WINDOWS OF OPPORTUNITY: TEMPORAL PATTERNS OF TECHNOLOGICAL ADAPTATION IN ORGANIZATIONS

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Abstract

This paper examines the introduction and adaptation of technologies that support productive operations. The authors argue that the process of technological adaptation is not gradual and continuous, as often argued in the innovation literature, but is instead highly discontinuous. Evidence from three manufacturing and service organizations indicates that there exists a relatively brief window of opportunity to explore and modify new process technology following initial implementation. Afterwards, ① modification of new process technologies by users is limited by the increasing routinization that occurs with experience. Thus, the technology and its context of use tend to congeal, often embedding unresolved problems into organizational practice. ② Subsequent changes appear to occur in an episodic manner, triggered either by discrepant events or by new discoveries on the part of users. These findings have important implications for theories of technological change.

> "Here is Edward Bear, coming downstairs now, bump, bump, bump, on the back of his head behind Christopher Robin. It is, as far as he knows, the only way of coming downstairs, but sometimes he feels that there really is another way, if only he could stop bumping for a moment and think of it ..."
>
> (Milne, 1926:3)

ADAPTATION OF TECHNOLOGIES IN USE

New technologies are almost never perfect upon initial introduction. Instead, users' efforts to apply technologies reveal problems and contingencies that were not apparent before introduction (Rosenberg, 1982; Dutton and Thomas, 1985). These problems, in turn, require adaptation of the technologies already in use.

A close understanding of the process of adaptation is critical for several reasons. First, users' adaptations to technologies-in-use often help to shape further development and research activities (von Hippel, 1988; Dutton and Thomas, 1985). Second, the operating efficiency ultimately achieved with a new technology depends heavily on users' modifications (Enos, 1958; Hollander, 1965; Dutton and Thomas, 1984). Third, modifications affect not just the technology-in-use, but also its physical and organizational context (Leonard-Barton, 1988). As Van de Ven (1986:591) points out, once in use, new technologies "not only adapt to existing organizational and industrial arrangements, but they also transform the structure and practices of these environments." Thus, only by understanding how such adaptations occur can we begin to build more adequate theories of technological change in organizations.

The process of technological adaptation, however, is not yet well understood, and an important area of uncertainty involves the timing of adaptations. The objective of the current paper is to explore this issue by examining two questions. First, what is the pattern of technological adaptation in organizations? Specifically, do users' modifications accumulate over time in a gradual and continuous fashion, or do they occur in discontinuous spurts or episodes? Second, what organizational forces help to explain the pattern of adaptation observed over time?

Our research finds that adaptation drops off dramatically after an initial burst of intensive activity. Organizational forces such as production pressure and team erosion appear to contribute to this rapid decline. We also find that this decline of adaptation is not irreversible, in that later, unexpected events can trigger new spurts of adaptive activity. These later episodes, however, are also of limited duration. This leads us to posit that the process of technological adaptation is highly discontinuous. Specifically, the initial introduction of technology--as well as subsequent,

unexpected events--provide limited but valuable *windows of opportunity* for experimentation and adaptation. We argue that this discontinuous pattern has important implications for the theory and management of technological change.

EXISTING LITERATURE

The adaptation of technologies-in-use has been studied by several researchers. Their work demonstrates convincingly that it is only through experience with a new technology that users discover its ramifications. Rice and his colleagues argue that, in response to new discoveries, users often "reinvent" the technology and their procedures surrounding it, thus becoming part of the innovation process (Rice and Rogers, 1980) and ultimately increasing their satisfaction with the new technology (Johnson and Rice, 1987). Further research by Leonard-Barton (1988) shows that undertaking such modification is a complex, recursive process, involving "mutual adaptation" of both the new technology and the existing organization, and requiring the active cooperation of both users and technology developers.

For the sake of brevity, we will use the term "technological adaptation" to refer to adjustments and changes following installation of a new technology in a given setting. In keeping with prior research, adaptations may address physical aspects of the technology, as well as users' procedures, assumptions, knowledge, or relationships. These changes may stem from users' efforts alone, or from joint efforts between users and technology developers.

The Timing of Technological Adaptation

Research on the process of technological adaptation has focused mainly on the short period immediately following implementation. Thus, there has been little investigation of how adaptation activities vary over time. Even when authors have explicitly mapped changes over time (e.g., Barley, 1986), they have not focused on identifying general trends in the timing of technological adaptation.

While little direct evidence exists on the timing of changes, the issue of adaptation is addressed in both the innovation and behavioral literatures. Yet these two bodies of research contain conflicting implications about the timing of technological adaptation. The innovation literature describes a relatively continuous pattern of technological adaptation over time, while research into the behavior of individuals, groups, and organizations suggests that the pattern of modifications is likely to be discontinuous or uneven.

