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The joint influence of technology uncertainty and interorganizational interaction on external technology integration success

Gregory N. Stock [a,*], Mohan V. Tatikonda [b,1]

[a] *Department of Operations Management and Information Systems, College of Business, Northern Illinois University, DeKalb, IL 60115, USA*

[b] *Kelley School of Business, Indiana University, 801 W. Michigan St., Indianapolis, IN 46202-5151, USA*

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Abstract

This paper empirically examines the acquisition of a technology from a source outside the firm and its incorporation into a new or existing operational process. We refer to this key activity in process innovation as *external technology integration*. This paper develops a conceptual framework of external technology integration based on organizational information processing theory and technology management literature. The primary hypothesis underlying the conceptual framework is that external technology integration will be most successful when the level of interaction between the source of the technology and recipient of the technology is appropriately matched, or fit, to the characteristics of the technology to be integrated. The conceptual framework also develops other hypotheses relating to contextual factors that may also influence the success of external technology integration. A cross-sectional survey methodology is employed to test the four hypotheses of the conceptual framework, with the results indicating strong support for the fit hypothesis and general support for the contextual hypotheses. The paper closes with a discussion of the implications of this study for both theory and practice.

Keywords: Interorganizational interaction; Technology uncertainty; Information processing theory; Technology projects

1. Introduction

Consider a firm that must replace or augment a key element of technology in its production process. This technology might be, for example, a CNC machine tool or new manufacturing production scheduling software. It might be intended to provide incremental operational improvements or significant production process changes. Such a technology could be developed internally or acquired from an outside source. While a firm might have the expertise, resources and motivation to build such technology internally, in reality in many instances the new process technology is acquired from some external source. We refer to the process of managing the acquisition and incorporation of technology from external sources as *external technology integration* (ETI). Managing this process successfully leads to the technology performing well in its target application, and in a timely and cost-effective manner.

For many firms, ETI is no longer an occasional activity that can be managed in an ad-hoc fashion; rather, it is a recurring process that requires purposeful

* Corresponding author. Tel.: +1 815 753 9329; fax: +1 815 753 7460.
E-mail addresses: gstock@niu.edu (G.N. Stock), tatikond@iu.edu (M.V. Tatikonda).
[1] Tel.: +1 317 274 2751.

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management supported by a well-developed portfolio of organizational skills. There are multiple challenges in the ETI process. First, the firm must be able to assess the characteristics of the technology relative to the firm's own capabilities and experience. Second, the firm must be able to determine the extent to which it must interact with the technology's external source. Third, and possibly most importantly, the firm must be able to implement the organizational skills needed to successfully execute the external integration process.

This paper aims to contribute by providing theoretical insight and practical guidance on how a firm can better manage its ETI process. The present paper is the latest in a line of research we have conducted on external technology integration. Our first paper (Stock and Tatikonda, 2000) drew on several literature streams to theorize performance aspects of the execution of project-level technology transfers for product and process technology instances. The resultant conceptual framework is summarized by the ''Inward Technology Transfer Typology'' (see Fig. 1) which posits archetypal transfer types given certain technology and interorganizational factors. That framework (also called the ''Inward Technology Transfer Matrix'') is oriented primarily towards inter-organizational aspects, and parallels the well-known ''Product-Process Matrix'' which is instead oriented primarily towards internal, single-organization aspects. An even more detailed and expanded conceptual framework elaborating on both planning and execution factors in ETI projects is provided in Tatikonda and Stock (2003). Stock and Tatikonda (2004) then presented a cross-case analysis of 17 ETI projects, and confirmed, using this small field-based sample, the general notion of fit. That study also helped us elaborate on the central conceptual constructs through observation of practice.

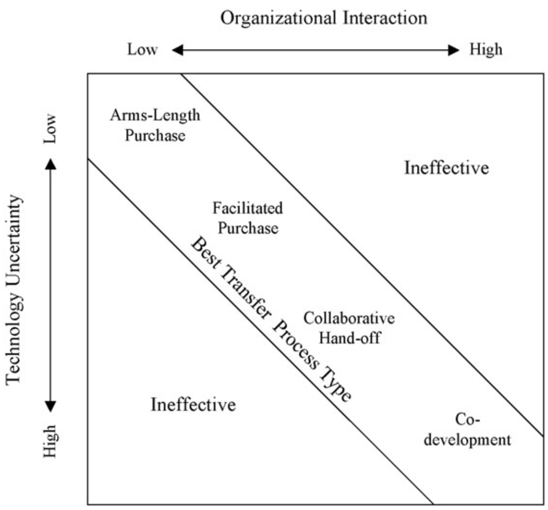

Fig. 1. Matrix view of effective external technology integration. Adapted from figure (titled ''The Inward Technology Transfer Typology'') of Stock and Tatikonda (2000).

In conducting this line of research we have followed a systematic and iterative theory-development and theory-testing approach informed by extant organizational theory along with field research and observations of practice. The present paper leverages the prior conceptual development and field-based investigation to set a firm and contextually grounded basis for the current larger-sample, cross-sectional, theory-testing study.

Section 2 presents a theoretically derived framework that guides the management of ETI, and focuses heavily on the ''fit'' of a technology's uncertainty with the interorganizational approach used by the source and recipient of that technology. Sections 3 and 4 explain the empirical methodology and report the findings of the cross-sectional survey conducted to empirically test the framework. Sections 5 and 6 discuss the research and managerial implications of the results.

2. Theoretical bases and conceptual framework

Some of the key issues related to the management of external technology integration are illustrated by the following examples. In the first example, a firm accomplished a modification of its electronic data interchange software. This software was sourced from an external vendor, and the firm was able to make the modification and installation into the broader information technology system successfully with very little interaction with the software supplier. The recipient firm understood the software very well and needed little information about how to implement it. In a second example, a manufacturing firm decided to replace a set of manually controlled general purpose machines in one segment of its production line with a flexible manufacturing system (FMS) purchased from an external supplier. In this case the recipient firm had never used an FMS and had little information about how to implement and operate the system. The integration of the FMS was ultimately successful, but took far longer than originally expected and at greater cost than originally targeted and budgeted. The firm neglected interacting with the vendor in a substantial way, and did not learn early enough about the technology and its integration requirements. There is a high likelihood that the firm would have enjoyed greater success had it had more substantial interaction with the vendor.

In these two examples, the structure and management of the interorganizational relationship between the recipient and the source of the technology play an important role in the success or failure of the implementation of the technology within the recipient firm's operational process. In addition, each example can be characterized as a project. There is an episodic nature to ETI processes, and each ETI process instance is unique. This is analogous to the episodic nature of product development processes and projects.

