INDUSTRY STUDIES ASSOCIATION

INDUSTRY STUDIES ASSOCATION

WORKING PAPER SERIES

Managing Outsourced Product Design:

The Effectiveness of Alternative Integration Mechanisms

By

Edward G. Anderson Jr.
McCombs School of Business
University of Texas at Austin
Austin, TX 78712

Alison Davis-Blake
Carlson School of Management
University of Minnesota
Minneapolis, MN 55455

Geoffrey G. Parker
Freeman School of Business
Tulane University
New Orleans, LA 70118

2007
Industry Studies Association
Working Papers

WP-2007-01
http://isapapers.pitt.edu/

Managing Outsourced Product Design:
The Effectiveness of Alternative Integration Mechanisms

Edward G. Anderson Jr.
McCombs School of Business
University of Texas at Austin
Austin, TX
Edward.Anderson@mccombs.utexas.edu

Alison Davis-Blake
Carlson School of Management
University of Minnesota
Minneapolis, MN
ADavis-Blake@csom.umn.edu

Geoffrey G. Parker
Tulane University
Freeman School of Business
New Orleans, LA
gparker@tulane.edu

29-March-2007

Over the past decade, firms as diverse as Applied Materials, Frito-Lay, IBM, 3M, General Electric, and General Motors have outsourced many of the activities they once performed in-house to networks of specialist suppliers. Having first learned to outsource production, these same firms are now learning how to outsource the design and development of their products, services, and processes. Although outsourcing these activities may reduce some costs such as component procurement, it also creates a new challenge: How can firms effectively create and subsequently coordinate their supplier networks in an environment characterized by rapid technological and market change and global competition?

The organizations, economics, and operations literatures contain numerous reasons why firms may subcontract portions of product, process, and other technical development work (hereafter, for ease of exposition, the term product development will be assumed to also embrace process and other technical development work) (see e.g. Williamson, 1975; Monteverde and Teece, 1982; Lieberman, 1991). Our interest lies in how lead firms manage the flow of technical and non-technical information necessary for successful product development across firm boundaries once outsourcing has been decided upon. This re-weaving together of outsourced components and processes into one coherent product is generally referred to as product integration, and it often decisively influences a product's eventual success (Iansiti 1995b; 2000). Although the problem of integration of different subsystems inside the firm has received substantial attention (see e.g., Lawrence and Lorsch, 1967; Galbraith, 1973) relatively less is known about the effectiveness of different mechanisms used to integrate complex information flows across firm boundaries.

One mechanism that has been used to integrate networks of outsourced suppliers involved in product and process development is the "keiretsu" model. In Japanese automobile firms, outsourcing much of a product's development became common during the 1970s using the keiretsu model, which is generally speaking a long-lived (40 years or more in many cases) alliance with mutual equity ownership (Cusumano & Takeishi, 1991; Gerlach, 1992; Wasti & Liker, 1999, Dyer and Nobeoka, 2000). But, in rapidly evolving markets, such as those described by Sturgeon (2002) in Silicon Valley, firms do not have the luxury of spending decades to develop effective supplier relationships and thus must rely on alternative integration mechanisms. The effectiveness of these alternative mechanisms is the subject of our research.

To describe supply chain integration theoretically, we extend Galbraith's (1973) analysis of how information is processed within an individual firm to how it is processed among a group of firms. A recent case study at Hewlett-Packard (Parker & Anderson, 2002) provides an initial framework with which to extend Galbraith's theory across firm boundaries and to particularize it into the realm of product design. Galbraith argued that the most basic intrafirm information processing mechanisms are (1) corporate rules and standard operating procedures (or organizational norms and practices), (2) referring problems to someone higher in the hierarchy, and (3) management by objective. Parker and Anderson's (2002) case study suggests that outsourcing may compromise these three basic information processing methods. For example, Hewlett-Packard's suppliers each typically have different rules and standard operating procedures, and there is no obvious common hierarchy to which to refer problems. The case also suggests that product development becomes more complex when firms are pushing technological barriers, making it difficult to set clear product development objectives.

Galbraith further suggests that a firm can supplement the first three information processing methods by either (1) accepting performance degradation, (2) creating modular tasks such as decomposing a system into more easily managed and outsourced subsystems or relying on industry standards (see e.g., Schilling, 2000), or (3) investing in lateral resources to glue the system back together. Lateral resources could include information systems, co-location of lead firm and supplier personnel, and dedicated individuals (hereafter referred to as supply chain integrators) whose sole task is integrating knowledge flows across the boundary between lead-firms and their suppliers. Performance degradation is obviously undesirable. Indeed, it appears that Hewlett-Packard invested in additional interfirm coordination mechanisms in order to improve their product design performance (on cost measures). More recently, Hewlett-Packard has increased its reliance on creating modular tasks, a staple of the PC industry for some time (Fine,1998) and has also invested heavily in lateral resources in the form of supply chain integrators. Hence, when it changed from a single vertical firm into the lead firm of a virtually organized, disaggregated supply chain, Hewlett-Packard needed to shift emphasis from vertical control mechanisms to horizontal ones. While the Hewlett-Packard case study provides evidence about one company's use of horizontal integration mechanisms across firms, very little is known either about the frequency with which these mechanisms are actually used or the relative effectiveness of various mechanisms.

Our research addresses three questions. (1) For those elements of product development that are outsourced, which interorganizational integration mechanisms and other project coordination tools are being employed to manage these barriers and how frequently are they used? (2) What is the impact of these mechanisms and tools on the success (e.g., project performance, cost, and execution time) of outsourced projects? (3) For those firms that employ dedicated supply chain integrators, are there particular skills and training that appear to increase the effectiveness of these personnel in integrating outsourced projects across firm boundaries?