In the innovation field, research on experience or learning effects in production (e.g., Conway and Schultz, 1959; Alchian, 1963) reveals regular productivity improvements over time in many industries. This has prompted theorists to suggest that such "progress can be thought of as a continuous process of adaptation" (Dutton and Thomas, 1984:244). However, these results are based on aggregate data that pool multiple technologies introduced at different times and used at different scales of operation. These studies, thus, do not reveal the timing of adaptation around a specific technology.

Studies of industry evolution also treat the modification of technologies over time at an aggregate level. For example, Dosi (1982), Abernathy and Utterback (1978), and Tushman and Anderson (1986) posit long periods of continuous but gradual change in most technologies, fueled in part by existing users who encounter problems and respond with minor improvements. By contrast, only "radical" shifts in technology are seen as extraordinary and rare events (Abernathy and Clark, 1985; Tushman and Anderson, 1986).

Another theme in the innovation literature is more prescriptive. This view suggests that, because many problems emerge only after a technology has been in use for a period of time, adaptive problem solving in user organizations should be gradual and persistent. Rogers (1983) states that when organizations try to rush the introduction process, they fail to identify and correct problems that later hamper productive use of the technology. Thus, "too-rapid implementation of the innovation ... can lead to disastrous results" (Rogers, 1983:364). Similarly, Hughes (1971:152) maintains that "trying to force the pace" of adaptation is counterproductive, while Hage and Aiken (1970:106) suggest that "the longer the elite allow [the] period of trial and error to

continue, the greater the chances of the new program achieving its intended objectives." Finally, Imai (1986) and Johnson and Rice (1987) argue that continuous adaptive efforts are needed to maximize the effectiveness of new technologies.

While the picture of gradual and continuous technological adaptation offered by this research has gained considerable support, it is not compatible with widely-accepted results from behavioral research. In particular, behavioral theories indicate that as organizations, groups, and individuals gain experience, they tend toward increasingly habitual modes of operation. Research at each level of analysis suggests that attention and effort are only occasionally or temporarily devoted to modification of routines. For example, a well-established concept in organizational theory is that organizational actors use experience to create routines that simplify their information-processing needs (March and Simon, 1958). Because such routines determine which environmental cues are noticed and the manner in which information about them is disseminated, increasing experience may lead organizational actors to overlook or ignore many problems or misfits between a technology and its setting (Kiesler and Sproull, 1982; Starbuck, 1989). Groups in organizations also develop tendencies toward routine behaviors. Over time, they become increasingly unlikely to recognize and respond to new kinds of problems (Kelley and Thibaut, 1954; Katz, 1982; Hackman, 1990). Even research teams have been shown to be reluctant to alter a given technical approach once it has been selected, and the longer the approach has been used, the greater their rigidity (Allen, 1966).

At the individual level, research suggests that people's arousal, attention, and motivation to engage in effortful problem solving is not constant over time. Specifically, active problem solving and information processing appear to drop sharply as soon as tasks become familiar or manageable (Langer and Imber, 1979; Kruglanski and Freund, 1983). With increasing exposure, observers tend to "chunk" activities into larger units that convey less information than fine-grained observations, although a sudden surprise can sometimes reverse the process (Newtson, 1973; Louis and Sutton, 1991). Familiarity also breeds routinized response patterns; once activities are

well entrenched, even superficial resemblance to a known stimulus is sufficient to trigger a familiar response (Luchins, 1942).

One of the few scholars to have considered the implications of these behavioral tendencies for technological adaptation is Weick (1990). Following Winner (1986), Weick (1990:21) suggests that "the point at which technology is introduced [may be] the point at which it is most susceptible to influence." Weick argues that "beginnings are of special importance ... because they constrain what is learned about the technology and how fast it is learned" (1990:21-22). However, he also hints that later change is not impossible, because interruptions in the regular use of a technology can increase arousal and thereby change the focus of users' attention.

Taken together, these behavioral insights suggest that the attention and effort required to discover and respond to problems in the use of a given technology may be applied discontinuously over time, and not in the continuous way suggested by the innovation literature. This paper confronts these conflicting characterizations of technological adaptation by examining the timing of adaptation activities in three organizations. The following section of the paper describes the study and research methodology employed. Next, the results of the research are discussed. The final section presents implications for a temporal theory of technological adaptation that takes into account both technological and behavioral aspects of the adaptation process.

RESEARCH DESIGN AND METHODS

Research Design

The data for this study come from three research projects, undertaken by or with the authors, investigating the implementation and use of process technologies in production settings. Each of the three projects focused on multiple technologies within a single organization, and examined use and adaptations by groups or individual users. The studies were matched on four dimensions to ensure comparability (Leonard-Barton, 1990:253): (i) The technologies studied had passed the test of technical and organizational feasibility, hence failure of technological adaptation would not be due to either technical infeasibility or user rejection. (ii) The technologies studied

altered the work in some obvious although not radical ways, hence failure of technological adaptation would not be due to users being unaware of changes in their process technology. (iii) The technologies were open-ended in the sense that users (with or without assistance) had the means to make changes, hence failure of technological adaptation would not be attributable to an inability of users to manipulate their technologies. (iv) The focus of the research was consistent across the three studies, that is, all investigated new process technologies from the time of initial installation of the technology until full and regular use was achieved.