We now employ a well-established organizational theory to understand the key interorganizational factors that affect the success or failure of the external technology integration process. This theory, organizational information processing theory (OIPT), has a long history in general management research, but its use specifically in operations management research has been limited. We provide a brief overview of this organizational theory and then apply it to the specific context of external technology integration projects. The conceptual framework of ETI project effectiveness is developed below, along with four hypotheses following from the framework.

2.1. Organizational information processing theory

Information processing is the purposeful generation, aggregation, transformation and dissemination of information associated with accomplishing some organizational task (Robey and Sales, 1994). Here, the task of interest is external technology integration. Although specific sub-tasks, information sources, and information transformation requirements may differ among ETI situations, all ETI projects involve some information processing. Accordingly, it is useful to view external technology integration from the perspective of organizational information processing theory (OIPT). This theory underlies the conceptual framework of external technology integration. OIPT explains that organizational tasks present information processing requirements to the organization. Various organizational forms and managerial approaches provide information processing capacity. The degree to which requirements and capacity are appropriately matched determines the quality of task outcomes (Galbraith, 1977; Tushman and Nadler, 1978). When information processing capacity is less than what is necessary to perform the task, performance standards will not be met, the task will not be completed on time, and/or the task will be completed at a higher than desired cost. On the other hand, when the organization employs an approach that provides more information processing capacity than is required, the task will be accomplished in an inefficient manner.[2]

Organizational tasks vary in the degree to which the means to accomplish them are known. Task uncertainty is "the difference between the amount of information required to perform the task and the amount of information already possessed by the organization" (Galbraith, 1977, p. 36). In addition to the quantity of information that must be processed, the quality (or richness) of the information is also important (Daft and Lengel, 1986). In particular, characteristics of the task cause or contribute to task uncertainty. Further, task uncertainty is organization-specific: a task that is certain to one organization may be uncertain to another (Galbraith, 1977; Robey and Sales, 1994).

Organizations use various approaches to process information in performing a task. Galbraith (1977, p. 39) explains that "variations in organizing modes are actually variations in the capacity of organizations to process information and make decisions about events which cannot be anticipated in advance.". "Mechanistic" organizations, at one extreme, and "organic" organizations, at the other, span the overall spectrum of information processing capacity (Burns and Stalker, 1961). Mechanistic organizations provide lower levels of information processing, while organic organizations provide higher levels of information processing.

2.2. Organizational theory applied to external technology integration

The task in ETI is the integration of technology acquired from an external source into an operational process within the recipient firm. Once the decision is made that a technology must be acquired from an external source, there are several steps that must be accomplished to complete the ETI process. The source of the technology must be identified and there must be agreement to acquire the technology from that source; the technology must be transferred from the source organization to the recipient; the technology must then be installed and incorporated into the specified process in the recipient organization.

[2] Organizational information processing theory has been applied extensively in prior literature, in settings such as enterprise resource implementation (Gattiker and Goodhue, 2005), strategy-information technology alignment (Fairbank et al., 2006), deployment of information technology in global firms (Jarvenpaa and Ives, 1993), and interorganizational supply chain relationships (Premkumar et al., 2005).

External technology integration instances are projects. Traditional tactical performance dimensions for a project include time, cost, and technical performance (Gerwin and Barrowman, 2002; Swink et al., 2006; Tatikonda, 2007). Applied to the ETI context, these dimensions result in three specific elements of ETI project effectiveness: the functional operation of the technology in the target operational process (analogous to technical performance), ETI project costs (budget expenditures), and the extent to which the ETI project meets schedule objectives.

Two essential dimensions influence ETI performance (see Fig. 2). The first dimension is technology uncertainty. In this paper, for the specific context of ETI, the general OIPT concept of task uncertainty corresponds to *technology uncertainty*. OIPT describes task uncertainty as the lack of information about how to perform the task. Therefore, technology uncertainty in ETI is defined to be the lack of information needed to obtain and implement the technology to be integrated. More precisely, technology uncertainty is the difference between: (1) the information needed by the recipient organization to obtain and implement the technology, and (2) the information the recipient actually has at the start of the ETI process.

The second dimension is *interorganizational interaction*, which corresponds to the general OIPT concept of organizing mode. Interorganizational interaction characterizes the interorganizational relationship between the source and recipient of the technology in an ETI project. Walton (1966) identified three essential ''components of the relationship'' between organizations: (a) exchange of information in the joint decision process, (b) structure of inter-unit interactions and decision-making, and (c) attitudes towards the other unit. These three components contribute to information processing capacity, and we refer to them as communication, coordination, and cooperation in the context of ETI. Higher levels of communication, cooperation, and coordination reflect higher levels of interorganizational interaction.

2.3. The fit between technology uncertainty and interorganizational interaction

The application of information processing theory to the context of ETI leads to the primary hypothesis of the conceptual framework. Information processing *requirements* result from technology uncertainty, and information processing *capacity* results from the form of interorganizational interaction. The greater the technology uncertainty, the greater the information processing requirements. And, the greater the interorganizational integration, the greater the information processing capacity. The level of interorganizational interaction between the source and recipient should be appropriately fit to the level of technology uncertainty posed by the technology that is to be integrated. This leads to a better match of information processing requirements and capacity. This more appropriate fit between technology uncertainty and interorganizational interaction in turn leads to more effective ETI.

A fit between technology uncertainty and interorganizational interaction occurs when the levels of technology uncertainty and interorganizational interaction in an ETI project are relatively the same. In other words, if there were relatively high levels of both interorganizational interaction and technology uncertainty, we would expect that performance would be

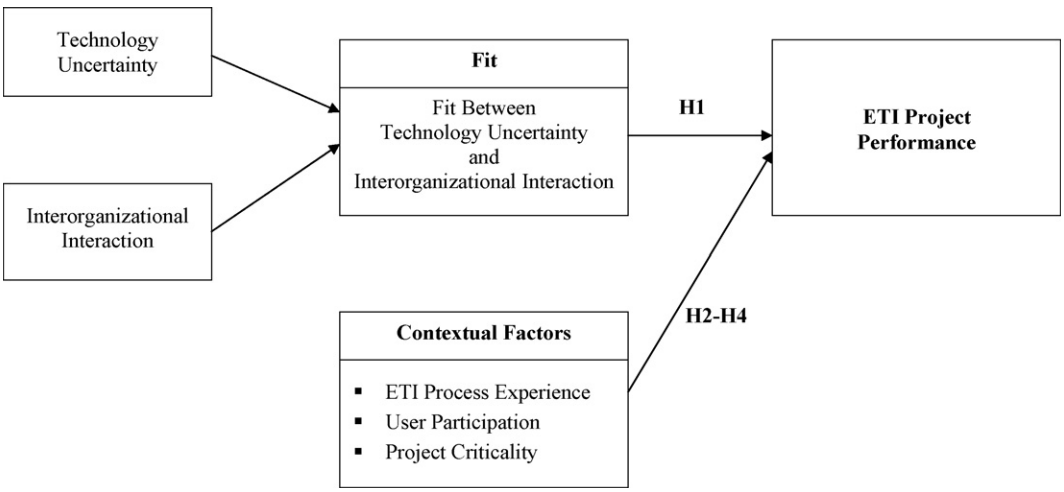

Fig. 2. Conceptual framework of external technology integration project performance.

higher than if there were a high level of technology uncertainty and a low level of interorganizational interaction. We would also expect that performance would be higher if there are low levels of both interorganizational interaction and technology uncertainty than if there were a low level of technology uncertainty and a high level of interorganizational interaction. The primary hypothesis follows:

H1. There is greater overall ETI project performance when there is a fit between technology uncertainty and interorganizational interaction.