Interestingly, the extant literature relevant to these issues is sparse. Although the literature on organizations has examined a variety of interorganizational relationships, most of these relationships are more formal and less transient than the kinds of activities examined here. With respect to managing the organizational boundary, Handfield et al. (1999) discuss the factors that go into choosing suppliers with whom to partner on product development activities. Mclvor and McHugh (2000) discuss the organizational changes that go into working with suppliers more closely. Das and Narasimhan (2000) study "purchasing competence" and establish a positive relationship to manufacturing performance. Along with Fine and Whitney (1996), they suggest that “the basis of competition in many industries in the future may revolve around the development of supply chain competence by organizations.” Further, Das and Narasimhan (2000) go on to emphasize the importance of purchasing integration. Nickerson and Zenger (2004) put forward an information processing theory of the firm. They argue that in solving problems, complexity determines the optimal organizational form to search for solutions. However, while these studies address integration broadly, they tend to focus on the selection of supply chain partners and the initial design of a supply chain network rather than the organizational mechanisms (including personnel and their skills) required to efficiently operate and exploit the network once it is in place.

Hence, we build specifically upon the exploratory research presented in Parker and Anderson (2002) and extend their qualitative case study of outsourcing and integration practices to a quantitative and qualitative analysis of multiple firms in multiple industries. Similar work within firms has previously born much fruit. For example, Iansiti (1995a; 1995b; 1998; 2000), specifically documented that those firms that invest heavily in a centralized technology integration capability substantially outperform those firms that allow integration to occur ad-hoc within research and development or manufacturing operations. Further, those firms that specifically address technology integration issues are most likely to survive during times of radical change in how a product is designed, which has been shown to cause most firms to fail (Henderson & Clark, 1990). However, whereas Iansiti and similar studies look primarily within firms, this work focuses on the interface between firm and supplier, and the sorts of mechanisms, such as supply chain integrators, that enable effective operation of a supply chain network.

Given the relatively sparse literature in this area and the early stage of the data collection reported here, we present a descriptive and exploratory analysis of the research questions rather than developing formal hypotheses.

DATA AND MEASURES

The research presented here is part of an ongoing project for which data are still being collected. Below, we briefly describe the overall data collection strategy and then discuss the data collected to date. The data presented here represent the first three years of data collection in a four-year data collection effort. The data is being collected using interviews and surveys, both of which were pretested on several respondents within practitioner firms before the versions discussed here were put into use.

Overall Data Collection Strategy

The sampling plan is to collect a convenience sample based on a nested design of 90 projects inside 30 firms (with a target of 3 projects per firm) in at least 7 industries (with approximately 4 firms per industry). The unit of analysis for data collection is the project, defined as a set of completed outsourced product or process development activities in which the lead firm (the firm doing the outsourcing) outsources activities either to a single supplier or, if to a group of suppliers, a clear lead supplier. We focus on outsourcing activities in which there was either a clear or single lead supplier so that we can examine the specific integration activities that actually occurred between the lead firm and the supplier, rather than the lead firm's usual, typical, or prescribed integration practices, which may not occur in any specific instance. We focused on completed projects so that these integration activities could be related to the production of a clear deliverable (e.g., a specific product, process, or other technological project) that the lead firm was able to evaluate. We limited our investigation to projects that had been completed within the past three years so that informants in the lead firm would still be able to recall various dimensions of project performance. Prior to beginning the main data collection, we conducted preliminary interviews and held informal conversations with supply chain and procurement managers in several companies. They were readily able to identify many activities that conformed to our definition of a project. These activities were generally coordinated by a single person in the lead firm (sometimes referred to as the supply chain integrator), although that person might call on the technical expertise of others in the lead firm.

Data have been collected the following industries: aerospace, automotive, consumer electronics, consumer products, medical devices, pre-packaged food, semiconductors, and software. The sample is designed to include a broad cross-section of industries ranging from high volume products with relatively little engineering effort (consumer products), to durable goods requiring some engineering effort (automotive), to low volume, highly engineered products (aerospace). Such sample diversity is desirable because these industries have approached the problem of systems integration in different ways. In aerospace and defense contracting, there has always been a necessity for high-level systems integration. Higher volume industries such as computer or automobile manufacturing may be able to learn from integration practices that have a long history in lower volume industries. Finally, the food and medical industries are subject to many standards and regulations (such as those by the U.S. Federal Food and Drug Administration) that the other industries are not which might affect how these firms integrate their outsourced product development work. The goal is to get a highly detailed view of integration practices within approximately four firms per industry segment.

Within each firm, data were collected on approximately three projects. We collected interview and survey data from two classes of informants—project engineers and their supervisors. Both classes of personnel may have various titles depending upon the individual firm. For example, the project engineer may hold the title “project manager” or “innovation manager,” despite the fact that, at each firm, this class of personnel is responsible for the same task of managing the day-to-day technical interface between the lead firm and the supplier. Similarly, supervisors may be referred to as “department managers” or “directors.” However, these supervisors typically have several project engineers managing multiple outsourced development projects reporting to them

Upon gaining access to a firm, we worked with a supervisor to identify three projects under his or her supervision with a range of performance outcomes (ideally, one high performing project, one low performing project, and one project with average performance). For each project, the supervisor completed a brief (3 page) survey that provides basic descriptive data about the project (e.g., percentage of the total project outsourced, timeline, incentive structure, identification of lead supplier and nature and length of the relationship with that supplier) and also assesses project outcomes on five dimensions by comparing final project outcomes to initial project targets. The five project performance dimensions are: quality of the working relationship with the supplier, reliability of the deliverable, performance/functionality of the deliverable, project cost, and timeliness of project completion. Immediately after completing the survey, the supervisor participated in an individual interview where he or she answered open-ended questions about general challenges in managing outsourcing as well as challenges faced in the specific projects discussed in the survey.

The supervisor also identified the lead project engineer for each project. The project engineer serves as the key point of contact between the lead firm and the supplier and handles the day-to-day integration of the two firms' activities. Each project engineer completed an extensive (12-page) survey about the nature of the project (e.g. geographic location of the lead firm and supplier, language spoken by each party, size and complexity of the project), integration and communication mechanisms used on the project, and about his or her own background and training. The project engineer also answered questions about project performance identical to those answered by the project manager. After completing the survey, the project engineer participated in an interview (alone or with other project engineers) about challenges in managing outsourcing generally and in the specific project for which they completed the survey.