Given these similarities, an advantage of the research design was that it enabled us to examine adaptation of new technologies at both group and individual levels. In two of the research sites, the technologies studied were complex production systems whose implementation, use, and adaptation required group effort. Individuals either could not make changes independently to the technologies (due to technical complexity), or were prevented from doing so by work norms and procedures. Since the technologies were shared, any changes made by an individual would affect other users. In the third site, the technologies studied were stand-alone systems that were used and adapted by individuals. Any change made by one person did not affect others' use of the technologies. Further, the technologies were designed to enable individuals to make changes without special technical skills or facilities.

We deliberately sought variety in the settings studied, the technologies introduced, and the type of users involved so as to enrich the range of insights and to enhance generalizability (Leonard-Barton, 1990; Van de Ven and Poole, 1990). The first study investigated the introduction and adaptation of new capital equipment in eight European and U.S. factories of BBA,[1] a leading manufacturer of precision metal components. The second study examined the introduction and modification of computer-aided software engineering tools in three U.S. offices of SCC, a multi-national software consulting firm engaged in the custom development of computer-based information systems. The third study investigated users' modification of user-customizable software tools at Tech, a research university in the U.S. The technologies studied

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[1] Names of all organizations have been disguised.

range from metal-shaping equipment to graphics software, and are used to produce physical products (in BBA), software (in SCC), and services (in Tech).

Further, the studies encompass organizations with very different priorities and practices. At SCC, where hours spent on software production translate directly into fees billed to clients, the dominant objective is the maximization of production for current revenues. Priorities are more mixed at BBA, where factory personnel are directly responsible for identifying and implementing process improvements as well as for producing products. At Tech, innovation and novelty are central concerns, and many users regard these as more important than current output or productivity. Indeed the technology examined at Tech, user-customizable software, specifically allows adaptation by individuals during use. Many users at Tech have technical backgrounds, and several of those interviewed were involved in the initial development of the technology they were using.

The three settings studied also span geographic locales (U.S. and Europe). This diversity reduces the risk of our findings being merely an artifact of American management practices, and increases the validity of our findings (Downs and Mohr, 1976; Van de Ven and Rogers, 1988).

Research Methods

The three research studies utilized multiple data collection approaches. All three included in-depth field research, ensuring that the concepts and patterns identified were grounded in the experiences and terminology of users (Glick et al., 1990:302). Two of the studies were longitudinal, thus allowing for the situated and processual investigation of technological adaptation as it unfolded over time, without researchers or participants knowing the outcomes of the process being studied (Van de Ven and Rogers, 1988:640). The third study was retrospective and relied on project records and documentation to reconstruct users' initial expectations and their activities over time. The methods used in the three studies are described below and summarized in Table 1 (see over).

Table 1: Sites and Data Collection Methods across Research Studies

	BBA	SCC	Tech
Nature of Site	• Manufacturer of precision metal components • Eight plants in Italy, Germany, and U.S.A. • Outputs: physical products	• Multi-national consulting firm building custom software • Three offices in north-east U.S.A. • Outputs: software	• Research university in north-east U.S.A. • Technical/Administrative Services department • Outputs: services
Process Technology	• Production equipment, e.g., machining cell, molding equipment, and automatic assembly lines	• Computer-aided software engineering tools, e.g., program code generators and screen design tools for a customer information system, state tax system, and a distribution/scheduling system	• Personal computing environments, including text editors, graphic tools, and message handlers for providing consulting services, writing code, and managing user budgets/accounts
Level of Adaptation	• Group	• Group	• Individual
Sample	• 41 project groups	• 5 project groups	• 51 users
Informants	• 89 participants	• 119 participants	• 51 participants
Methods	• 105 semi-structured interviews • 41 questionnaires • Review of company, plant, and project documents	• 125 unstructured and semi-structured interviews • Observation of all five projects • Review of company, project and technology documents	• 51 semi-structured interviews • 153 questionnaires (each participant completed three separate questionnaires) • Automatic collection and analysis of participants' customization activities
Time Frame	• Retrospective	• Longitudinal (8 months)	• Longitudinal (4 months)

Research Site and Method at BBA

BBA is a European-based manufacturer of precision metal components, and a world leader in market share and product quality. The study was carried out in eight BBA-owned plants in three countries: Italy, Germany, and the U.S. Forty-eight projects involving the introduction and use of new process technology were studied. Due to missing data in seven cases, forty-one cases are included in the current sample. Projects were selected on three criteria: (i) they were undertaken during the last four years; (ii) each project represented an investment of $50,000 or more; and (iii) key project personnel were available for interviews. Process technologies included metal turning and precision machining equipment, assembly and inspection systems, thermal treatment and metal forming equipment, and handling systems.