2.4. Contextual factors influencing ETI performance

Above we discussed how the fit between technology uncertainty and interorganizational interaction influences overall ETI project performance. Other essential factors relating to the ETI project context might also influence the effectiveness of the integration of the technology. Here we address three key factors: ETI process experience, user participation and project criticality. We include these variables as important predictors and to allow additional rigorous assessment of the robustness of the fit hypothesis (H1) results.

2.4.1. ETI process experience

The recipient firm's experience with prior ETI projects is expected to influence the effectiveness of the ETI process. This factor specifically considers the recipient organization's experience with the *process* of ETI, which is independent of its experience with the *technology* to be integrated from the source. The concept of the learning curve applies. Initial conceptions of the learning curve focused primarily on how unit production costs decline with accumulated production experience. More recent research examines the organizational and managerial principles leading to the learning curve effect and considers outcomes other than production costs (Lapré and Van Wassenhove, 2001; Argote et al., 2003). Learning curve principles would suggest that a firm with greater experience would be more effective in managing tasks in general. We therefore expect that a recipient firm with more experience in conducting the ETI process would be more effective in managing the latest instance of the process of integrating a technology acquired from an external source. The second hypothesis follows:

H2. Greater ETI process experience is positively related to overall ETI project performance.

2.4.2. User participation

Given that ETI involves the eventual implementation of a technology that is acquired from an external source, factors related to technology implementation are relevant as well. Literature on advanced manufacturing technology (AMT) and information systems implementation addresses how a recipient firm may prepare for and ramp-up a new technology. One of the most common findings in this literature is that increased user participation in the process of technology implementation is associated with greater implementation success (Tait and Vessey, 1988; McDermott and Stock, 1999). Recent research has found that project teams in which the team leader encouraged a more participatory role (by the team members involved in the implementation) experienced more effective implementation.

User participation is an essential factor in the conceptual framework for several reasons. First, as noted above, this factor has been shown to be especially important to the success of technology implementations in general. Second, to our knowledge, user participation in the ETI interorganizational process has not been specifically studied before. Third, although ETI is an *interorganizational* (dyadic) process, there are *internal* (single-firm) factors (such as user participation) that may influence the success of this interorganizational process. The third hypothesis follows:

H3. Greater user participation in the ETI process is positively related to overall ETI project performance.

2.4.3. Project criticality

Factors relating to the management or execution of the project are also relevant. A key lesson from the project management literature is that more critical projects and tasks merit greater management attention. Bowers (1995) conceptualizes criticality to be whether an activity is on the critical path. However, his analysis also recognizes that in a resource constrained project, there are generally "near-critical" paths, which suggests that criticality for a project activity is not an "all or nothing" characteristic and therefore may be characterized as a continuum of lower to higher values. In practice, a project or task having a higher criticality is likely to receive more management attention and resources. Greater attention and resources lead to the greater likelihood of successful completion of the activity (Dodin and Elmaghraby, 1985; Bowers, 1995; Tatikonda and Rosenthal, 2000a). The fourth hypothesis follows:

H4. Higher ETI project criticality is positively related to overall ETI project performance.

3. Methods

Overview. The four hypotheses of the conceptual framework were tested via a large-sample ($n = 91$) cross-sectional methodology employing a survey instrument completed by ETI project managers. The unit of observation is an ETI project, and the informants responded about their most recently completed ETI project. The data were collected in 2003. This section addresses: respondent qualifications and characteristics; respondent access and sampling procedure; survey validation and pre-test; variable operationalizations; and scale reliabilities.

3.1. Sample

3.1.1. Respondents

Survey respondents were required to be managers of recently completed external technology integration projects. These qualification stipulations were made to assure: that all phases of the ETI project had occurred (which then allows assessment of a variety of relevant project aspects, including end-of-project performance); that the respondent's memory of the project was fresh; and that the respondent had a substantive, overall, managerial understanding of the project. The single respondent method was employed. Harman's one-factor test shows no evidence of common method bias (Podsakoff and Organ, 1986). Table 1 summarizes the characteristics of the respondents, including job position, functional representation, and industry representation of the respondent's firm. Chi-square tests of *respondent position* and *respondent function* show there is no statistically significant bias in the respondents' organizational positions or functions.

3.1.2. Respondent access

Potential respondents were contacted by company co-workers who were MBA students enrolled in a Midwestern business school. The students were provided a cover letter containing instructions for questionnaire distribution and completion. The students received no

Table 1
Respondent characteristics and technology categories

Respondent position	Frequency	Percentage
Middle management (e.g., operations manager, IS manager, department manager)	35	38.46
Top management (e.g., president, CIO, vice-president, director of operations)	24	26.37
Other professional (e.g., consultant, engineer, analyst)	32	35.17
Respondent function		
Operations/engineering (e.g., operations, engineering, R&D, transportation)	25	27.47
Information systems (e.g., information technology, MIS, information systems)	29	31.87
Other (e.g., finance, accounting, marketing, sales, human resources)	37	40.66
Respondent industry		
Manufacturing	28	30.77
Financial services, industry, banking	15	16.48
Information technology, telecommunications	15	16.48
Consulting, market research	15	16.48
Healthcare	6	6.59
Education	4	4.40
Government	3	3.30
Other services	5	5.50
Technology category		
Operations software (e.g., MRP)	17	19
Operations hardware (e.g., CNC machining center, barcode reader)	10	11
All operational technology	27	30
Non-operations function-specific software (e.g., financial, human resources)	19	21
Database software	7	8
Office software (e.g., operating system, email, document management)	15	16
Miscellaneous other technology (e.g., facility access software, planning software, mapping software)	10	11
Communications software (e.g., Internet, telecommunications)	10	11
Other information systems hardware (e.g., PC server)	3	3
All non-operational technology	64	70

description of the study's goals beyond that provided in the cover letter, nor were they provided with hypotheses or any other information about the study that would bias the manner in which questionnaires were distributed or respondents were approached. They were instructed not to complete the questionnaire themselves, but to distribute the questionnaires to managers who were involved in ETI projects in their firms.