Currently Available Data

To date, we have collected and coded data on 48 projects in 17 firms (due to missing data, Ns less than 48 are reported in some tables and models later in this paper). The firms are in the following eight industries: aerospace, automobiles, electronics and consumer products, manufacturing equipment, materials processing, medical devices, semiconductors, and software. Given that data collection is still ongoing, we will present only descriptive statistics, preliminary regression models, and accompanying qualitative data from the interviews to help elucidate and explain the descriptive statistics. The results presented below should thus be considered preliminary and suggestive rather than conclusive.

Measures

Integration Mechanisms. Data about integration mechanisms in use on a project were provided by the project engineer. Project engineers provided two types of data about integration mechanisms. First, project engineers were given a list of integrative mechanisms and were asked to indicate "the **main ways** [emphasis in survey] that our firm used to coordinate our personnel's activities with the supplier's on this project;" respondents were asked to circle all activities that applied. The list of integration activities was (for some itemsa bit more detail was provided in the survey than in the following list): dedicated personnel—within your firm; dedicated personnel—within the supplier firm; unifying purchasing and engineering management functions; shared information systems between your firm and the supplier; co-location of your personnel at the supplier firm; co-location of supplier personnel at your firm; videoconferencing; joint meetings at your site or the supplier's; designing project specifications to minimize communication; and use of industry engineering standards. Second, project engineers were asked to report how often "you personally typically communicate with your primary supplier contact using the following media?" Six media were listed (face-to-face, videoconferencing, telephone, E-mail or other electronic communication, fax, paper communication). Based upon earlier surveys and interviews, seventh, web conferencing, was added to surveys administered after 2006. Respondents provided answers on a five point scale—5=daily, 4=weekly, 3=monthly 2=quarterly, or 1=never.

Project Engineer Training. Project engineers were asked whether they had received training in several types of skills relevant to managing outsourced product development. A complete list of these skills is shown in Table 3. Project engineers were asked to indicate if they had received training in these skills through a college or university, through company-sponsored training, or through professional society training. Project engineers were also asked to indicate if they had no formal training. This measurement system does not assess two important source of learning: on-the-job training and direct experience. All of our informants indicated that they had gained a substantial amount of the knowledge necessary to perform their tasks on the job, typically through informal observation of others or though direct experience. Thus, we chose not to assess these variables because they appeared to be universally present and informants were not able to respond clearly about the amount or quality of on-the-job learning they had done, probably because it happened very informally and they did not consciously track it. Our measure therefore assesses the use of formal training efforts and not all possible training modalities. Given the high levels of experiential learning reported by project engineers, the absence of formal training should not be equated with the absence of skill. In later analysis, we may be able to assess levels of experiential learning by using the demographic variables of time in industry, at firm, and in job as a proxy.

Project Coordination Tools. Project engineers were also asked to rate how greatly they relied upon a number of common project coordination tools and methodologies (e.g. a formally documented design change process) using a five point Likert scale. Scores for each tool could range from 1 to 5, with 1 representing a reliance on the tool "not at all," 3 representing "to some extent", and 5 indicating "to a great extent".

Project Outcomes. In order to assess outsourcing effectiveness, it would be ideal to obtain archival measures of project outcomes. However, our preliminary attempts to do so uncovered two difficulties with this approach. First, many firms did not regularly and reliably track project level outcomes. In fact, we have asked all of our informants if their firms are obtaining the expected benefits from outsourcing. The most typical response is that, with the exception of some highly visible items such as reductions in labor costs, which are tracked by some managers, their firms have not attempted to formally assess the effectiveness of outsourcing. Second, even where firms did have some archival measures of project effectiveness, these measures were not comparable across firms and industries. Hence, we used managerial perceptions of project success as our primary outcome measure. This approach is consistent with the team performance literature (e.g., Ancona, 1990; Keller, 1994), and the automotive supply chain literature (e.g., Wasti & Liker, 1999). Project managers and project engineers each independently responded to the same five questions about project outcomes, each on a five-point scale (where higher numbers indicate better outcomes)

(1) How good was your working **relationship** with this supplier on this project? [emphasis in original questionnaire here and in the questions below]

(2) What was the quality of the deliverable in terms of **reliability and non-defective ("good") parts** relative to initial project targets?

(3) What was the **performance or functionality** (other than reliability) of the deliverable relative to initial project targets?

(4) What was the **cost** of the deliverable relative to initial project targets?

(5) Relative to initial targets, what was the effect of the deliverable upon the **ramp-up time** of the final product(s) up to normal production volume?

Due to the currently small sample size, we are not able to assess inter-rater reliability at this time, and thus we report only the project manager data here.

RESULTS AND DISCUSSION

Table 1 reports the means and ranges for the five project outcome variables (as assessed by the project manager). The projects represent a wide range of outcomes on all dimensions; projects in the sample achieved the full range of outcomes on each dimension. Interestingly, on average project managers indicated their highest level of satisfaction with the working relationship with their supplier and less satisfaction with quality and timeliness of the deliverables. Of additional interest is the fact that other analyses not presented in this paper show that many of the projects may be strong in one outcome, poor in another, and mediocre in a third. That is, the outcomes for any given project are not strongly correlated. Bivariate correlations between project outcome measures range from 0.02 to 0.67.

TABLE 1
Outcome Measures

Outcome Measure	Mean (1-5 scale)	Range
Working relationship with supplier	3.75	1-5
Cost of deliverable	3.29	1-5
Performance/functionality of deliverable	3.24	1-5
Quality of deliverable (good parts)	3.13	1-5
Effect on time to complete implementation or to achieve production volume ("ramp-up time")	3.02	1-5

N=46 projects

Use of Interorganizational Integration Mechanisms.

Table 2 reports the frequency with which various interorganizational integration mechanisms were used, while Table 3 reports the frequency with which project engineers themselves used various communication modalities (e.g., telephone, E-mail).