Projects were studied using three types of data. Description and experiences were obtained from retrospective, semi-structured interviews. Interviews lasted from one to four hours and occurred between zero and 18 months after project completion. One-on-one interviews were supplemented by multi-participant discussions where possible. Respondents included project managers, operating and technical personnel, and plant and division managers. Project activities and their timing were reported on written questionnaires (see below). Participants were interviewed both before and after completing questionnaires to clarify their responses. In most cases, respondents made heavy use of project documentation in completing questionnaires. In addition, historical data were collected from company and plant documents. (For further details, see Tyre and Hauptman (1992).)

Research Site and Method at SCC

SCC is a multi-national software consulting firm that builds customized software applications for client firms across various industries such as financial services, manufacturing, retail, and government. The software products produced by SCC typically consist of large transaction-processing systems used to support major administrative activities such as order entry and customer service. SCC's operations are organized by project, with project teams varying from

ten to over a hundred people. Projects last from a few months to a number of years, and product budgets range from one hundred thousand to several million dollars.

The research consisted of an in-depth field study conducted over eight months in three SCC offices located in the northeast U.S. The focus of the study was the introduction and use of Computer-Aided Software Engineering (CASE) tools--a new process technology intended to automate the software production process at SCC. Five ongoing application projects (four large and one small) were selected for detailed analysis. The selection process ensured exposure to the introduction and use of the CASE technology in all major phases of the software production process (requirements analysis, conceptual design, detailed design, programming and testing). Data were collected via on-site observation of participants, unstructured and semi-structured interviews, review of project and software documentation, and informal social contact with the participants. One hundred and twenty-five interviews were conducted, each lasting an average of an hour and a half. Participants spanned SCC's hierarchic levels from the most junior consultants and programmers, to senior project managers. Other key informants from within and outside of SCC included the director of research, sales directors, major client managers, and former SCC employees. (For further details, see Orlikowski (1992).)

Research Site and Method at Tech

Tech is a research university in the northeast U.S. Its educational computing department provides a variety of technical and administrative computing services to the university. Members of this department rely heavily on computer software tools, such as electronic mail, graphics, spreadsheets, and word processing, to deliver services. Tech differs from the other sites in that individuals rather than teams perform adaptations, and individuals' modifications rarely affect others. Hence, there are fewer opportunities for conflicts to constrain adaptive behavior. Tech is thus an extreme case where ongoing adaptation may be most likely.

The study focused on how various users (managers, secretaries, technical specialists, support staff) customized new versions of their software tools. The research was longitudinal and

included three primary data collection methods: questionnaires, interviews, and computer-generated records of customization activity. Each of the 51 users completed three questionnaires over a period of four months, beginning shortly before installation of the new technology. Semi-structured interviews with each user drew on data from the questionnaires and computer-generated records to explore users' customization decisions, and the factors that facilitated or hindered customization (for critical incident technique, see Chapanis, 1969). (For further details, see Mackay (1990).)

Definition and Measurement of Adaptation Activities

At BBA, adaptation activities were defined as actions intended to modify the new technology or relevant aspects of the operating context (including users' skills or procedures). Examples include debugging machine software, designing new tooling, training machine operators, or developing new maintenance procedures. Adaptation could be done through formal channels (such as engineering change orders) or through informal activities. Activities were considered part of normal production when the new technology was used with no effort to alter the hardware, software, or related context and procedures.

As part of the written questionnaire at BBA, respondents rated the level of effort devoted to adaptation activities such as modification of machine software or change in factory procedures. Respondents also filled out a project history in the form of a time-line, showing when activities were undertaken, and when unusual events (e.g., arrival of additional new equipment) took place. For each activity mentioned, respondents noted the level of adaptive activity during the period (rated as high=3, medium=2, low=1, and not significant or none=0). Based on this information, the level of monthly adaptive activity in each project was computed as the sum of the scores for activities noted during that period. Respondents also used the time-line to note major project milestones, including date of equipment installation, date when new equipment was considered "production worthy" (i.e., when it was producing parts on a consistent basis, even if cost, quality or other parameters were not yet satisfactory), and date when the new equipment was considered

fully integrated (i.e., satisfactory efficiency and quality achieved, and operating parameters fully defined). During interviews, respondents also described the specific problems they had dealt with, and when these problems were resolved. Other variable measures for BBA (including summary statistics and correlation matrix) are shown in the appendix.