3.1.3. Sample size, response rate and generalizability

Ninety-five surveys were returned. Four surveys addressed very complex and substantial system-level technologies (e.g., ERP systems), and were excluded from the analysis sample because their inclusion could potentially skew the analysis results given the unusual nature of these particular technologies. The resulting samples used for the analysis included 91 ETI projects. A proxy for a response rate can be estimated by computing the overall participation rate of the students in this activity. Seventy-two of 92 students participated, for a proxy rate of 78%. In addition, in a subset of 41 of the completed questionnaires, the students who collected them were asked to indicate how many managers they actually approached to complete the questionnaire. Forty-six managers were approached, for a second proxy response rate of 89% in this subset of the data. There are constraints on the generalizability of the sample because it is not a true random sample. A convenience sample approach was employed, and is consistent with sampling methods taken in prior studies of technology projects where MBA and executive MBA students were either survey respondents themselves or a means of obtaining respondent access (e.g., Tushman et al., 2002).

3.1.4. Technology categories

Respondents described the technology that was the subject of the ETI project. Table 1 summarizes the technologies in the sample by category type. To test whether the technology categories influence the statistical analysis results, we aggregated technologies into operational and non-operational categories and constructed a dummy variable corresponding to these aggregated categories. This dummy variable was included in the regression models described in Section 4.

3.2. Survey instrument

3.2.1. Instrument development

The survey instrument addressed factors relating to the ETI project context. We adapted existing survey scales to this context, and also developed two new scales due to lack of existing scales for the phenomena of interest. Such scale development is often necessary in more nascent research areas (Spector, 1992). The new scales were developed based on the theoretical constructs and on literature presented in Section 2, and were further informed by earlier field research conducted by the authors. Survey instrument pretesting included careful review of the compiled scale items by three industry managers (experienced in managing ETI projects) and three academics (experienced in survey instrument design and analysis). Questionnaire items were examined for scale content, face validity and clarity. Potentially unclear or ambiguous items were revised. Variable operationalization items were five-point Likert-type scales.

3.2.2. Independent variable measures

The technology uncertainty (TU) scale contained items asking the respondent to indicate the extent to which the recipient firm: understood the technology; had enough information about the technology; and had a good understanding of how to incorporate the technology into its intended application. This scale is an adaptation of Tatikonda and Rosenthal's (2000b) technology novelty scale to the ETI project context.

The interorganizational interaction (IOI) scale contained items measuring communication, coordination and cooperation between the source and recipient firms. In Section 2 we identified communication, coordination and cooperation as the central elements of interorganizational interaction that provide information processing capacity in the ETI project context. This is a newly developed scale for the ETI project context.

The ETI process experience (EXPER) scale consisted of a single item measuring the firm's experience with ETI projects (that is, projects where technology was acquired from another firm). ETI process experience relates to experience with the *process* of ETI rather than experience with the particular *technology* to be integrated. The scale wording was carefully chosen (and evaluated in the pretests) to reflect this. We found no scale in the extant literature that captures the concept of ETI process experience, and so developed this new scale.

The user participation (USERPART) scale contained items reflecting the participation of users in the specification of the technology's functions, in the selection of the technology, and in the process of implementation. This scale is a modification, to the ETI project context, of related scale items found in extant literature (Tait and Vessey, 1988; McDermott and Stock, 1999).

The project criticality (CRITICAL) scale consisted of a single-item measuring the relative criticality of that project. This scale is an adaptation, to the ETI project context, of a scale used in the product development context (Tatikonda and Montoya-Weiss, 2001). In addition, it is consistent with the notion of criticality developed in analytical modeling of resource constrained project networks (Bowers, 1995).

3.2.3. Dependent variable measures

The primary dependent variable measure is OVERALL, the respondents' assessment of the overall ETI project success. As noted in Section 2.2, ETI project performance can also be assessed on the specific dimensions of time, cost, and technical performance. These specific dependent variables are captured in the ETI project context as: meeting project budget objectives (BUDGET), meeting project schedule objectives (SCHED), and the extent to which the technology functioned in its intended application (FUNC).

Certain specific dimensions may have higher priority than other dimensions. For example, some projects emphasize rapid project completion over project cost. Other projects emphasize cost-control, with time-achievement as a flexible, lower priority. As such, each ETI project has a unique profile of performance dimension priorities. The OVERALL measure allows the respondent to implicitly weight these different performance dimensions in the manner most appropriate for that particular project. That is why OVERALL is the dependent variable for the conceptual framework hypotheses. In addition, in Section 4.4, we conduct supplementary exploratory analyses at the level of the specific dimensions (BUDGET, SCHED and FUNC).

3.2.4. Principal components analysis and variable-item composition

A principle components analysis of the items measuring technology uncertainty, interorganizational interaction, user participation was conducted, yielding three components (per the Kaiser (1960) criterion of retaining components whose eigenvalues are greater than one). See Table 2 for the components and loadings.

Table 2
Principal components analysis (varimax rotation) and variable definitions (significant loadings shown in bold)

Variable name	Questionnaire item	Component			
		1	2	3	Cronbach's α
Interorganizational Interaction (IOI)	Effective communication with source	**0.778**	−0.013	−0.210	0.80
	High degree of coordination with source	**0.823**	0.109	0.045	
	Cooperative relationship with source	**0.859**	0.026	−0.081	
User participation (USERPART)	Users participated in the specification of the technology	−0.004	**0.850**	0.040	0.79
	Users participated in the implementation of the technology	−0.033	**0.819**	−0.064	
	Users participated in the selection of the technology	0.173	**0.842**	−0.087	
Technological uncertainty (TU)	This technology was well understood[a]	−0.121	−0.002	**0.792**	0.76
	Had enough information about this technology[a]	−0.197	−0.083	**0.858**	
	Understanding of how to incorporate this technology[a]	0.062	−0.028	**0.789**	
	Percent variance explained	24.4	23.6	22.8	
	Cumulative percent variance explained	24.4	48.0	70.8	
ETI project experience (EXPER)	Project team's experience with ETI projects				Single item
Project criticality (CRITICAL)	ETI project is on the overall project critical path				Single item
Overall project success (OVERALL)	Overall, the ETI project was successful				Single item
Project schedule performance (SCHED)	Project met schedule objectives				Single item
Project budget performance (BUDGET)	Project completed within planned budget				Single item
Project functional performance (FUNC)	Technology functioned properly				Single item
Firm size (FIRMSIZE)	Log_{10}(number of employees)				Single item
Technology type (TECHTYPE)	1 if operational technology; 0 if non-operational technology				Single item

[a] Reverse scored item.

