. A profile of the 194 projects on various size characteristics is provided in Table 2. The average reported project budget was just under $5 million with an average effort of 150 person months and an average duration of 15 months. Respondents indicated that 93 percent of the completed projects were implemented and 7 percent cancelled. The ratio of cancelled projects is similar to industry reports [29, 30], suggesting the responses have some external validity.

## Measures

Measures were developed in a two-step process. We first identified measures used previously in the literature to model IT project performance. Then, new measures were developed when none were available. For variables measured through scales, previously developed scale items were used wherever possible. Averages for these scale variables, incorporating all scale items, were used as subconstructs in the model. The Appendix provides a summary of the measures used in the study, including the source, item text, number of items, and reliability score (Cronbach's alpha) associated with the measures. Scale items were measured using seven-point Likert scales.

### Outcome Measures: Project Performance

Four outcome measures were collected. Two measures related to process outcomes (schedule variance and budget variance). These variables were measured as a percentage of targets as originally planned [30]. Variables were then transformed into a positive direction. For example, a percentage of original schedule of 140 percent would indicate the project was 40 percent later than originally planned, whereas a percentage of original schedule of 90 percent would indicate the project was completed 10 percent earlier than expected. In this case, 90 percent is better performance than 140 percent. To transform into the positive direction, we subtracted 100 percent from each number and then multiplied the result by –1.

The two outcome measures relating to product outcomes were measured as a percentage of expected quality delivered or percentage of expected benefits delivered. Because these variables are already in the positive direction (where 140 percent would

Table 2. Profile of Projects in the Sample

| Attribute | Mean | Median | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Budget (thousands of USD) | 4,859 | 975 | 12,270 | 10 | 250,000 |
| Duration (calendar days) | 449 | 360 | 354 | 61 | 2,131 |
| Effort (person months) | 150 | 24 | 450 | 1.5 | 3,400 |

be better performance than 90 percent), no transformation of these product outcomes was necessary.

### Input and Process Measures

Five input and process constructs were included—knowledge resources risk, size and complexity, project management practices, volatility, and organizational support risk. Because measures did not exist for these five primary constructs, each of the constructs was measured by considering subconstructs. For instance, because no single measure of project size is available, project size was measured by considering its subconstructs (duration, budget, effort, and relative size).

Each of the five constructs is multidimensional and the subconstructs (and related measures) for each construct were not a priori interchangeable. Jarvis et al. [16] suggest that under these conditions the constructs should be modeled as formative. Modeling constructs as formative allows for the combination of different measures within the same construct without requiring that the measures share significant covariance. Formative constructs can be estimated in the partial least squares (PLS) approach to structural equation modeling [8, 13]. The measures for each of the five input and process constructs are discussed below.

*Knowledge resources risk* takes two forms—individuals' knowledge limitations and uncertainty. The former reflects the lack of knowledge and experience available to the project. While every individual contributes to the available knowledge resource, there are three primary sources of knowledge exposure—executive sponsor, project manager, and team members. Lack of project sponsor knowledge, team knowledge, and project manager knowledge have been identified as important considerations in overall project risk [12, 15, 35, 37].

A four-item scale was developed by taking elements of expertise identified by Barki et al. [2, 3] and Basselier et al. [4]—knowledge of application technology, business environment, project role, and project management practices. The items were coded so that lower levels of knowledge were represented with higher numbers. The four items were then averaged for each case, creating a single measure of knowledge risk for each of the executive sponsor, project manager, and overall team members.

Requirements uncertainty has also been identified as an important knowledge resource risk [19, 25, 28]. The level of requirements uncertainty was measured with a three-item scale adapted from Nidumolu [26]. These items were coded so that increased uncertainty was represented with higher numbers. The items were averaged for each case to create a single measure of requirements uncertainty. These four subconstructs (requirements uncertainty, executive sponsor knowledge, project manager knowledge, and team knowledge) were then used formatively to create the knowledge resources risk construct.

*Structural risk (project size and technical complexity)* has long been recognized as an important factor in project performance [24, 38]. Project size is multidimensional, and effects of duration, for example, have been shown to be different from those of budget [30].

Four elements of project size were included as subconstructs—relative size, budget, duration, and effort as measured in person months. Each was assessed with a single item. Project duration was the difference between start and end dates. Project budget and person months associated with the project were also collected as measures.

Technical complexity [3] of the project was also measured. Because technical complexity is a measure of the project and not the knowledge of people working on the project, technical complexity is included in this category of initial conditions. Technical complexity was measured with two items from Barki et al.'s [3] measure related to application complexity. These items were then averaged to create the technical complexity subconstruct. The four subconstructs for project size and the measure of technical complexity were then used formatively to create the structural risk construct.

*Organizational support risk* is an aggregate measure of the lack of support that the project and the project manager were given by the base organization. There are three subconstructs to organizational support:

1. lack of participation of the users [3, 37],
2. lack of participation by the client manager [3, 37], and
3. lack of support from executive sponsor [32, 37].

Three items used for user participation and client support were adapted from Barki et al. [3]. A similar three-item measure, adapted from Schmidt et al. [31], was created to measure actions taken by executive sponsors in support of the project. The items were coded so that lower perceived support or participation was represented with higher numbers. The items were then averaged for each case creating three subconstructs (client manager support, top management support, and user participation) that formed the organizational support risk construct.