At SCC, project teams started with a generic skeleton of the CASE tools to be used in software production. Adaptations were defined as any action intended to correct, extend, or otherwise customize these tools to reflect the specific operating requirements of a particular client context. Examples include the addition of batch routines, customization of input and output templates, and modification of file access paths. Normal production work was defined as the use of the CASE tools, with no modification, to generate software and documentation for clients. Textual accounts of adaptations described or observed during the course of the research were captured in detailed field notes.

At Tech, adaptation activities comprised users' individual customizations of their software-based work environments. Customizations involve modifications to a particular work environment that persist though future uses of the software (such as defining a new layout for the screen, or specifying a set of rules for automatically sorting incoming electronic mail, or associating a series of commands with a given function key). Daily use of the software, even if it involved some new behaviors (e.g., trying a different combination of keystrokes) did not constitute adaptation unless changes were embedded into the work environment. Data on the occurrence of customizations over time were collected as described above.

Method of Analysis

Data analysis proceeded in four phases, the first three constituting within-study analyses, and the fourth consisting of a cross-study analysis. First, we searched for temporal patterns in the adaptation of new technologies at each site. Second, we examined the identified patterns for evidence of whether technological problems had been resolved or not. We were particularly interested in instances where adaptation activity ceased before problems with the use of the new

technology were solved. Third, having identified patterns, we searched for evidence of underlying forces that would explain their occurrence in each site. This follows Eisenhardt's (1989) suggestion that observed relationships be validated by seeking reasons for them in the local context.

Finally, we compared the patterns and organizational forces we had identified across the three sites and determined similarities and differences. Consistency of results was evident across multiple investigators using multiple data collection methods (Eisenhardt, 1989) and across two levels of analysis (Staw, Sandelands, and Dutton, 1981). Further, findings from each site were corroborated by evidence from the others. This increases the likelihood that the patterns of adaptation identified are intrinsic to the process of technological adaptation, rather than consequences of a specific organizational approach or particular type of technology.

RESULTS

In this section, we first present evidence of an initial, intensive episode of adaptation, and its rapid decline. Next, we discuss four organizational reasons for this decline of adaptation effort. Finally, we show that later episodes of adaptive activity do occur, but that they are also short-lived.

Timing of Technological Adaptation following Introduction

A striking finding across the three research sites was that adaptation efforts appeared to fall off abruptly after a short initial introduction period. This initial period seemed to represent a finite window of opportunity during which users found it relatively easy to make changes to new technologies-in-use. Afterward, adaptation efforts dropped off, with users finding few opportunities to examine outstanding questions or to review initial choices.

This pattern was echoed in each of the operating environments studied (see Table 2, over). Experimentation was more likely to occur and significant changes more apt to be implemented <u>immediately</u> following introduction than at any later time, despite ongoing problems or additional insights that might be gained over time. For example, at SCC a large amount of adjustment and

Table 2: Evidence of a Limited Initial Window of Opportunity

		Frequency with which the Pattern Occurred in the Sample[1]	
Site	Examples from Research Studies	Number	% of Total
BBA	"We worked on this project for a long time, but the real learning happened mainly during our first week of working and training on the cell." "We got most of the gains in the first three weeks after set-up; after that, it was just a matter of applying what we'd found."	34 groups	86%
SCC	"Our methodology pressures you to keep going forward, so we tend to neglect the refinement of tools or their generalization--sometimes to the detriment of long-term productivity or the development of better tools."	4 groups	80%
Tech	"I used to customize ... [but even though] replacing software is smoother now, I'm so tired, I'm not adventurous anymore." "It's just the way I do it. I'm too lazy to change. It's not that it's hard, it's just that it's not worth the effort."	33 users	65%

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[1] In BBA, the initial episode was deemed limited if there was a month-to-month decrease in the level of adaptive activity of ≥ 50% during the first four months after equipment installation. In SCC, project schedules were examined and team members observed to determine what activities--production or adaptation--they were engaged in over time. This evidence was corroborated and elaborated in interviews with project managers and technology developers. In interviews at Tech, users indicated the point in time when they had reached a comfortable work set up. Examination of these users' customization records then determined any subsequent adaptation activities.

modification took place directly following initial installation of CASE tools into a new project site to adapt them to the particular client organization. These adjustments were accomplished by technical developers, many of whom had participated in the design and construction of the CASE tools. Following such initial adaptation of the tools, application programmers (who were responsible for the actual production of new application software) were brought onto the project. Once these programmers began using the CASE tools as process technology, they halted further changes to the tools, insisting that the process technology be stable and reliable to facilitate their production work. Thus, the programmers became frustrated when technical developers kept trying to perfect the tools. This frustration is evident in two representative comments by programmers:

> [The technical developers] do not want to release stuff until it is perfect. But we would rather they give us something to walk with [so we can begin production work], and then they can enhance it later to give us a racing car. But right now [at the beginning of the project] we need basic transportation.
>
> There is a tendency among our technical developers to spend too much time on technical wizardry, to come up with the perfect solution, the Rolls Royce. But what we really need is something more practical, something that will allow us to get our work done, like a Volkswagen.