Table 3
Means, standard deviations and correlations

		Mean	S.D.	1	2	3	4	5	6	7	8	9	10
1.	FIRMSIZE	3.18	1.27	1.00									
2.	TU	2.82	0.91	0.21	1.00								
3.	IOI	3.56	0.84	−0.04	−0.20	1.00							
4.	EXPER	3.16	0.95	−0.14	−0.35**	0.11	1.00						
5.	USERPART	3.14	1.08	0.00	−0.09	0.11	−0.03	1.00					
6.	CRITICAL	3.99	0.90	−0.04	0.12	−0.06	0.04	0.08	1.00				
7.	OVERALL	3.87	0.92	−0.14	−0.31**	0.36**	0.10	0.28**	0.27*	1.00			
8.	BUDGET	3.42	1.31	0.01	−0.22*	0.33**	0.32**	0.10	0.38**	0.46**	1.00		
9.	SCHED	3.30	1.31	−0.14	−0.29**	0.30**	0.10	0.25*	0.21*	0.69**	0.51**	1.00	
10.	FUNC	3.63	1.08	−0.09	−0.41**	0.38**	0.20	0.15	0.19	0.72**	0.39**	0.62**	1.00

* Significant at 0.05 level.
** Significant at 0.01 level.

Three composite variables were constructed from these components per the method of Dunteman (1989), where the constituent items for each component are averaged.

Table 2 also summarizes each variable's definition, scale operationalizations and Cronbach's α. Table 3 provides descriptive statistics and correlations for the variables. All composite variables had Cronbach's α values exceeding 0.7, indicating an acceptable level of reliability (Nunnally, 1978). Hence, all multi-item variables are internally reliable and were retained for the subsequent regression analyses. Single item variables were used to measure the constructs of ETI process experience (EXPER) and project criticality (CRITICAL).

Prior literature suggests that organizational size can be related to technological innovation effects (Lee and Xia, 2006). To account for possible effects of firm size, we included a control variable, FIRMSIZE, which measures the number of employees in the recipient firm. A log transformation of this variable was taken (as is traditionally done to reduce potential problems with skewness and non-normality) (Kleinbaum et al., 1988). In addition, to control for possible effects of different types of technology, we included a dummy variable, TECHTYPE. This variable was defined to 1 for operational technologies (i.e., operations hardware such as a CNC machine tool and operations software such as a warehouse management information system) and 0 for non-operational technologies.

4. Results

4.1. Hierarchical regression methodology

Hierarchical regression analysis is used to test the hypotheses (Kutner et al., 2004). Hierarchical regression has significant prior usage in extant literature as a means to test both main effects and fit or interaction effects. The hierarchical approach used here first enters the control variable(s), then the theoretical variable(s) of interest, and then the term(s) associated with measurement of fit. For each successive model, a test is conducted to assess whether the added variables or terms contribute significantly to the variance explained over and above the previous model.

Centered (deviations from the mean) and standardized (mean = 0 and standard deviation = 1) variables were employed in the regression analyses. Centered variables are employed to mitigate any potential multicollinearity effects (Kleinbaum et al., 1988). Acceptable condition indices and variance inflation factors were found in all of the regressions, providing evidence that multicollinearity is not a problem. Standardized variables are employed to ensure that differences in scale among the variables did not affect the results and to increase interpretability of the regression terms.

The regression results are shown in Table 4. Regression Model O1 enters the control variables (Firm Size and Technology Category). Model O2 enters all the theoretical variables of interest (Technology Uncertainty, Interorganizational Interaction, ETI Process Experience, User Participation and Project Criticality). Models O3 and O4 enter the appropriate fit terms. As we explain in more detail below, the O3 model reflects the *fit as matching* approach, while the O4 regression model reflects the *fit as moderation* approach.

4.2. Effect of fit on ETI performance (H1)

H1 posits that greater *fit* between technology uncertainty and interorganizational interaction leads to greater overall ETI project success. To test this hypothesis it is necessary to assess the fit effects. Two

Table 4
Regression results: overall ETI project performance

	DV: OVERALL			
	O1	O2	O3	O4
TECHTYPE	−0.225 (0.230)	0.208 (0.208)	0.062 (0.094)	0.104 (0.204)
FIRMSIZE	−0.126 (0.106)	−0.054 (0.092)	−0.053 (0.090)	−0.081 (0.089)
TU		-0.247^{*} (0.098)	-0.347^{**} (0.105)	-0.226^{*} (0.095)
IOI		0.319^{***} (0.093)	0.389^{***} (0.096)	0.312^{***} (0.090)
EXPER		−0.013 (0.096)	−0.038 (0.094)	−0.059 (0.094)
USERPART		0.178^{+} (0.092)	0.181^{*} (0.090)	0.190^{*} (0.089)
CRITICAL		0.300^{**} (0.091)	0.337^{***} (0.090)	0.336^{***} (0.089)
MATCH			0.236^{*} (0.105)	
TU × IOI				0.272^{**} (0.100)
Overall F	1.36	6.07^{***}	6.20^{***}	6.63^{***}
Overall R^2	0.03	0.34	0.38	0.39
F for change	1.36	7.74^{***}	5.04^{*}	7.36^{**}
R^2 change	0.03	0.31	0.04	0.05

Standard errors are shown in parentheses next to coefficient estimates. $n = 91$. $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.10$. For models O3 and O4, the R^2 change is relative to model O2.

methods to assess the effects of fit are found in the literature. One method is the *fit as matching* approach and the other is the *fit as moderation* approach (Venkatraman, 1989; Hoffman et al., 1992; Carte and Russell, 2003). Both methods have been widely employed in empirical studies of fit, and the literature does not clearly favor one method over the other. We employ both methods to test H1 in order to provide the most rigorous confirmatory statistical tests possible. The results of these two methods are now described in detail in Sections 4.2.1 and 4.2.2 below.

4.2.1. Test of "Fit As Matching"

In the *fit as matching* approach, the last term entered into the regression is a variable titled "MATCH". This is shown in the O3 model. MATCH is a measure of fit, and is calculated as the absolute value of the deviation between the two hypothesized fit variables (TU and IOI). Lower values of the deviation score indicate that the two variables are "closer" and have greater fit. A statistically significant MATCH term indicates support for the fit hypothesis.

We now conduct the *fit as matching* approach and describe its results for H1. The variable titled "MATCH" is computed as follows: $\text{MATCH} = 4 - |\text{TU} - \text{IOI}|$.

The maximum possible value of the absolute deviation is 4 (because the variables TU and IOI both have a maximum value of 5 and a minimum value of 1). Therefore, when TU and IOI are equal, which indicates a perfect fit, the value of MATCH will be 4. When TU is 5 and IOI is 1, or when TU is 1 and IOI is 5, both cases indicating a very poor fit, the value of MATCH will be 0. The matching variable is defined and computed in this manner so that greater values of MATCH indicate better fit. The coefficient estimate for the MATCH term in regression model O3 of Table 4 is statistically significant ($p < 0.05$) and positive. This significant parameter estimate provides statistical support that better *fit* between technology uncertainty and interorganizational interaction is associated with higher overall ETI project performance. Thus, H1 is supported using the "fit as matching" approach.