*Volatility risk* refers to events that occur during the project that create significant changes. Volatilities include events such as changes in key project personnel or changes in targets such as budget or schedule [30]. Ropponen and Lyytinen [28] and Wallace and Keil [35] also suggest changes to the external environment as another form of volatility.

Following Sauer et al. [30], a three-item measure of target volatility was created from questions asking for the number of changes in budget, schedule, and scope. These items were summed to create a single measure of target volatility on a ratio scale. Governance volatility was measured using three items asking for number of changes in project sponsor, project manager, or client manager. These items were summed to create a ratio-scaled measure of governance volatility. These two ratio scale items were standardized before estimating the model.

External volatility was assessed with four items measured on a seven-point scale requesting participants to rate the impact of changes in the external environment, business strategy, suppliers/vendors, and government on project performance. These four items were then averaged across each case to create the external volatility subconstruct. The three volatility subconstructs were then used to reflectively form the volatility risk construct.

*Project management practices* include the actions taken to overcome risk in projects and meet overall project goals. Three practices have been identified as important management practices in IT projects including:

1. integration of users [3], which is related to horizontal coordination [25];
2. administrative coordination [12], which is related to vertical coordination [25] and formal planning [3]; and
3. expertise coordination [12].

A three-item scale adapted from Nidumolu [25] was used to collect data regarding the integration of users. A two-item scale for administrative coordination was adapted from the formal planning measure provided in Barki et al. [3] and the notion in Faraj and Sproull [12] of the use of formal project management techniques. A five-item scale was adapted from Faraj and Sproull [12] to measure expertise coordination. The items in each scale were then averaged for each case creating three subconstructs that were used to create the project management practices construct.

## Measurement Validation

No standard to measure the content validity of formative constructs has been developed [16]. We have attempted to establish content validity for the measures reported in this study through an extensive literature review, the combined experience of the research team, the use of previously developed scales, and pretesting and piloting of the research instrument.

The construct validity related to formative constructs is also difficult to establish empirically. Because the subconstructs are assumed to jointly form the constructs, it is not clear that the correlations between subconstructs must be higher than correlation among other subconstructs [7]. This is in contrast to the use of reflective constructs where interitem correlations are expected to be higher in comparison with items outside the scale [13].

While no standard rules apply for establishing convergent and discriminant validity of formative constructs, it can be argued that subconstructs associated with a particular construct should, in general, be more highly correlated with each other than with subconstructs that measure other distinct latent variables. We therefore provide a correlation matrix of subconstructs used in this analysis. Of the 113 cross-correlations measured between subconstructs forming different constructs, only nine are larger than the highest correlations of subconstructs within constructs. These are highlighted in Table 3. These results show that subconstructs related to the same construct generally have higher correlations than subconstructs measuring different constructs. This provides some evidence for both convergent and divergent construct validity.

## Results

### Analytical Methods

Data from the survey were used to test two models using PLS. PLS is a structural equation modeling technique utilizing a principal component-based approach to estimation. PLS was chosen because it is preferred over covariance based techniques for theory development and the use of formative constructs [13]. Seven multi-item constructs were estimated.

A third-order factor model with primarily reflective measures as first-order factors and formative measures as second- and third-order factors was tested. Reflective measures were used in the first order when the items were strongly correlated with each other. Formative measures were used in the higher-order factors because items were expected, in sum, to form the factor. Testing of higher-order factor models is supported in PLS [21] and has been used in previous research [4]. Nested models were used to explore the effect of separating the elements of emergent actions from initial risk conditions as presented in Figure 2. A model M1 is nested within another model, M2, if M2 contains exactly the same constructs as M1 and if M2's freely estimated parameters are a subset of those estimated in M1. Nested model comparison is possible in PLS [1]. The significance of a nested model is examined by comparing the $R^2$ of the revised model with that of the original model using an $f^2$-statistic [13, appendix C].

### Test of Measurement Model

Formative models can only address the error of measurement at the construct level [10, 23]. Because all constructs are formative in both models, the standard of reporting average variance extracted and establishing appropriate loadings is not appropriate [9]. The Appendix provides Cronbach's alpha scores for first-order factors used in the model. Only one of the alphas (project management knowledge) is below the suggested value of 0.70. Since it is arguably an important portion of the formative construct of "knowledge resources," the project management knowledge scale was retained in the model.