Once the technical developers had handed the tools over to the application programmers there was very little further refinement of the tools. Only under extreme conditions (such as a breakdown in the CASE tools) were refinements tolerated and scheduled.

Even when project members recognized the need for ongoing process modifications and incorporated that into their schedules, opportunities for change narrowed over time. This occurred at BBA despite increasing insight and experience among users and developers. For instance, in the case of a very innovative metal shaping machine, users and developers both acknowledged the need for adaptation based on accumulated shop-floor experience. The new equipment was installed in the factory under a development contract stating that machine concepts as well as tooling would be adapted further to fit emergent local requirements. But, once the equipment was installed and operating in the plant, users found that it became difficult to revisit basic decisions made during the development process. They complained that:

> We would get the development engineers in here for a meeting, but after a while it was like too many cooks -- we never got any action.
>
> We are <u>done</u> appeasing them. If they can prove the need, <u>only</u> then is action by us warranted.

Similarly at Tech, the level of customization activity fell off abruptly soon after initial implementation of new software. In particular, exploration or experimentation as a means of learning about the technology virtually ceased after the first few weeks of use. Instead, users quickly settled on a computing environment and actively worked to maintain its stability. One Tech member explained why she had stopped customizing after her initial efforts when she arrived at Tech four years ago:

> It's just the way I do it. I'm too lazy to change. It's not that it's hard, it's just that it's not worth the effort.

Data from BBA provide further detail on the dimensions of the window of opportunity provided by initial introduction of technology. Figure 1 shows the pattern of adaptation undertaken over time for 32 projects.[2] To derive the curve, we calculated both the total level of adaptive activity reported for a given project, and the percent of the total completed during the first, second, etc., months following installation. Calculations were based on month-by-month measures of adaptive activity from project timelines and written questionnaires. Results by month were then averaged across projects. They show that on average 28% of all adaptation undertaken in a project was completed during the first month following installation; an additional 16% was completed in the second month, and so on. Thus, an average of 54% of all adaptive activity was completed in the first 2.8 months, or only 12% of the average total time to full integration. The time period of this initial window was remarkably consistent across projects: despite the fact that the time to full integration varied widely, only four projects (10%) maintained their initial activity level for more than four months.[3] Further, there was no relationship between the size of the project (as measured by dollar investment) and the duration of the initial episode of adaptation ($r = .06$, ns).

A possible explanation for this pattern could be that adaptation activities decreased after a short time because all (or most) problems had been identified and solved by then. This was not the

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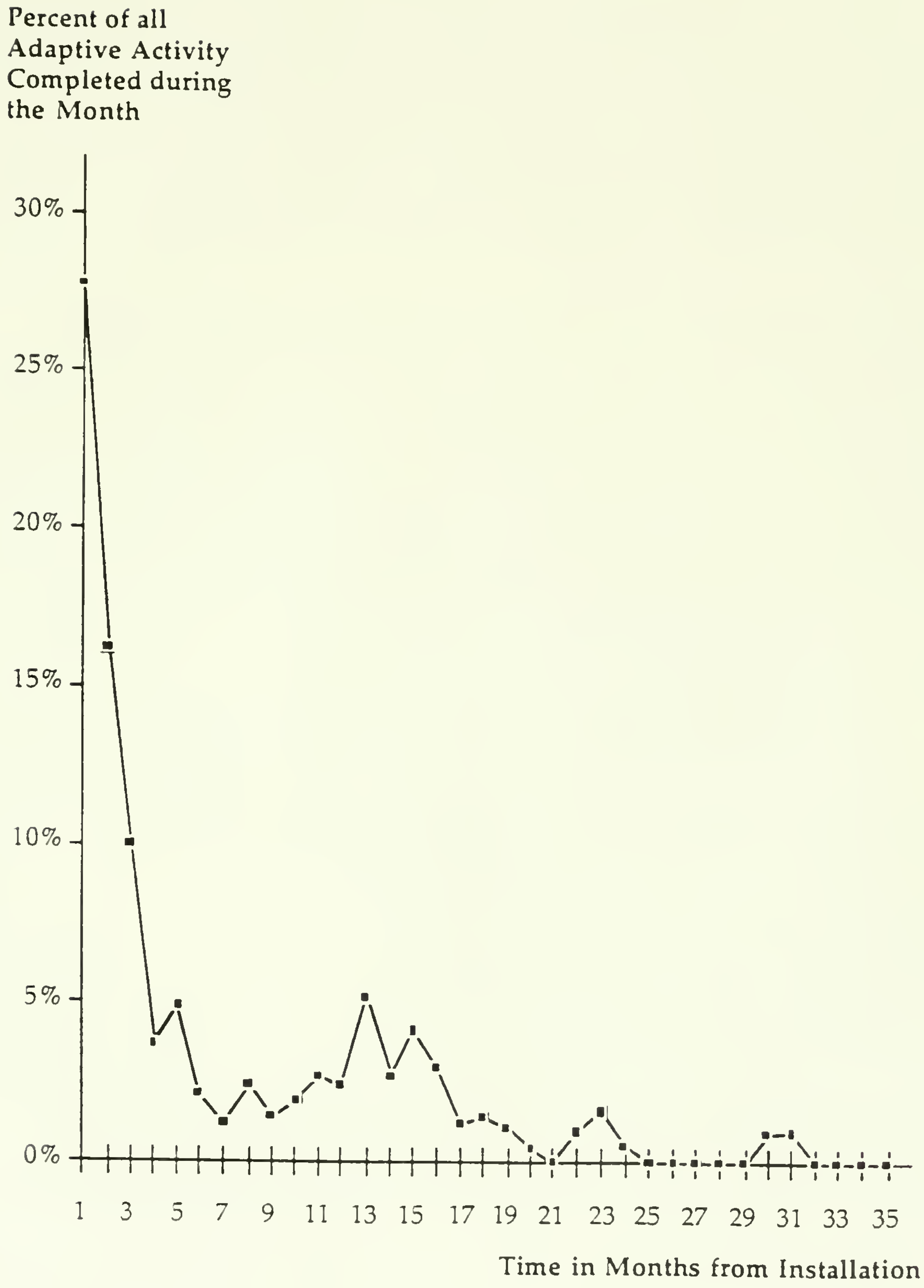
[2] Nine projects were deleted from this calculation because their total time to full integration was less than twelve months. While each of these projects reflected the pattern discussed here, including these shorter projects would have positively biased the results, since adaptation necessarily ceases early when the project is short.