4.2.2. Test of "Fit As Moderation"

In the *fit as moderation* approach, the last term entered into the regression is an interaction term (the cross-product between technology uncertainty and interorganizational interaction). The fit as moderation test is shown in the O4 model. A statistically significant interaction term would indicate that the two variables (TU and IOI) exhibit a fit, and that this fit influences a dependent variable (overall ETI project success). Further evaluation is necessary to determine the direction of the relationship between fit and the dependent variable.

We now conduct the *fit as moderation* approach and describe its results for H1. To assess the results of the fit as moderation approach, it is necessary to interpret the regression model containing the interaction term of interest. The interaction term must first be statistically significant. Model O4 in Table 4 shows that the interaction term is significant ($p < 0.01$). Then the direction of the effect of fit must be interpreted. This cannot be interpreted solely from the coefficient of the interaction term because the main effects (single variable terms) and interaction term must be interpreted collectively (Venkatraman, 1989; Hoffman et al., 1992). All three terms share the information in a two-way interaction, so all three terms must be considered together in interpreting the effects of the interaction. To do this, we now employ the multi-step general approach demonstrated by Hoffman et al. (1992). First, a reduced form of Model O4 is stated: OVERALL = 0.312IOI − 0.226TU + 0.272(TU × IOI).

Second, the equation is rewritten as: OVERALL = (0.312 + 0.272TU)IOI − 0.226TU. Because we are interested in the effects of the interaction between technology uncertainty and interorganizational interaction, this equation includes only the Model O4 coefficients for TU, IOI and the product term TU × IOI. IOI. The intercept term is zero because standardized variables were employed.

Third, we now substitute a low and a high value of TU into the equation. This results in two different equations, each of which expresses the dependent variable, OVERALL, as a function of IOI. We selected the low and high TU values to be the mean minus one and a half standard deviations and the mean plus one and half standard deviations. Because the variables are standardized, the low and high levels are −1.5 and + 1.5, respectively. The resulting equations are:

$$\text{Low TU}\,(\text{TU} = -1.5):\quad \text{OVERALL} = -0.096\text{IOI} + 0.339$$
$$\text{High TU}\,(\text{TU} = +1.5):\quad \text{OVERALL} = 0.720\text{IOI} - 0.339$$

The equations show that at a low level of technology uncertainty there is a negative relationship between interorganizational interaction and performance. The equations also show that at a high level of technology uncertainty, there is a positive relationship between interorganizational interaction and performance.

Fourth, we now substitute low and high values of IOI into each equation. These values are −1.5 and +1.5, respectively. Fig. 3 plots the two equations above using the low and high example values. This figure shows that there is higher overall performance in ETI projects when there is greater fit between technology uncertainty and interorganizational interaction. This can be seen by examining the endpoints of the two lines shown in Fig. 3. For a high level of interorganizational interaction (IOI = +1.5), there was a higher level of performance for the ‘‘high technology uncertainty’’ line (TU = +1.5) than for the ‘‘low uncertainty technology’’ line (TU = −1.5). For a low level of interorganizational interaction (IOI = −1.5), there was a higher level of performance for the low technology uncertainty line (TU = −1.5) than for the high technology uncertainty line (TU = +1.5). The results are robust across other high and low TU and IOI example values (Hoffman et al., 1992).

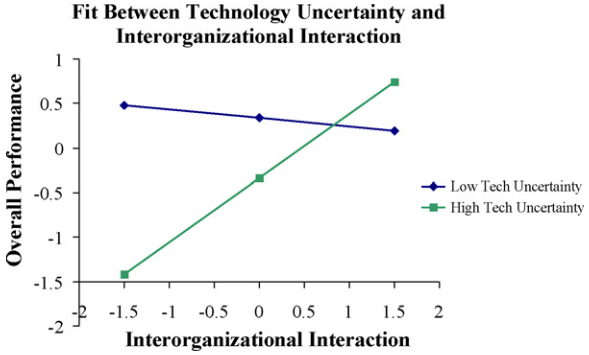

Fig. 3. Overall ETI project performance (OVERALL) as a function of interorganizational interaction (IOI) for low and high levels of technology uncertainty (TU).

The equations derived from the O4 regression model and the graphical representation in Fig. 3 provide support that better fit between technology uncertainty and interorganizational interaction is associated with higher overall ETI project performance. Thus, the results show that H1 is supported using the ‘‘fit as moderation’’ approach.

To summarize, H1 was evaluated using two methods to assess the significance of fit and the relationship between fit and project performance. This multi-method evaluation provides a rigorous assessment of the hypothesis. The results indicate that H1 was supported using both the fit as moderation and the fit as matching approaches. Below we now consider the influence of non-fit factors (contextual factors) on ETI project performance.

4.3. *Effects of contextual factors on ETI performance (H2–H4)*

To test H2–H4, we now examine the coefficients of the corresponding variable terms in the O3 and O4 regression models (see Table 4). H2 suggests that greater experience with the ETI process will result in better overall project performance. The coefficient for EXPER was not significant in either regression model O3 or O4, so H2 is not supported. H3 asserts that greater user participation in the ETI process results in higher levels of overall ETI project performance. The coefficient for USERPART was positive and statistically significant ($p < 0.05$) in both the O3 and O4 regression models, indicating that H3 is supported. H4 posits that higher levels of overall ETI performance arise when the ETI project has a higher criticality. The coefficient for CRITICAL was positive and statistically significant ($p < 0.001$) in both the O3 and O4 regression models, indicating that H4 is supported.

4.4. Additional analyses: individual dimensions of ETI project performance

Above we presented the results of the four hypotheses. These hypotheses were expressed and purposefully tested in a confirmatory manner. Further, all four hypotheses employed "Overall ETI Project Performance" as the dependent variable. Now we go a bit further, in an exploratory spirit, by conducting additional analyses to gain deeper insights into the specific dimensions of ETI project performance (namely, schedule, budget and functionality).

We explained earlier that each ETI project can have different priorities among the specific project performance dimensions of schedule, budget and functionality. Each project has a unique profile of the relative importance of each of these objectives. As such, focusing on a single performance dimension does not allow a sense of the relative priorities and what contributes to overall project success for that particular project. The overall project outcome is inherently composite, since the respondent implicitly considered the trade-offs across budget, schedule, and functional objectives in assessing the overall ETI project success. Hence, single dimension analysis conducted in isolation can be myopic. Indeed, for this reason the conceptual framework did not state hypotheses at the level of individual performance dimensions.