Table 3. Construct Validity—Correlations Among Subconstructs

| Correlations | Code | ES_K | TM_K | PM_K | RC | B | D | E | R_S | T_C |
|---|---|---|---|---|---|---|---|---|---|---|
| Executive sponsor knowledge | ES_K | 1.00 | | | | | | | | |
| Team member knowledge | TM_K | 0.19 | 1.00 | | | | | | | |
| Project manager knowledge | PM_K | 0.12 | 0.01 | 1.00 | | | | | | |
| Requirement certainty | RC | 0.13 | 0.23 | 0.07 | 1.00 | | | | | |
| Budget ($) | B | –0.03 | –0.27 | 0.14 | –0.09 | 1.00 | | | | |
| Duration (days) | D | –0.06 | –0.28 | –0.08 | –0.37 | 0.38 | 1.00 | | | |
| Effort (person months) | E | 0.14 | –0.20 | 0.03 | –0.15 | 0.36 | 0.37 | 1.00 | | |
| Relative size | R_S | 0.02 | –0.15 | 0.01 | –0.23 | 0.42 | 0.49 | 0.28 | 1.00 | |
| Technical complexity | T_C | –0.08 | –0.12 | 0.14 | –0.07 | 0.17 | 0.04 | 0.10 | 0.14 | 1.00 |
| User participation | U_P | 0.22 | 0.16 | 0.13 | 0.08 | –0.10 | 0.00 | 0.22 | 0.06 | 0.06 |
| Top management support | M_S | 0.32 | 0.15 | 0.17 | 0.01 | 0.05 | 0.02 | 0.14 | 0.17 | 0.17 |
| Administrative coordination | A_C | 0.09 | 0.27 | 0.22 | 0.10 | 0.01 | –0.06 | 0.03 | 0.03 | 0.10 |
| Expertise coordination | E_C | 0.17 | 0.37 | 0.07 | 0.18 | –0.11 | –0.17 | –0.03 | 0.10 | 0.10 |
| User integration | U_I | 0.10 | 0.21 | 0.09 | 0.10 | 0.06 | –0.10 | 0.09 | 0.10 | 0.18 |
| Target volatility | T_V | –0.02 | –0.21 | –0.12 | –0.28 | 0.24 | 0.45 | 0.00 | 0.25 | 0.05 |
| Governance volatility | G_V | –0.09 | –0.23 | –0.02 | –0.30 | 0.16 | 0.45 | 0.05 | 0.20 | 0.02 |
| External volatility | E_V | 0.00 | –0.20 | –0.03 | –0.31 | 0.23 | 0.30 | 0.18 | 0.05 | –0.01 |

*(continues)*

Table 3. Continued

| Correlations | Code | U_P | M_S | A_C | E_C | U_I | T_V | G_V | E_V |
|---|---|---|---|---|---|---|---|---|---|
| Executive sponsor knowledge | ES_K | | | | | | | | |
| Team member knowledge | TM_K | | | | | | | | |
| Project manager knowledge | PM_K | | | | | | | | |
| Requirement certainty | RC | | | | | | | | |
| Budget ($) | B | | | | | | | | |
| Duration (days) | D | | | | | | | | |
| Effort (person months) | E | | | | | | | | |
| Relative size | R_S | | | | | | | | |
| Technical complexity | T_C | | | | | | | | |
| User participation | U_P | 1.00 | | | | | | | |
| Top management support | M_S | 0.41 | 1.00 | | | | | | |
| Administrative coordination | A_C | 0.20 | 0.36 | 1.00 | | | | | |
| Expertise coordination | E_C | 0.27 | 0.32 | 0.45 | 1.00 | | | | |
| User integration | U_I | 0.27 | 0.34 | 0.53 | 0.72 | 1.00 | | | |
| Target volatility | T_V | –0.08 | –0.05 | –0.19 | –0.18 | –0.15 | 1.00 | | |
| Governance volatility | G_V | –0.19 | –0.12 | –0.19 | –0.24 | –0.16 | 0.37 | 1.00 | |
| External volatility | E_V | –0.06 | 0.01 | –0.02 | –0.16 | –0.13 | 0.26 | 0.23 | 1.00 |

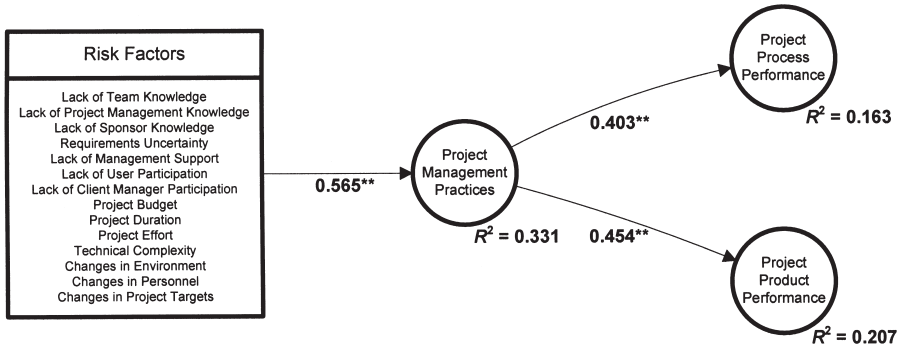


*Figure 4.* Pooled Risk Model—Path Coefficients and $R^2$
** Significant at the 0.01 level.

## Evaluating the Structural Models

Problems of identification present in covariance-based approaches to structural equation modeling are not present in the PLS approach [9]. The overall approach to evaluating the structural model is the same as evaluating reflective models, except that emphasis is placed on the weights, rather than the loadings, of the formative subconstructs. The $R^2$ is similar to regression analysis and significance tests are performed similar to those for reflective models as described in Gefen et al. [13]. The bootstrapping procedure in PLS was used to generate *t*-statistics and standard errors [9].

Figure 4 presents the path coefficients and $R^2$ from the PLS results for the pooled risk model. The individual measures of risk were combined to form the performance risk exposure construct. The model, tested with data from 194 projects, explains 16 percent of the variance in process performance, 21 percent of the variance in product performance, and 33 percent of variance in project management practices. The path coefficients for this model are all significant at the 0.01 level. This pooled risk model provides a baseline for our discussion.

Figure 5 presents the path coefficients and $R^2$ for a variation of the pooled risk model, in which the single construct of risk factors has been replaced with the four categories of risk posited earlier. The model again explains 16 percent of the variance in process performance and 21 percent of the variance in product performance. The model explains 31 percent of variance in project management practices, which is a 2 percent decrease from the model provided in Figure 4. The path coefficients for project size/technical complexity and volatility to project management practices are not significant. The path coefficients from knowledge resource risks and organizational support risks are significant at the 0.05 and 0.01 levels, respectively.