TABLE 2
Integration Mechanisms between Focal and Supplier Firm Personnel

Integration Mechanism	% Using Integration Mechanism
Dedicated Personnel Within Lead Firm	85.0
Dedicated Personnel Within Supplier Firm	85.0
Unifying Purchasing and Engineering	27.1
Shared Information System	60.4
Co-location of Personnel at Supplier	14.6
Co-location of Personnel at Lead Firm	14.6
Videoconferencing	8.3
Joint Meetings at Site or Suppliers	79.2
Designing Project to Minimize Communication	37.5
Use of Industry Engineering Standards	27.1
Other (e.g. design specs, cost sheets, alignment meeting)	not coded

N=48 projects

TABLE 3
Use and Frequency of Communication Mechanisms by Lead Project Engineer

Communication Mechanism	% Using Communication Mechanism				
	Daily	Weekly	Monthly	Quarterly	Never
Meetings	0.00	20.8	31.3	37.5	10.4
Videoconferencing	0.00	4.3	6.4	5.56	89.3
Telephone	41.7	45.8	12.5	0.00	0.00
E-mail or other electronic communication	75	20.8	4.2	0.00	0.00
Fax	4.3	10.6	4.3	6.4	74.4
Paper communications such as memos/surface mail	4.2	10.4	12.5	12.5	60.4
Web conference	16.7	0.0	0.0	16.7	66.6

N=48 projects (Web conference N=6)

Dedicated personnel on both sides of the interface are used nearly universally throughout the sample. This indicates both the importance of the interface and the need to devote "high bandwidth" resources (human beings capable of processing complex information) to integrate effectively across it. However, this presumably occurs only if the integrators have an appropriate combination of technical, business, and interpersonal skills. Interestingly, integrators' large stock of tacit knowledge about how to recognize and reconcile differences across firm boundaries makes lead firms particularly vulnerable to turnover of these personnel, because respondents at several firms indicated that a prime skill for successfully integrating outsourced projects requires—in the words of one respondent—"Wide knowledge of the supply chain, years of experience and engineering background, cross functional background [i.e. including manufacturing], and understanding costs [cost accounting].”

This vulnerability to turnover is only exacerbated by the fact that experience in many of these activities, such as manufacturing and detailed product engineering, were gained within once vertically integrated firms that are now outsourcing these very activities to a fragmented network of specialist suppliers. Hence, the question naturally arises: how can new supply chain integrators can be developed within firms dependent on outsourced product and manufacturing development? Some interview evidence indicates that finding integrators may indeed be difficult. One supervisor stated bluntly when asked how to create effective supply chain integrators: “We have been unsuccessful. I am constantly being brought back to work the interface of strategic sales for both customers and suppliers [which several subordinate, supply chain integrators should be doing instead].” Another indicated the lengths that his firm needed to employ to obtain skilled supply chain integrators. “I caused quite a pay disparity to bring this person in [to manage the supply chain interface].” Hence paradoxically, the very conditions that require supply chain integrators—the disaggregation of development projects through outsourcing to a network of specialist suppliers—may hinder the ability of firms to develop future supply chain integrators.

Another mechanism for devoting human resources to manage the supply chain interface is co-location. Surprisingly, we find that this is used in less than a third of the projects when co-location at both the lead firm and the supplier are considered. Lead firms co-located personnel at the supplier in only 15% of projects surveyed (and supplier firms co-located personnel at the lead firm in only 15% of projects). We suspect that the infrequent use of co-location has two causes. First, is it very expensive and time-consuming to set up such arrangements, which often involve relocating personnel and acclimating them to a foreign organizational and national culture. In fact, during their interviews, two of the respondent firms indicated that they were in the process of establishing co-located personnel in the vicinity of their non-domestic suppliers in an attempt to reduce problems experienced with earlier projects. Presumably, they would not have taken this time or expense to do this without the previous difficulties to spur them on. Yet none of the interviewed firms stated that they were pursuing co-location with domestic suppliers. The reason for this dichotomy may be that co-location facilitates high-bandwidth communication when there are language issues to complicate technical exchanges. Numerous respondents have mentioned that it is much easier to make oneself understood by someone whose first language is different when communicating face-to-face rather than over the telephone. This observation is corroborated by Sosa et al. (2002).

A second problem with co-location is that co-located personnel become experts in a single supplier and project, but this knowledge is often not applicable to other suppliers (or even to different projects using the same supplier). Co-location can also increase project costs and contribute to employee turnover, making it difficult to redeploy co-located personnel to other interfirm coordination assignments. Thus, because they are not re-usable and therefore not very flexible, the cost of co-located personnel looms especially large given their relatively short useful life.

The advantage of face-to-face discussions discussed earlier may explain why joint meetings were extremely common, even when co-location was eschewed. These meetings typically involved travel by the project engineer to the supplier site. Interestingly, most firms did not use videoconferencing technology for these meetings even when it was available. This may be because videoconferencing still does not yield quite the "bandwidth" of face-to-face discussions. For example, it is quite difficult to conduct a breakout meeting to look over a manufacturing fixture *in situ* in a supplier plant with current videoconferencing techniques. Also, most videoconference facilities still blur the broadcast of high-speed images such as hand gestures or introduce time lags into the conversation, both of which reduce the "bandwidth" of the conversation. Whatever the drawbacks of video-conferencing are, they must be severe, for nearly all project engineers report to us extreme levels of fatigue and even burnout associated with frequent travel over long distances and multiple time zones. Thus, it is unclear how robust the strategy of frequent meetings is over the long run in situations involving great distances. This may provide another explanation for the apparently emerging trend of sample firms to establish co-located employees near non-domestic versus domestic suppliers after coordination methods involving extensive travel had already been attempted. .

Project engineers reported using some sort of shared information system about three-quarters of the time. However, upon further questioning, they revealed that much of this consisted of low-level information technology such as common e-mail systems between lead-firm and supplier rather than more sophisticated tools for technological integration. This may be because the cost of establishing common systems in such areas as computer-aided design (CAD) or enterprise resource management (ERP) systems has proven to be too expensive to be justified by short-term project-to-project relationships such as those studied in our sample. Faxing was also not heavily used. Presumably, this is because it has been superseded by e-mail attachments. The generally poor visual resolution of faxes is likely to contribute to this trend.