However, specific insights can be gained by looking at how the various conceptual framework variables are related to each of the specific individual dimensions of ETI project performance, especially if they are considered in the context of other, potentially competing, individual project performance dimensions and the overall project performance. We think of the overall ETI project performance as an "aggregate" indication of performance. We refer to the more specific, detailed performance dimensions as "individual" performance dimensions. In this section, we consider these relationships for specific performance dimensions (budget, schedule and functionality) in detail.

To explore the individual performance dimensions, we assess the regressions presented in Table 5. This table presents three sets of hierarchical regression models, each of which employs one of the individual performance dimensions as the dependent variable. As in the models of Table 4, the control variables FIRMSIZE and TECHTYPE are entered first, followed by the theoretical variables of interest, followed by the "fit" variable (respectively, the MATCH or TU × IOI term, in the third and fourth regression models of each regression set).

The B3 and B4 regression models in Table 5 show that the terms for ETI process experience, project criticality and fit are significantly, positively associated

Table 5
Regression results: individual ETI project performance dimensions

	DV: BUDGET				DV: SCHED				DV: FUNC			
	B1	B2	B3	B4	S1	S2	S3	S4	F1	F2	F3	F4
TECHTYPE	−0.173	0.007	−0.023	−0.069	−0.041	−0.093	−0.058	−0.143	−0.069	−0.043	−0.050	−0.129
FIRMSIZE	−0.004	0.084	0.085	0.065	−0.147	−0.085	−0.084	−0.098	−0.090	0.012	0.013	−0.011
TU		−0.155	-0.234^{*}	−0.139		-0.241^{*}	-0.285^{*}	−0.231		-0.365^{***}	-0.455^{***}	-0.347^{***}
IOI		0.293^{**}	0.348^{***}	0.288		0.242^{*}	0.273^{*}	0.239		0.308^{**}	0.370^{***}	0.302^{**}
EXPER		0.253^{**}	0.233^{*}	0.220		−0.026	−0.037	−0.048		0.055	0.032	0.017
USERPART		0.015	0.018	0.024		0.193^{+}	0.195^{+}	0.199		0.068	0.071	0.078
CRITICAL		0.441^{***}	0.471^{***}	0.468		0.232^{*}	0.248^{*}	0.249		0.251^{**}	0.285^{**}	0.281^{**}
MATCH			0.187^{+}				0.105				0.213^{*}	
TU × IOI				0.199^{*}				0.130				0.227^{*}
Overall *F*	0.28	7.13^{***}	6.82^{***}	6.97^{***}	0.95	3.96^{***}	3.56^{**}	3.65^{**}	0.37	6.01^{***}	5.96^{***}	6.13^{***}
Overall R^2	0.01	0.38	0.40	0.40	0.02	0.25	0.25	0.26	0.01	0.34	0.37	0.37
F for change	0.28	9.81^{***}	3.27^{+}	4.03^{*}	0.95	5.07^{***}	0.83	1.38	0.37	8.21^{***}	4.04^{*}	4.95^{*}
R^2 change	0.01	0.37	0.02	0.02	0.02	0.23	0.00	0.01	0.01	0.33	0.03	0.03

$n = 91$. $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.10$. For models B3 and B4, the R^2 change is relative to model B2. For models S3 and S4, the R^2 change is relative to model S2. For models F3 and F4, the R^2 change is relative to model F2.

Table 6
Summary of analysis of individual performance dimensions

	Independent variable			
	TU–IOI fit	ETI process experience	User participation	Project criticality
Performance dimension				
Budget	+	+		+
Schedule			+	+
Functionality	+			+

"+" indicates statistically significant, positive, regression coefficient in regressions of Table 5. A blank cell indicates no statistically significant regression coefficient in regressions of Table 5.

with budget performance. The S3 and S4 regression models in Table 5 show that the terms for user participation and project criticality are significantly, positively associated with schedule performance. Finally, the F3 and F4 regressions in Table 5 show that project criticality and fit are significantly and positively associated with functionality performance.[3] No statistically significant, negative associations were found between the individual performance dimensions and ETI process experience, user participation, project criticality or fit. In all, interesting patterns arise across the three individual performance dimensions. These are summarized in Table 6, and are discussed in Section 5.

5. Discussion

5.1. The importance of fit in interorganizational processes

The fundamental empirical finding is that the theoretical notion of fit of technology uncertainty and interorganizational interaction is supported in the ETI context. This finding is a very important one because fit is a significant predictor of ETI project success. The results show that a recipient firm should manage the relationship with the technology source in a manner that best matches the recipient's understanding of the technology. This theory-based empirical finding is supported by a multi-method testing approach (via the "fit as matching" and "fit as moderation" statistical techniques), which gives even greater confidence in the finding. Further, the fit finding is robust across the contextual factors. If user participation, ETI process experience and project criticality are treated as control factors, then it is clear that the fit results hold across different levels of those factors. Finally, the fit finding sets a foundation for further research generally on multi-organization aspects of technology integration, a practical operations management concern that to date has seen little large-sample empirical research.

5.2. Contextual factors

A contribution of this study is the empirical investigation of both interorganizational (dyadic) and internal (single-firm) factors. Here we address single-firm factors that provide a context for the execution of an ETI project. The results of the hypotheses positing a positive relationship between user participation and overall project success (H3) and a positive relationship between project criticality and overall project success (H4) are not surprising. User participation has been shown in many other technology project contexts to be an important contributor to implementation success. This is, to our knowledge, the first time this factor has been studied in the interorganizational case of ETI.

Clearly project criticality matters. While that is commonly accepted in other technology project fields, such as new product development, it has not been studied or shown in the ETI context. And it raises further questions about how a firm determines whether a project should be considered critical and how exactly criticality translates into day-to-day opportunities and resources for the project. What may be heartening for those managing a project that is not considered critical is that there are other factors that still contribute to project success, factors that the managers can influence (fit and user participation).

The non-significant relationship between ETI process experience and overall project success (H2) was surprising. We provide two speculations as to why the non-significant finding arose. First, the general notion of learning is that knowledge from a prior task can be applied to a later task. There must be some similarity between the tasks for learning to exhibit itself and thus have value. Perhaps each instance of ETI is so unique that the learning effect does not come to fruition.

[3] Using the approach described in Section 4.2.2 for fit as moderation, we find the same general direction of fit relationships as we did with OVERALL in Section 4.2.2 (although of course the specific slope values differ).

Frankly, we are not persuaded by this speculation because we have observed in the field that there are similar aspects across different ETI projects. Still, this speculation merits further structured study. Second, perhaps ETI process experience leads to greater success indirectly rather than directly. This could happen if greater ETI process experience leads a project team to be better able to assess the uncertainty of a technology. Better assessments would lead to better fit choices and in turn better project outcomes. However, the scope of this study did not allow assessment of the accuracy of technology uncertainty assessments and their mediating relationships with project success.