The results suggest that the model presented in Figure 5, denoted the traditional risk model (TRM), where risks are divided into four categories, provides broadly similar results to the pooled model in Figure 4. The model in Figure 5 has been estimated because it contains exactly the same constructs as the proposed TMPP. This base will allow for a direct comparison of results in Model 6 with the proposed TMPP and

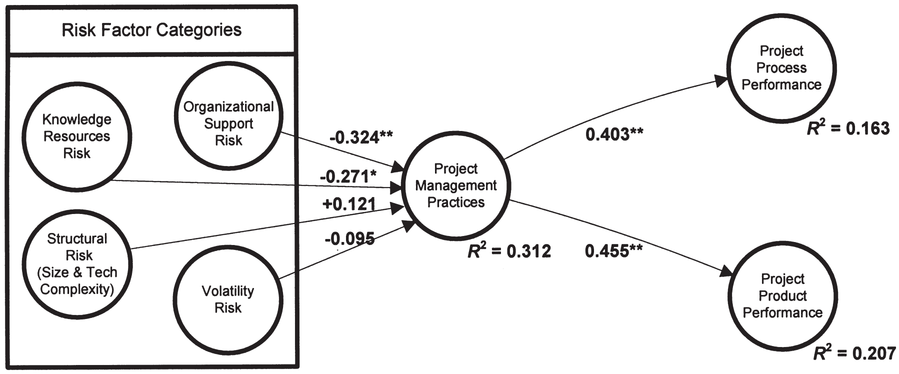


*Figure 5.* Traditional Risk Model—Path Coefficients and $R^2$
* Significant at the 0.05 level; ** significant at the 0.01 level.

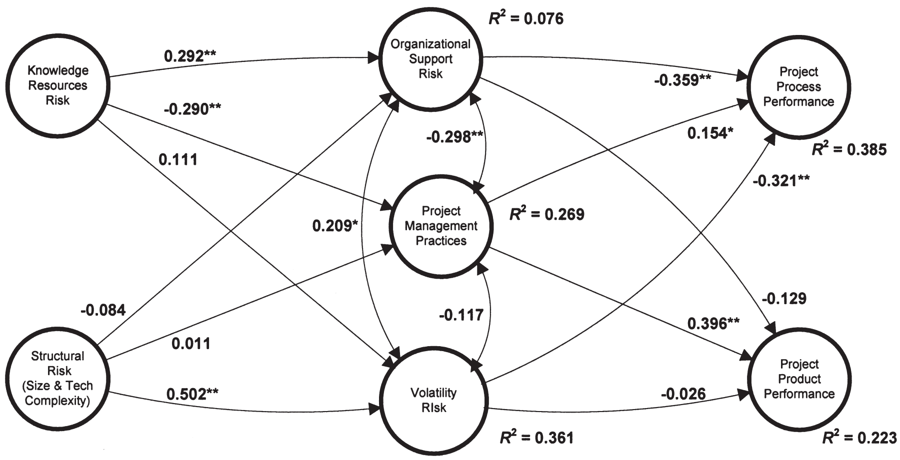


*Figure 6.* Path Coefficients and $R^2$ for TMPP
* Significant at the 0.05 level; ** significant at the 0.01 level.

provides the best opportunity to contrast the traditional single-stage view of risk and the model of IT project performance provided by the TMPP.

Figure 6 presents the path coefficients and $R^2$ for the TMPP, in which the interaction between a priori and emergent risks and the interaction between emergent risks and project outcomes are modeled. This model explains 38.5 percent of the variance in process performance, 22 percent of the variance in product performance, and 27 percent of the variance in project management practices. In addition, the TMPP explains 36 percent of the variance in volatility risk and 8 percent of the variance in organizational support risk. The level of significance is highlighted in Figure 6.

## Comparing Nested Models

We argued that the separation of initial conditions from emergent actions and events may provide an improved model for IT project performance. This hypothesis can be tested using nested models, a technique that has been applied previously to test to the technology acceptance model (TAM) [18]. Using nested models allows us to see where the model can be improved [13]. Because the models in Figures 5 and 6 utilize the same constructs and many of the same paths, the use of nested comparison is appropriate.

We are interested in exploring the traditional model that is nested within the TMPP. When nested models are compared using PLS [1], the differences are examined by comparing the $R^2$ of the revised model with that of the original model using an $f^2$ statistic [13, appendix C]. The additional paths can be considered to have a small, medium, or large effect if $f^2$ is above 0.02, 0.15, or 0.35, respectively [9]. The equation for $f^2$ in this comparison is calculated as follows:

$$f^2 = \frac{R^2\text{TMPP} - R^2\text{TRM}}{1 - R^2\text{TRM}}.$$

Note that we can compare the nested models across three constructs—process performance, product performance, and project management practices. The results of the nested comparison are provided in Table 4.

The results suggest that temporally modeling the risk factors provides a significant increase in the explained variance of process performance, a small decrease in the explained variance of project management practices, and no significant change in the explained variance of product performance.

There are additional benefits from this model. The most obvious are the variances explained in both volatility and organizational support, which are 0.361, and 0.076, respectively. Beyond the benefit of its improved explanatory power, the TMPP also yields interesting insights through discussion of the path coefficients relating the various constructs in the model.