Hence, the "modern" technologies of video-conferencing and information systems may be inadequate to provide the rich, tacit knowledge required to achieve adequate integration. This may explain why, as indicated in Table 3, our informants indicated that an "old" technology, the telephone, was so heavily used. However, telephone use created its own issues. The informants indicated that frequent telephone contact with individuals in distant time zones (thus forcing the conversations to occur at unusual hours; sometimes in the middle of the night) was a key stressor in their jobs. Therefore, it is not certain whether further development of the "new" technologies of information systems and video-conferencing may be required to sustain non-domestic outsourcing in the long run.

Despite the recent emphasis on modularity in the academic and popular press (Schilling, 2000), it was not the dominant strategy for managing integration. Presumably, this is because the work we studied here cannot be easily decomposed into separate modules. This can be seen by the difficulty inherent in properly decomposing software tasks as evidenced by the number of "bugs" in most commercial packages resulting from unanticipated module interactions. This is despite the fact that software typically does not have interactions in the physical spheres of geometry, weight, heat, electricity, etc., which are of concern to most other technical projects, and hence provides the best environment possible for decomposition of technical tasks. Hence, if modular decomposition is difficult in software, it should not be surprising that it is more difficult in the projects included in this study. Eschewing modularization of tasks may also be a cause of the relatively infrequent use of industry standards in this study. Perhaps this is because standards typically do not exist or are infeasible in fast-changing technological environments where standards lag can lag practice by months or years.

Having presented data on frequency of use and speculation about why firms use different organizational coordination mechanisms to manage outsourcing arrangements and emphasize different media interaction, we now present preliminary results to relate those choices to project outcomes.

Effectiveness of Organizational Mechanisms

Table 4 presents results from ordered logistic regressions of outcome measures against different organizational mechanisms.

Table 4
Ordered logit regression for non-software projects of each outcome variable against organizational mechanisms used heavily during each project.

	Relationship	Quality	Functionality	Cost	Time
Unify purchasing and engineering	-2.61**** (0.95)	-1.84**** (0.85)	-1.78**** (0.89)	-1.16* (0.85)	
Colocation		1.62*** (0.88)			-2.28**** (1.01)
Face-to-face meetings	-2.94* (1.22)	-2.25**** (1.05)	-1.61* (1.21)	-2.76**** (1.22)	
Pseudo-R^2	0.13	0.08	0.07	0.07	0.04
N	34	34	34	34	34

* p<.2, ** p<.15, *** p<.10, **** p<.05, ***** p<.01

For clarity, only coefficients that are significant or approaching significance are shown. Please note that coefficients are presented rather than odds ratios. Three coordination tools (formal design/process change process, formal materials management process, overlapping product and process development phases) were left out of the model as they did not approach statistical significance for any outcome variable.

Software projects were removed from the analysis of organizational form, because when software projects were included, almost no significant relationships were observed at all. We speculate that software projects may be using somewhat different organizational forms than projects that also include mechanical systems. As we increase the size of the data set going forward, we hope to explore this issue more fully. For clarity, only coefficients that are significant or approaching significance are shown. Note that coefficients are presented rather than odds ratios (as is true of all tables in this paper). All other coordination mechanisms (dedicated employees, information systems, video conferencing, modular tasks, and reliance on industrial standards) were insignificant with respect to all outcomes variables and so have been dropped from the models presented above. In our survey, the use of organizational mechanisms is a dichotomous variable. Interestingly, the unification of purchasing and engineering appears to be associated with worse outcomes. While this result needs further analysis to check for robustness, we speculate that firms may have difficulties responding quickly to the dynamic circumstances that characterize most of these outsourcing arrangements. Since unification of these functions is likely to be a relatively stable organizational form, causality is easier to assign. An increasing frequency of face-to-face meetings is also associated with worse project outcomes. Unlike purchasing/engineering unification, however, it may be the case that projects that are in trouble will require more meetings to bring them to completion. Co-location of personnel is associated with improved project quality but it also increased project duration. It may be that co-located personnel surface and resolve many more issues, thus enhancing project quality. However, the decisions made by the on site co-located personnel then need to be communicated back to the lead firm, which may result in additional delays if those decisions are not aligned with other project concerns present in the lead firm.

Effectiveness of Media Interaction

Table 5 presents results from ordered logistic regressions of outcome measures against the frequency of different media interactions.

Table 5
Ordered logit regression for all projects of each outcome variable against frequency use of each communications medium.

	Relationship	Quality	Functionality	Cost	Time
Face					
Videoconferencing		1.06**** (0.52)	1.09*** (0.56)		
Telephone	-0.70* (0.54)	-0.63* (0.49)	-0.75* (0.56)	-0.82** (0.55)	-1.28**** (0.54)
E-mail					1.33*** (0.71)
Fax		0.68**** (0.34)			0.60*** (0.34)
Paper	0.47* (0.33)		0.45* (0.33)	0.65*** (0.34)	
Pseudo R^2	0.05	0.08	0.09	0.06	0.09
N	44	44	44	44	44

* p<.2, ** p<.15, *** p<.10, **** p<.05, ***** p<.01

For clarity, only coefficients that are significant or approaching significance are shown. Again, note that coefficients are presented rather than odds ratios. Also note that frequency of media usage varies categorically from 1=Never to 5=Daily. Although used in only about 10% of projects, video conferencing is associated with good outcomes. Interestingly, heavy telephone use is associated with more negative outcomes. Similar to the negative association of outcomes with a heavy reliance on meetings, this can be interpreted in at least two ways. The first is that projects that are experiencing difficulty are likely to be the same ones where frequent telephone use is needed. A second potential interpretation is that the varying time zones are causing project engineers to schedule their work across a longer stretch of time and is leading to ineffectiveness as a result.