5.3. Individual performance dimensions

Section 4.4 explained that the individual project performance dimensions (relating to budget, schedule and functionality) do not necessarily move in the same direction. This can occur because there are trade-offs among the priorities (e.g., an emphasis on faster completion might come at the detriment of the cost target). The scope of our study did not allow detailed evaluation of trade-offs, but does allow exploratory analysis of relationships among the conceptual framework factors and individual performance outcomes (see Table 6 for a summary of the results).

Table 6 shows that project criticality is a very influential factor. Its positive association with all project performance dimensions is striking, and this merits future research. Table 6 also suggests that each performance dimension has at least one managerial ‘‘lever’’ that influences it. For example, the results suggest that in order to better achieve budget targets, it would be helpful to have more ETI process experience in place. And to achieve greater schedule performance, it would be better to have more user participation in the ETI project. Finally, to achieve greater functional performance, it would be better to have a higher project criticality.

The fit factor appears to be a managerial lever for both budget and functionality, but not schedule. This is a surprising result. We speculate that for this sample that schedule achievement may have been consistently of lower priority. That is, in this sample, relatively poor schedule achievement may have been traded-off for greater budget and functionality achievement.

5.4. Study limitations and future research directions

The fit hypothesis involved three core variables, each of which merits further scrutiny in continuing research. First, accurate assessment of the technology uncertainty will aid in better achievement of appropriate fit. Future research should investigate the technology uncertainty assessment process, identify contributors to inaccurate assessments, and develop tools or protocols for more accurate technology uncertainty determinations. Second, knowing what level of interorganizational interaction to implement is helpful, but is not the end-all if the firm does not have the ability to implement that level of interorganizational interaction. Future research should evaluate how firms may assess their interorganizational interaction abilities, grow and disseminate greater abilities, and assure proper execution of these interorganizational processes. Also meriting study is how exactly firms go about assessing and making fit. Third, how do firms go about setting realistic project targets for budget, schedule and functionality? This study investigated ETI project execution. Future research can study the planning phase of ETI projects where project targets and priorities are set, the technologies are chosen, and fit assessments are made.

The performance measures in this study are traditional tactically oriented project objectives. There are other dimensions of project performance such as learning, user satisfaction with the technology, and strategic competitive advantage gained from integration of the technology. Future research employing these additional dimensions would allow a more nuanced view of ETI performance. Some project outcomes are not seen or known at the immediate completion of a project. For example, as we discuss in the implications for practice, no project is a complete failure if there was some learning opportunity gained (e.g., about the technology, the source firm or the interorganizational process). In particular, the tactical project outcome of cost provides only a partial window on the total system costs and lost opportunities resulting from poor fit and other factors. Future research should employ more sophisticated measures of cost to obtain determination of true inefficiencies.

The research methodology employed presents some limitations. The sample size of 91 respondents is not as large as might be desired to provide maximal statistical confirmation. A convenience sampling approach (leading to a non-random sample) was employed, in turn possibly constraining the generalizability of the findings. Future replication studies should employ larger and randomly generated samples to overcome these limitations. Future research can also overcome other limitations of this study by employing multi-item dependent variables (rather than an array of single-item dependent variables) to provide even greater confidence in measurement reliability, and through a multiple-respondent approach (for each ETI observation) to overcome any potential common method bias and provide greater confidence in data validity. Finally, this study investigated single projects with no consideration of long-term relational context. We recommend that future research investigate a longer-term or serial relationship between a recipient and a single source firm. This ''relational embeddedness'' may influence factors in execution of single ETI projects.

6. Implications for practice

The fundamental managerial implication is that ETI projects are more effective if there is a fit, alignment or congruence between technology uncertainty and interorganizational interaction. A combination of high technology uncertainty and high interorganizational interaction tends to result in greater performance than a combination of high technology uncertainty and low interorganizational interaction. Similarly, a combination of low technology uncertainty/low interorganizational interaction tends to result in greater performance than a combination of low technology uncertainty/high interorganizational interaction.

The combination of high technology uncertainty/low interorganizational interaction is particularly problematic and will likely result in an ineffective ETI project due to insufficient application of interorganizational interaction resources. Such a combination may result from the recipient's inaccurate assessment of the technology uncertainty, in turn leading the recipient to put in place an inadequate level of interorganizational interaction. This combination might also result when the level of interorganizational interaction that actually occurs during the ETI project is not as high as it was intended to be. Here, ineffective management of the relationship would result in an unsuccessful outcome even if the technology has been accurately assessed and the appropriate combination of technology uncertainty and interorganizational interaction has been specified. Careful attention to continuing management of the relationship is therefore just as important to the project outcomes as defining the proper structure of the relationship initially.

The combination of low technology uncertainty/high interorganizational interaction, although also a mis-fit, is likely to have less serious repercussions. From a theoretical perspective, this combination incurs excessive organizational costs. From Fig. 3, it is apparent that the penalty in overall performance for the high technology uncertainty/low interorganizational interaction combination is much greater than that for the low technology uncertainty/high interorganizational interaction combination. As such, when in doubt about fit, managers should err on the side of too much interorganizational interaction than too little.

Both technology uncertainty and interorganizational interaction are managerial decision variables. In the short term, the firm should seek to align the interorganizational interaction with the uncertainty represented by a chosen technology. But the technology, and the concomitant uncertainty it poses, are managerial choices as well. If a firm is aware that it does not have the wherewithal (due to lack of resources, interest or ability) to conduct a high level of interorganizational interaction, then it can purposefully choose to only integrate those technologies having low uncertainty. This is a strategic choice between developing and implementing organizational capability for interfirm interactions versus obtaining and integrating highly certain technologies. A firm that routinely integrates only highly certain technologies would likely not compete on innovation, but rather on other factors, such as low cost.

7. Conclusions

The traditional emphasis of business teaching and research has been on the management of the internal organization and its processes. But the emergence of supply chain management and other newer perspectives that focus on interorganizational processes has resulted in fundamental changes in the way business management is viewed. For some firms in dynamic markets, the ability to manage interorganizational processes is their distinctive competitive competence. And firms are increasingly employing external sources for technology.

This study has highlighted the importance of interorganizational factors in implementing new process technology. The results of this study show that ''fit'' is very important to external technology integration success: recipient firms should match or align their interorganizational interaction approach with the technology (and its concomitant uncertainty). This study also supports the importance of non-dyadic factors in external technology integration. Factors internal to the recipient firm, such as user participation in the technology integration process and the criticality of the technology integration instance, are notable correlates of success. A central lesson is that operations managers need to be cognizant of, and should purposefully manage, both internal and interorganizational factors in order to most effectively integrate new technologies into their operations processes.

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