## Discussion

Our principal concern in this paper was to develop a better approach to modeling the relationships between risk factors, project management practices, and performance. This discussion aims to (1) examine the improvements offered by the TMPP and their implications for future research, (2) focus on the significant findings and frame them as story lines, and (3) discuss the contributions and limitations of the research.

## Modeling Risk, Management, and Performance

Our research developed a more comprehensive temporal model of project performance than previously available in the literature. The empirical test of the TMPP shows that

Table 4. Results from Nested Model Testing

| | M1: Traditional risk management model | M2: Temporal model of IT project performance | $R^2$ improvement | $f^2$ | Effect strength |
|---|---|---|---|---|---|
| $R^2$ of process performance | 0.163 | 0.385 | 0.222 | 0.27 | Medium |
| $R^2$ of product performance | 0.207 | 0.223 | 0.016 | 0.02 | None |
| $R^2$ of project management practice | 0.312 | 0.269 | –0.043 | 0.06 | Small |

it offers improved explanatory power for project process performance and no worse for product performance (Table 4). It therefore unambiguously improves upon the TRM ability to explain performance (Figure 5). The $R^2$ of 0.385 is higher than has previously been achieved for process performance. The potential of our modeling approach is therefore confirmed.

We examine, in turn, the four individual improvements we proposed:

1. risk factors should be summarized into risk categories based on time,
2. the influence of earlier (a priori) risks on later (emergent) risks should be modeled,
3. the differential impact from different risk categories to project management practices should be considered, and
4. the direct effects between emergent risks and performance should be modeled.

### Risk Categories Based on Time

We categorized risk factors consistent with the assumption that some (a priori) risk factors are created in project formulation and should be treated separately from other (emergent) risk factors that occur during the project. This categorization alone offers no explanatory benefits (Figure 5 is no better than Figure 4).

### Influence of A Priori Risks on Emergent Risks

Modeling benefits arise when the influence of a priori risks on emergent risks is introduced, based on the proposition that emergent risk factors may be influenced by a priori risk factors and may influence and be influenced by other emergent risk factors. These temporal relationships have not been explored in previous research, with one exception: the existence of a relationship between project size and volatility was established in Sauer et al. [30]. The TMPP (Figure 6) supports this finding and demonstrates other statistically significant relationships between a priori risk factors and emergent risk factors. First, a substantial amount of variance in the level of emergent risk (volatility) is explained by its relationship to a priori structural risk (size and technical complexity).

Second, a significant relationship between volatility risk and organizational support risk is shown in Figure 6. This relationship has not been reported previously. The direction for causality cannot be established, so it is not clear whether lack of organizational support contributes to increased volatility or increased volatility leads to low levels of organizational support or both.

What is clear is that one type of emergent risk can significantly affect other emergent risks. Future research should therefore include temporal considerations in models of performance. This may require further refinement of our risk categories and greater care in defining emergent risks. For example, we have defined lack of executive sponsor support as an emergent risk but some deficiency in support may be apparent at the outset and thus may also be considered an a priori risk [3, 19]. To cope with this, we may need two distinct risks comprising lack of initial support and lack of revealed support.

### Relationships Between Risk Categories and Project Management Practices

The TMPP implies that we expect different relationships between the different categories of risk and project management practices. We confirmed this conjecture to the extent that we found significant relationships between project management practices and two risk categories—one a priori and one emergent—and no significant relationship with the other two (Figure 6). Thus, future research should explore such relationships.

### Relationships Between Emergent Risks and Performance

The TMPP includes direct effects between emergent risk factors and performance as well as the indirect paths through project management practices. The influence of project management practices on project management performance has been established previously [3, 12, 25]. Our results show significant relationships between process performance and both project volatility and organizational support risk (Figure 6). To the best of our knowledge, these finding have not been reported previously. The implication of these relationships is that, in contrast with the traditional model (Figure 5), emergent risk factors cannot be, or are not currently, completely mitigated by project management practice. This implies that future researchers should consider these relationships in their models.

Our argument has been that the TMPP proposed is more explanatory as a whole than its predecessors and that the individual innovations we have introduced are justified. Although we conclude that the model structure holds promise, we are conscious that there is much room for improvement. In particular, our model has generated only insignificant improvement in the explanation of product performance. As we talk to project managers, they tell us that this is the increasingly critical area of their performance. We suspect that the reason our model is not more helpful is that in drawing upon the established literature for our constructs and measures, we have tapped into its prior emphasis on process performance. Our measures and data sources for product performance are relatively crude at present. This presents both a challenge and an opportunity for researchers. Our model offers a starting point.

## Findings, Story Lines, and Insights

The second task for this discussion is to explore the empirical findings for insights. To support the discussion, we created Figure 7 by simplifying and redrawing Figure 6. Simplification entails showing only the significant relationships. We also find it a simplification to reverse the conceptualization of knowledge resource risk and organizational support risk into project resources by recoding the levels (to reverse the direction of the construct) and changing their labels. We noted earlier that low levels of organizational support and knowledge are often referred to as "risks" and that high levels are viewed as resources for projects. In redrawing the model, we are therefore conceptualizing knowledge and organizational support as resources that a project