Training for Integrators

TABLE 6
Training in Relevant Skills

Skill	% Receiving Training		Where Trained		
	Formal Training	No Formal Training	University	Company	Professional Society
Project management techniques or software	72.9	27.1	31.3	66.7	10.4
Formal methods to decompose projects	64.6	35.4	33.3	45.8	6.3
Estimating project costs	58.3	41.7	22.9	45.8	2.1
Business case analysis	43.8	56.2	16.7	31.3	2.1
Design for manufacturing	42.6	57.4	6.4	38.3	2.1
Manufacturing or service process analysis	41.7	58.3	22.9	22.9	4.2
Negotiations	56.3	43.7	12.5	45.8	4.2
Mediation or conflict resolution	50.0	50.0	8.3	50.0	0.00
Leadership	75.0	25.0	27.1	70.8	6.3
Managing teams	75.0	25.0	14.6	68.8	6.3
Interpersonal communication	72.9	27.1	29.2	60.4	4.2
Information systems analysis/specification	39.6	60.4	20.8	25.0	2.1
Legal issues	56.3	43.7	14.6	47.9	2.1

N=48 project managers

Table 6 reports the percentage of project engineers who reported receiving formal training in particular skills that may be useful for integrators to have. It also reports, for those who received formal training, where the training was obtained (note—these percentages can sum to more than

100% as a person may have received training in multiple venues). Several notable trends appear in these results:

- Universities appear to provide very little formal training for project engineers in skills that our interviewees repeatedly identified as most critical (negotiations, conflict resolution, managing teams). Even in more technical subjects such as project management, less than a third of our respondents had received any formal university training in the topic. These results point to the need to better align university curricula for engineering and other technical graduates with the realities of the tasks many graduates will perform.
- Costing was also identified as a critical skill by respondents at approximately half the interviewed firms. As one respondent put it: "You don't want to put these [suppliers] out of business. The last thing you want is an unprofitable supplier. He has to be able to pay his people and meet his bottom line. Cost accounting is key." Yet, fewer than two-thirds of supply chain integrators received any formal training in this subject. Perhaps this is linked to the separation of the purchasing and engineering management functions seen in nearly three quarters of firms in the sample.
- Although many of our respondents received company training, the interviews indicated that it tended to be rather brief and did not fully reflect the realities of respondent's jobs.
- Professional societies do not appear to be meeting the need for training in any skills required for effective integration in any significant manner.

Tables 7A and 7B present ordered logistic regressions of outcomes against the dichotomous variables of whether the project engineer received training in a university setting or a companysetting. We leave the analysis of interactions for later study (and larger N).

Interestingly, systems engineering (decomposing projects) at the university level is associated with more poorly performing projects. One potential explanation that needs to be ruled out is that more complex projects that are naturally falling behind (Brooks, 1995) are also those that are staffed by people with systems level training. With cross-sectional data it is difficult to assign causality. Another interesting outcome is that university business case analysis is associated with negative outcomes while company sponsored training in the same skill appears to be associated with positive outcomes. This may be due to the fact that training in business case analysis, while useful in itself, is typically restricted in the university environment to business school students, who may potentially lack the technical domain competence to effectively manage a technical project. In contrast, university-based negotiation training is associated with positive outcomes (or no significant relationships) while company-sponsored negotiation training is associated with negative outcomes. This may be due to a complaint raised during interviews with project managers that many company courses lasted only for one to two days and hence were quite "shallow." Given that negotiation is a learned skill that only improves with coaching and practice, a university training course in negotiations would provide much more scope development than a "one-day wonder" course sponsored by the company.

Table 7A
Ordered logit regression for all projects of each outcome variable against university training of project engineers.

	Relationship	Quality	Functionality	Cost	Time
Project management					
Decomposing projects into sub-projects (e.g. systems engr.)	-1.37*** (0.83)	-1.55*** (0.79)	-1.78**** (0.87)		
Cost Estimation					
Business Case Analysis	-2.62*** (1.40)	-2.64*** (1.33)	-2.82*** (1.49)		
Design for Manufacturing		2.25** (1.52)	4.76**** (2.11)		
Process Analysis				-2.69*** (1.44)	
Negotiation	2.75*** (1.47)				
Mediation or Conflict Resolution		2.59* (1.98)			-2.67* (1.98)
Leadership Skills				-2.03*** (1.18)	
Managing Teams			2.62* (1.86)	3.04** (1.91)	
Interpersonal Communication		1.51** (0.92)			
Information Systems Analysis or Specification	-1.37** (0.84)	-1.32** (0.83)	-1.60*** (0.84)	2.05**** (0.97)	
Intellectual Property Legal Issues					
Pseudo R^2	0.16	0.13	0.18	0.14	0.06
N	45	45	45	45	45

* is p<.2, ** p<.15, *** p<.10, **** p<.05, ***** p<.01

Table 7B
Ordered logit regression for all projects of each outcome variable against company training of project engineers.

	Relationship	Quality	Functionality	Cost	Time
Project management				-1.47* (1.03)	
Systems engineering					
Cost Estimation					
Business Case Analysis		2.17**** (1.11)	1.36* (0.98)	1.73** (1.10)	
Design for Manufacturing		1.79**** (0.90)			
Process Analysis					
Negotiation	-2.24**** (0.94)	-3.64**** (1.08)	-1.20* (0.90)		
Mediation or Conflict Resolution					
Leadership Skills		2.30** (1.46)			
Managing Teams		-5.44**** (1.83)		-2.93* (2.27)	
Interpersonal Communication		2.92**** (1.14)			-1.39** (0.91)
Information Systems Analysis or Specification			-0.97* (0.74)		
Intellectual Property Legal Issues					
Pseudo R^2	0.11	0.28	0.10	0.10	0.06
N	45	45	45	45	45

*** is p<.2, ** p<.15, *** p<.10, **** p<.05, ***** p<.01**

This is not to imply that all company sponsored courses are worthless. Training in design for manufacturing appears to be beneficial to project outcomes in any venue it is taught. Finally, we need to note the overall association of information training (both at the university and company levels) with poor outcomes. A number of different interpretations may apply. However, it may be that software projects are simply different from other development projects and perform worse as a class against initial expectations. Hence, the poor outcomes associated with information systems training is not a problem with the training per se, but rather that project engineers with information systems projects will be more typically put in charge of software projects than non-software projects.