[3] The initial episode of adaptation was defined as ending when the month-to-month change in the level of adaptation effort was negative and greater than 50%. New episodes were defined as beginning when recorded adaptation activity increased by more than 100%, or began again after a period of no such reported activity.

Figure 1: Monthly Adaptive Activity as a Percent of Total Adaptive Activities in BBA

(N = 32 projects)



case. On average, the new technologies took almost 14 months to be considered production-worthy (i.e., producing parts on a consistent basis), and they required another eight months to be fully integrated into the production process (all operating parameters satisfactorily defined). Further, respondents' reported an average of five problems still outstanding at the end of the first wave of intensive adaptation. Typically these were significant issues, such as software problems, undefined procedures or tooling, and malfunctions in automatic features. In several cases, respondents indicated that attention to problem solving fell off even though the machines remained inoperative.

In sum, evidence from all three sites reveals that the introduction of a new technology opens a brief window of opportunity for an intense, initial episode of adaptation. Below, we examine evidence relating to the organizational forces that shape this pattern of adaptation. Four forces were consistently mentioned or observed in the three sites: (i) the pressure of production, (ii) the constraining effect of habitual patterns of use, (iii) the adjustment of expectations based on experience, and (iv) the erosion of team membership and enthusiasm over time.

Organizational Forces Influencing Timing of Technological Adaptation

i. Production Pressure Impedes Adaptation

Data from all three studies suggest that one of the most powerful forces behind the failure of continuous modification was that, once technology was put into use, production activities quickly began to siphon off the time, energy, and resources that were needed to identify and solve new problems. Thus, even when users wanted to continue to improve the technology and its application, they felt they could not due to external pressures. (Table 3 shows the nature and incidence of this effect, and describes the measures used.)

At SCC, for example, both programmers and technical developers were acutely aware that making changes to the tools or experimenting with different technology options meant time away

Table 3: Evidence that Production Pressure Impedes Adaptation

Site	Examples from Research Studies	Frequency with which the Org. Force was Mentioned in Sample[1]	
		Number	% of Total
BBA	"Success tends to be measured by production. Now production loves [this machine] so engineering can't get in to play. There is lots of experimentation and further improvements that are possible, but we can't get in there to do them." "This project was a problem because we tried to mix testing and doing production. It meant that [the engineer in charge] had his hands tied--he could only make small changes, attend to small problems."	16 groups	40%
SCC	"The project's budgetary and time restrictions cause problems in scope. It forces a narrow view on [us]. It is frustrating for us as we see and know what should be done to improve, refine, or generalize the tools but we can't do that as we are required to get the specific application system done." "The managers didn't allow any changes or deviations during functional specification [a stage in production]. That's because they are working under management priorities and tight constraints such as time and budget. ... But we could have gotten improvements though, as the [tools] were not great."	3 groups	60%
Tech	"The biggest barrier to customizing is finding the time to do it. Life at Tech is like page thrashing [a computer condition that occurs when the operating system is overloaded]. I handle personnel first, otherwise I die; then administrative things. I have no time to read. It's amazing what I don't have time to do. " "[My boss] doesn't pay me for that [i.e., customization]."	32 users	63%