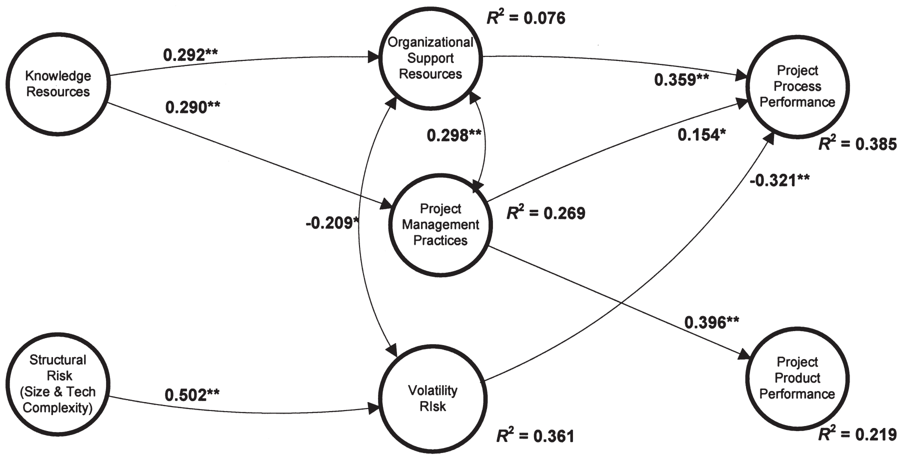


*Figure 7.* TMPP Showing Significant Relationships
* Significant at the 0.05 level; ** significant at the 0.01 level.

manager can use to productively advance the project. We found this conceptualization supported a more natural discussion of the relationship between risks, resources, practices, and performance. Structural risk factors (size/technical complexity) and volatility risk factors remain coded as "risks" to the project.

An important caveat should be noted before discussing insights from the model. The model described in Figure 7 has temporal elements, but it is a descriptive model and should not be viewed as a causal model of performance. When searching for insights, it is important not to draw causal relationships between the risk and resource categories and performance indicators.

## Six Key Findings

Six findings emerge from Figure 7. The first is that structural a priori risk (project size and technical complexity) is significantly directly related to volatility risk. In addition, volatility risk is significantly inversely related to project process performance. This suggests that projects that are large and complex will tend to have a larger number of changes to targets and personnel. Projects with a larger number of changes to people and targets are more likely to perform poorly on process indicators (i.e., budget and schedule). This confirms and begins to explain the link between larger projects and poor performance proposed previously [24, 38].

The second finding is that knowledge resources are significantly directly related to both organizational support and project management practices. This confirms the importance of the knowledge of the team, the sponsor, and the project manager [3, 35], and suggests that these knowledge resources act as an enabler for project management practices and organizational support. This result explains the emphasis that many project managers place on developing a strong team at the beginning of a project and ensuring that the sponsors and clients have a solid understanding of project management.

A third finding is that project management practices are significantly directly related to process and product performance. This suggests that projects that have higher levels of project management practices (i.e., horizontal integration, vertical integration, and expertise coordination) are associated with higher levels of performance. This relationship confirms previous work [12, 25] and underlines the contribution of the project manager to project success.

A fourth finding is the significant direct relationship between organizational support and project process performance. This relationship confirms the emphasis on top management support in previous research [2, 19, 35] and suggests that organizational support enables process performance.

A fifth finding is the two significant inverse relationships between (1) volatility risk and organizational support and (2) project management practices and volatility risk (influenced by organizational support). First, in the case of organizational support, the results suggest that when organizational support is low, project volatility tends to be high (and vice versa). This can plausibly be interpreted in either direction. For example, without organizational support, a project manager may be more inclined to leave the project. Conversely, when volatility is low, it may be easier to garner high levels of organizational support. The direction of the causality cannot be determined in this study. Second, the positive relationship between organizational support and project management practices means that project management practices are also indirectly and inversely related to volatility. While we cannot determine the direction of causality in relation to volatility risk, this does suggest some form of double jeopardy.

A sixth somewhat surprising finding is the lack of a significant relationship between organizational support and project product performance. We expected high levels of organizational support (i.e., executive support, client manager support, and user participation) would help to keep the project focused on value delivery and eventually lead to an increased realization of the benefits from the project. This finding warrants further research into these constructs and relationships.

## Story Lines and Insights

These findings can be combined into two concurrent but distinct "story lines." The first begins with knowledge resources, the second with structural risk. These story lines suggest reframing our thinking about the explanation of project performance.

We can interpret the top part of Figure 7 as saying that a project starts with an a priori endowment of knowledge resources. Higher levels of this resource positively influence both emergent organizational support and project management practices. Project management practices and organizational support influence each other positively. Although we are unable to confidently assert unidirectional causality, mutual reinforcement seems plausible on the grounds that with higher levels of organizational support, the easier it is to execute project management processes; and, conversely, the more it is apparent that the project is being proactively managed, the more support may be forthcoming.

Project management practice is then seen as affecting product performance directly and process performance both directly and indirectly, through organizational support. We could interpret these data as a story about the project manager who uses knowledge resources to manage the project and to positively influence organizational support and, through these mechanisms, to make substantive progress in achieving the project's goals. A variant of this story is that highly competent knowledge resources enable high levels of organizational support and project management practices, and that in this environment, organizational support can make its full impact on project success. It remains for future research to test these variants and provide us with more insight into these virtuous circles.

The second story line begins with structural risk that directly influences the risk of project volatility. In turn, project volatility negatively and significantly influences process performance. We realize that this story is a new one in that project volatility has not received much attention before this research. In due course, elaboration of this part of the TMPP is likely to result in more complex relationships.