In any case, the deficiencies of training, particularly company training with respect to a number of skills such as negotiation, may explain why job experience was cited by many respondents—as discussed earlier—as being key to supply chain integrator success. As Benjamin Franklin observed, however, "Experience is a dear [i.e. expensive] school." Thus, there may be a great opportunity for universities to provide firms with degree-related or continuing education for junior personnel in the skills necessary for supply chain integration.

Project Coordination Tools

Project engineers were asked to describe on the extent they used a number of common project coordination. Table 8 presents data on the relative frequency with which tools are employed on particular project.

TABLE 8
Extent of Reliance on Project Coordination Tools

Tool	Mean (1-5 scale) Not at all --- great extent	Range
Stage gate project management process	3.87	1-5
Overlapping product & process development	3.61	1-5
Project management (e.g. CPM, PERT, or MS Project)	3.56	1-5
Formal materials management system	3.53	1-5
Formal design/process change management process	3.51	1-5
Vendor pre-qualification program	3.31	1-5
Formal quality control program	3.25	1-5
Formal methodology to translate customer wants into technical specifications (e.g. QFD or DSM)	2.61	1-5

N = 48 projects (Stagegate N=23)

Stage-gate project management processes were employed to the greatest extent, which is not surprising given the fact that this tool has become almost universal in product development (Griffin 1997). There are also a cluster of tools with approximately the same reasonably heavy usage including formal project management techniques (such as CPM, PERT, or the use of

Microsoft Project, in which the CPM methodology is embedded), overlapping product and process development phases, formal materials management systems, and formal design/process change management processes. Interestingly, employment of formal quality control systems was relatively low given all the emphasis in modern operations management upon designing quality into the product up-front. Lower still was the employment of formal methodologies to translate customer wants into technical specifications, such as quality function deployment (QFD) and design structure matrices (DSM). This last point is interesting because an inability to match a product's design to customer wants often leads to late or overbudget projects (Thamhain and Wilemon 1986).

Table 9 present ordered logistic regressions of outcomes against the extent of reliance upon the various coordination tools. Again, we leave the analysis of interactions for later study. What is most interesting is that only four of the tools seem to be associated significantly with any of the outcome variables, and in fact, most of that significant association is with cost and timing. The one exception is vendor pre-qualification (e.g. 1SO 9000 certification), which is strongly associated with superior functionality and weakly associated with superior quality, in terms of non-defective delivered components. However, vendor pre-qualification did increase project cost, perhaps due to the resources required for the pre-qualification process or perhaps because pre-qualified vendors were also higher cost vendors. The other great surprise is that the use of formal project management methodologies such as CPM, PERT, or similar methods is associated with negative outcomes in cost and timing, which these methodologies *are explicitly designed to manage.* However, as stated earlier in the paper when similar results were found with respect to training in formal project management methodologies, this may merely be an artifact of these tools being used with more complicated projects, which tend to be more likely to run late and over-budget. Hence, caution must be used in interpreting the results of this table. Fortunately, we have also collected data on the number of employees involved in a project and the length of a project, which may potentially be used to construct a proxy for project complexity. This, however, will have to await future analysis.

Table 9
Ordered logit regression for all projects of each outcome variable against the use of each coordination tool.

	Relationship	Quality	Functionality	Cost	Time
Project Management (CPM, PERT, MS Project) Methodology				-0.43** (0.29)	-0.70**** (0.28)
Formal quality control program					0.62**** (0.31)
Vendor prequalification program		0.30* (0.23)	0.44*** (0.25)	-0.33* (0.25)	
Methodology to translate customer wants into technical specifications (e.g. QFD, DSM, etc.)				0.57** (0.33)	
Pseudo R^2	0.03	0.03	0.04	0.07	0.09
N	38	38	38	38	38

* is p<.2, ** p<.15, *** p<.10, **** p<.05, ***** p<.01

Another interesting point is that the relatively low usage of formal quality programs as well as QFD-like tools contrasts with these two tools' relative efficacy in controlling, respectively, timing and cost. A final observation with respect to all these tools is that, if they are beneficial, they tend to be beneficial to one or, at most, two outcomes. Hence, none of the tools represent a stand-alone solution to the product and process coordination challenges faced by firms.

Discussion

The results presented above suggest some interesting possibilities:

- The effects of many integration mechanisms and tools vary dramatically across different outcomes. For example, co-locating personnel seems beneficial to product quality but is associated with late projects. Many others may be beneficial to only one or two outcomes. For example, none of the coordination tools was associated with an improved working relationship. These effects point to the need to simultaneously use multiple integration mechanisms in order to achieve multiple desired project outcomes.
- Unifying purchasing and development organizations appears to be associated almost uniformly with poor project outcomes across almost all outcome dimensions.
- Face-to-face meetings were also associated with numerous poor outcome measures. However, they are highly used. Understanding this contradiction may be crucial. One possibility may be that the relationship is curvilinear. Few meetings may be so obviously a bad idea that almost all project embrace meetings to some extent. However, beyond a certain frequency, numerous meetings may waste time, escalate unimportant conflicts, and degrade project performance. Alternatively, many face-to-face meetings may only employed when projects are having serious problems, and the causality runs from performance to use of meetings rather than the other direction.
- Training in particular project skills by the company and by the university can lead to opposite effects on the success of project outcomes. We discussed earlier a number of potential reasons for this. However, understanding clearly why these differences come about is of the highest importance because many companies sponsor such training and anecdotal evidence from our interviews indicates that these skills are thought to be

crucially important. In particular, the poor results associated with formal project management techniques are of great concern.