We argue, though, that these two story lines suggest a distinction between project management and risk management. The first story is about proactive project management and organizational support whose focus is the constructive work of getting the project done. By contrast, the second is a more traditional story about the impact of risk. Prior research has not typically distinguished proactive project management from risk mitigation. Except for project management practices, most constructs have been viewed and modeled as risks—for example, the literature talks about lack of top management support, a negative, rather than its presence, a positive.

Future research therefore needs to do to the construct of project management practices what we have done to risk factors: to divide practices into categories that relate to the tasks of constructive project management and risk management. Then we can posit and test a set of relationships that are likely to be explanatory of both process and product performance. We would expect then to see one or more categories of risk management entering into relationships with the size and complexity and volatility constructs.

Finally, we would like to draw attention to two clear lessons for practice. Our findings suggest that some risk factors interact and appear to propagate. Emergent risks are, at least to some degree, a function of a priori risk. This indicates that project setup is critical to the lifetime risk profile of the project. It also suggests that risk assessment should be an ongoing activity. This should reinforce for practitioners the point that not only is it important to establish a risk register at the outset but that it should be actively updated and managed on a continuing basis throughout the project's life. Another clear lesson from these data is that our historic concern with project size and complexity is warranted and that one consequence of larger projects is increased project volatility. Therefore, projects that are unavoidably long should take proactive steps to minimize volatility, which, according to our analysis, principally implies ensuring continuity of key personnel.

## Contributions

This paper's chief contribution is a more explanatory temporal model of IT project performance. It achieves this by introducing several innovations to the structure of the model. It shows that a separation and categorization of risk factors into a priori and emergent risks reveals previously unrecognized interactions. It shows that the a priori risks affect the emergent risks. It shows that project management has a differential effect on risk categories. It also shows that emergent risks have direct effects on performance—that is, not all risk is mitigated—so the effects of risk cannot be completely modeled through the mediation of project management.

At the level of individual risk categories, the TMPP demonstrates empirically that researcher and practitioner concerns about size and complexity are well founded. These structural risks strongly influence project volatility, which, in turn, impairs attainment of project targets. It introduces a comprehensive project volatility construct, which will benefit from future elaboration.

The paper also makes three methodological contributions. First, it shows that PLS is an effective tool for working constructively with formative constructs within a temporal model of project performance. Second, the technique shows that in the complex, multivariate world of project performance, modeling the construction of higher-level variables formed by contributory or complementary components is a helpful device. The explanatory success of the model justifies this strategy. Third, in the absence of accepted theory, it demonstrates nested modeling as a useful method to assess alternative models of project performance.

## Limitations

We draw attention to three limitations of our current study. The first is that our sample was drawn from the membership of several chapters of the PMI in one state of the United States. It is possible that local idiosyncrasies could have biased the data. However, comparison, where possible, with data from a study of UK project managers suggests that the probability of geographical bias is low [30]. A more probable bias derives from the high level of experience and professional standing of the respondents. Compared with Standish Group data [17], our sample's performance is unusually high—their variance against target is low. If anything, this suggests that the TMPP modeling approach has great potential to generate even more explanatory analyses for a sample more representative of the total project manager population.

Second, the survey asked the project manager to respond to questions about product performance (i.e., attainment of organizational benefits from the project). We need to resolve who is the best source of this data and when the data should be collected. We expect some difference in responses between project managers, executive sponsors, and end users. We also expect that difference to vary according to when the question is asked. These limitations may partly explain the lack of improvement in our ability to explain product performance with the TMPP.

Third, our model provided a simple temporal model of project performance. In reality, we expect that the point in time at which a project management intervention occurs or a risk factor is realized will have differential effects. For example, turnover of a project manager may have less effect the closer the project is to completion. Executive sponsor support may have the most effect early and late in a project and be less important in the middle [20]. Future research will need to develop a more sophisticated approach to modeling the temporal element.

## Conclusions

Prior research has highlighted a large number of factors that can affect project performance, suggested that project management practices can mitigate risks, and indicated that performance is a complex phenomenon. This presents a challenge for modeling project performance. This study demonstrated a useful distinction between a priori and emergent risk factors. In doing so, it improved upon prior levels of explanation of project performance. Future research should identify further distinctions and interactions to help us better understand the relationship between risk and performance as a more complex function than the simple summation of component risks.

Our study reinforced work started by others [2, 11, 12, 25, 26, 37] that shows the role of project management practices in mitigating risk factors. All future work that attempts to relate performance to risk must factor in the role of these practices. This is probably the area in which the TMPP can be most effectively improved because research has so far paid relatively little attention to the operationalization of project management practice. A more developed project management practice construct will permit the formulation of more plausible guidance for practice—which actions under which circumstances have the most substantial effects on which kind of performance.

We argue that future research should distinguish between those project management practices that are aimed at delivering the project's outcome and those that are aimed at mitigating the risks that could impede success. Some practices, such as expertise coordination, are focused on delivery. Others, such as risk identification and contingency planning, are intended to mitigate risk. A third category, such as developing executive sponsor support, probably serves both purposes. This separation will increase the granularity of models and hopefully will increase our understanding of how project management delivers value and what are the most appropriate and effective project management practices. We see this as a critical conceptual development in the next challenge—opening up the black box of IT project management.

*Acknowledgments:* This research was supported by grants from the Social Sciences and Humanities Research Council of Canada (SSHRC) and the Natural Sciences and Research Council of Canada (NSERC).

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## Appendix: Measures Used in the Study

| Construct/subconstructs | Number of items | Cronbach's alpha | Source adapted from | Item |
|---|---|---|---|---|
| Knowledge resources risk | | | | |
| Requirements uncertainty | 3 | 0.775 | [25] | A lot of effort had to be spent in reconciling the requirements of various users. |
| | | | | Users differed a great deal among themselves in the requirements to be met. |
| | | | | Requirements identified at the beginning of project were quite different from those existing at end. |
| Sponsor knowledge | 3 | 0.815 | [3, 4] | At the beginning of this project, my knowledge about project management was 1 = very low to 7 = very high. |
| | | | | At the beginning of this project, my knowledge about the business environment of this project was 1 = very low to 7 = very high. |
| | | | | At the beginning of this project, my knowledge about the applications/technology used on this project was 1 = very low to 7 = very high. |
| Project manager knowledge | 3 | 0.657 | [3, 4] | At the beginning of this project, the sponsor's knowledge about project management was 1 = very low to 7 = very high. |
| | | | | At the beginning of this project, the sponsor's knowledge about the business environment of this project was 1 = very low to 7 = very high. |
| | | | | At the beginning of this project, the sponsor's knowledge about the applications/technology used on this project was 1 = very low to 7 = very high. |

| | | | | |
|---|---|---|---|---|
| Team knowledge | 3 | 0.707 | [4] and [4] | At the beginning of this project the client manager's knowledge about project management was 1 = very low to 7 = very high.<br>At the beginning of this project, the client manager's knowledge about the business environment of this project was 1 = very low to 7 = very high.<br>At the beginning of this project, the client manager's knowledge about the applications/technology used on this project was 1 = very low to 7 = very high. |
| Size and technical complexity | | | | |
| Application complexity | 2 | 0.819 | [3] | The application was required to integrate with other applications.<br>The technology was required to interface with other types of technology. |
| Relative size | 1 | N/A | N/A | How does the size of this project compare with others undertaken by the client organization over the past three years? |
| Duration | 1 | N/A | N/A | Months |
| Budget (USD) | 1 | N/A | N/A | U.S. dollars |
| Effort | 1 | N/A | N/A | Person months |
| Organizational resources risks | | | | |
| Top management support | 3 | 0.874 | [31] | To what extent did top management demonstrate interest in the implementation of the project?<br>To what extent did top management effectively communicate support for the project?<br>To what extent did top management provide the necessary help and effective resources for the project? |

*(continues)*

| Construct/subconstructs | Number of items | Cronbach's alpha | Source adapted from | Item |
|---|---|---|---|---|
| Client manager participation | 3 | 0.818 | [3] | To what extent did the client manager assign his or her best resources to the project? |
| | | | | To what extent did the client manager act as an ambassador for the project? |
| | | | | To what extent did the client manager actively support the use of project management processes? |
| User participation | 3 | 0.890 | [3] | To what extent were users able to make changes to the agreements of the work to be done? |
| | | | | To what extent did the project team keep users informed concerning project progress and problems? |
| | | | | To what extent did users formally evaluate the work done by the project team? |
| Volatility | | | | |
| Target volatility | 3 | Ratio scaled standardized | [30] | How many times was the project schedule changed during the course of the project? |
| | | | | How many times was the project budget changed during the course of the project? |
| | | | | How many times was the project scope changed during the course of the project? |
| Governance volatility | 3 | Ratio scaled standardized | [30] | How many times was the project manager changed during the course of the project? |
| | | | | How many times was the client manager changed during the course of the project? |
| | | | | How many times was the executive sponsor changed during the course of the project? |

| | | | | |
|---|---|---|---|---|
| External volatility | 4 | 0.765 | Developed | There was a change in the competitive environment that affected the project.<br>There was a change in the business strategy that affected the project.<br>There was a change in the supplier/vendor that affected the project.<br>There was a regulatory/governmental change that affected the project. |
| Project management practices | | | | |
| Administrative coordination | 2 | 0.948 | [25] | A project management methodology was used on this project.<br>Project management tools and techniques were used on this project. |
| Integrative coordination | 3 | 0.777 | [3, 25] | The project team met frequently.<br>Project team members were kept informed about major decisions concerning the project.<br>Project team members actively participated in the definition of project goals and schedules. |
| Expertise coordination | 5 | 0.878 | [12] | The team had a good “map” of one another’s talents and skills.<br>Team members were assigned to tasks commensurate with their task-relevant knowledge and skill.<br>Team members knew who on the team had specialized skills and knowledge that was relevant to their work.<br>People in our team shared their special knowledge and expertise with one another.<br>More knowledgeable team members freely provided other members with hard-to-find knowledge or specialized skills. |

*(continues)*

| Construct/subconstructs | Number of items | Cronbach's alpha | Source adapted from | Item |
|---|---|---|---|---|
| Project performance | | | | |
| Process performance | 2 | Formative | [30] | In terms of budget the project cost more than the initial budget by this percentage: |
| | | | | In terms of budget the project cost less than the initial budget by this percentage: |
| | | | | In terms of schedule the project was late against the initial schedule by this number of months: |
| | | | | In terms of schedule the project was ahead of the initial schedule by this number of months: |
| Product performance | 2 | Formative | [30] | In terms of quality the project was lower quality than desired by the client by this percentage: |
| | | | | In terms of quality the project was higher quality than desired by the client by this percentage: |
| | | | | In overall terms the client organization received less organizational benefits than expected by this percentage: |
| | | | | In overall terms the client organization received more organizational benefits than expected by this percentage: |