CONCLUSIONS TO DATE

While it is premature to draw strong conclusions based on the limited data presented here, the data do contain some particularly interesting information that warrant further investigation. Four points in particular seem striking. First, not all methods of interaction are equally effective at managing the outsourcing boundary. The benefits and costs of various methods of interaction as well as the potential for differential effectiveness of these methods for domestic and foreign suppliers warrant further investigation. Second, given all of the attention to modularity as a solution to managing outsourcing, the infrequency with which modularity is used—as well as its apparent ineffectiveness—in these firms is striking. Perhaps modularity is best suited to more well-understood and stable processes such as contract manufacturing. Our results certainly suggest that the boundary conditions for the effectiveness of modularity require further examination. Third, the infrequency with which various information technologies are used requires further, more fine-grained examination. In particular, it would be useful to know if there are some specific information technologies that are effective in the outsourcing of product design. Finally, while not surprising, our preliminary indications that specific integration mechanisms can increase effectiveness on some project dimensions while decreasing effectiveness on others, have significant implications for the design of the outsourcing interface. These results suggest that in order to design the interface effectively one must not only know the nature of the task but the importance of various outcome dimensions.

References

Abdel-Hamid, Tarek, and Stuart Madnick, 1991. Software Project Dynamics: An Integrated Approach. Englewood Cliffs, NJ: Prentice-Hall.

Ancona, D. G., 1990. "Outward bound: Strategies for team survival in an organization. Academy of Management Journal." Academy of Management Journal, 33: 334-365.

Brooks, Jr., F.P., 1995. The Mythical Man-Month: Essays on Software Engineering, 20th Anniversary Edition. Reading, MA: Addison-Wesley.

Cusumano, M. A. and A. Takeishi 1991. "Supplier Relations and Management: A Survey of Japanese, Japanese-Transplants, and U.S. Auto Plants." Strategic Management Journal, 12: (Nov-Dec).

Das, A. and R. Narasimhan, 2000. "Purchasing Competence and Its Relationship with Manufacturing Performance." The Journal of Supply Chain Management, Spring 2000: 17-28.

Dyer, J.H. and K. Nobeoka, 2000. "Creating and Managing a high-performance knowledge-sharing network: The Toyota case." Strategic Management Journal, 21(3): 345-367.

Fine, C. H. (1998). Clockspeed: Winning Industry Control in the Age of Temporary Advantage. Reading, Mass., Perseus Books.

Fine, C. H. and D. Whitney, 1996. "Is the Make/Buy Decision a Core Competence?" MIT Center for Technology, Policy, and Industrial Development. Available at web.mit.edu/ctpid/www/people/FinePapers.html.

Galbraith, J., 1973. Designing Complex Organizations. Reading, MA, Addison-Wesley.

Gerlach, M.L., 1992. "The Japanese Corporate Network - A Blockmodel Analysis." Administrative Science Quarterly, 37(1), 105-139.

Griffin, A. (1997). PDMA research on new product development practices: updating trends and benchmarking best practices. Journal of Product Innovation Management 14 (6), 429-458.

Handfield, R. B., G. L. Ragatz, et al., 1999. "Involving Suppliers in New Product Development." California Management Review, 42(1): 59-82.

Henderson, R. M. and K. B. Clark, 1990. "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms." Administrative Science Quarterly, 35: 9-30.

Iansiti, M., 1995a. "Technology development and integration: An empirical study of the interaction between applied science and product development." IEEE Transactions on Engineering Management, 42(3): 259-269.

Iansiti, M., 1995b. “Technology integration: Managing technological evolution in a complex environment.” Research Policy, 24(4): 521-542.

Iansiti, M., 1998. Technology Integration: Making Critical Choices in a Dynamic World. Boston, Mass., Harvard Business School Press.

Iansiti, M., 2000. “How the incumbent can win: Managing technological transitions in the semiconductor industry.” Management Science, 46(2): 169-185.

Keller, Robert T., 1994. "Technology-information processing fit and the performance of R&D project groups: A test of Contingency Theory." Academy of Management Journal, 37: 167-179.

Lawrence, P.R. and J.W. Lorsch, 1967. Organization and Environment: Managing Differentiation and Integration. Homewood, IL: Irwin.

Lieberman, Marvin B., 1991. "Determinants of Vertical Integration: An Empirical Test." Journal of Industrial Economics, 39: 451-466.

McIver, R. and M. McHugh, 2000. "Partnership Sourcing: An Organization Change Management Perspective." The Journal of Supply Chain Management, (Summer 2000): 12-20.

Monteverde, Kirk, and David J. Teece, 1982. "Supplier Switching Costs and Vertical Integration in the Automobile Industry." Bell Journal of Economics, 13: 206-213.

Nickerson, Jack, and Todd Zenger, 2004. "A Knowledge-Based Theory of the Firm---The Problem-Solving Perspective." Organization Science, 15(6): 617-632.

Parker, G. G., and E. G. Anderson, 2002. "From Buyer to Integrator: The Transformation of the Supply Chain Manager in the Vertically Disintegrating Firm." Production and Operations Management, 11 (1): 75-91.

Schilling, Melissa A., 2000. "Toward a General Modular Systems Theory and Its Application to Interfirm Product Modularity." Academy of Management Review, 25: 312-335.

Sosa, M. E., S. Eppinger, M. Pich, D. G. McKendrick, and S. K. Stout et al., 2002. “Factors that Influence Technical Communication in Distributed Product Development: An Empirical Study in the Telecommunications Industry.”. IEEE Transactions on Engineering Management, 49, 1.

Sturgeon, T., 2002. "Modular Production Networks. A New American Model of Industrial Organization." Industrial and Corporate Change 11, 3: 451-496.

Thamhain, H.J. and D.L. Wilemon (1986). "Criteria for Controlling Projects According to Plan." Project Management Journal, 17 (2): 75-81

Wasti, S.N. and J.K. Liker, 1999. "Collaborating with Suppliers in Product Development: A U.S. and Japan Comparative Study." IEEE Transactions on Engineering Management, 46, 4, 444-461.

Williamson, Oliver E., 1975 Williamson. Markets and Hierarchies: Analysis and Antitrust Implications. New York: The Free Press.

.