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[1] Production pressure was identified in all three sites by analyzing interview transcripts and noting where respondents made explicit, voluntary reference to the difficulties of undertaking adaptive activities due to production pressure. Further information was obtained through questionnaire responses in BBA, by analyzing answers to the open-ended questionnaire item "what factors were most detrimental to progress [in this project]?" and by seeking clarification of questionnaire responses such as "this project was a frustrating experience." Mentions of production pressure on a project or for an individual were counted to arrive at the above frequencies.

from producing application software. Since software was produced on-site to tight client specifications and time frames, SCC could not afford to let schedules slip. According to SCC managers, once software production begins:

> We push ourselves too hard. And the problem is that as a result we don't have time to learn how to do something new, or develop new tools.

Such problems are consistent with SCC's intensive focus on short-term productivity performance. More surprising is that similar patterns emerged at Tech. Despite users' stated preference for ongoing innovation and refinement, these same users were unlikely to adapt operational systems once they were in production mode unless forced to do so by external events. One user commented that making changes is something one does when one has "leisure time," while according to another typical user:

> [Customization] is the last thing on the queue. I feel guilty doing it. I feel that I should be doing something useful like testing an application [i.e., production work].

In part, such comments reflect the conflict between the certainty required by the production process, and the uncertainties involved in making changes to the technology. Users engaged in production perceived a significant risk that a seemingly straightforward adaptation would balloon into a major project. One user explained that due to work demands, "I can't afford to be a guinea pig." Further, users recognized the potential to make a mistake that would cause greater problems than the one they were trying to fix. One Tech user commented on his prior experiences of adaptation that had resulted in major rework and therefore lost productivity:

> So I gave up [on customization]. ... There has to be a compelling reason for me to go back over that threshold.

At BBA, an engineer at one of the German plants described the conflict between production and adaptation in the following terms:

> Once we got the equipment into the factory, time to do important engineering work was squeezed out by everyday work to keep things running.

Some users expressed the conviction that, since near-term production requirements left them no time to pursue further changes, extending the time frame for implementation would provide more opportunities for adaptation. However, our data suggest that this was not the case. As we discuss

below, we found that when users took a longer time to complete the introduction of the new technology, further barriers to adaptation often arose.

ii. Patterns of Use Congeal and Become Constraining Over Time

Another barrier to ongoing change in all three operating settings was the fact that users quickly adapted themselves to their new process technologies. As users gained experience, they established stable routines, norms, and habits for using the technology which decreased the need for discussion, coordination, or effortful decision making. This constrained further exploration and adaptation, apparently stunting the "learning" process that was expected by many managers.

The constraining effects of increased experience were pronounced at BBA. For instance, in the case of one novel grinding machine, productivity benefits were predicated on the integration of the new equipment into an existing automated processing line. However, initial integration problems forced project engineers to install a temporary manual "workaround." Although the manual workaround was inefficient, operators quickly learned to depend on it. Later, when the grinder was finally fully repaired, users clung to the system they had become accustomed to, and prevented engineers from dismantling the "temporary" workaround. Because of this, the new grinder's capabilities for efficient, high-precision machining were never fully developed and exploited.

The same tendencies surfaced among software users at Tech. Once functions became habitual or automatic, users resisted further change. To illustrate, when new software versions were installed, users often simply retrofitted the new versions to mimic functions of the familiar, original version. For example, when a new screen management system was installed at Tech, 78% of the users found a way to maintain their existing patterns of working--either by retrofitting the new screen management system to resemble the old one (60%), or by modifying their start-up procedures to invoke the old screen management system instead of the new one (18%).

Users often hastened the process of making their use of the new technology habitual by "customizing themselves" to the software as they first received it. One manager at Tech noted,

> [Many people] prepare personal cheat sheets, thus effectively customizing themselves rather than the software, for the uses of the software that they typically make.

This manager pointed out that such an approach was cumbersome, and so it was not likely that users would change their "cheat sheets" frequently. Indeed, once a given approach had been learned, many users were very reluctant to change. One user explained that he had wanted to learn the manual commands before automating them via customizations. But, having learned the commands, he purposefully avoids automating his software because "now that I know things, I've learned the keyboard commands, I'm happier." He no longer sees any need to perform the customizations.

Where production pressures were especially intense, the tendency for patterns of use to congeal was exaccerbated. In SCC, users chose tool repertoires that enabled them to meet production deadlines, and then quickly became dependent on those tools in their current form. They resisted ideas for improvements or adjustments that threatened to disrupt established ways of using the system. When such changes were occasionally introduced, users often tried to ignore them by bypassing the new versions to work with the original technology. A project manager noted that:

> We [were frustrated] during the spec stage, as the technical developers wanted continual changes to the tools... So we decided that we would just continue with [our version of the tools] so that we could get on with our schedules.

Even if the new tools were potentially superior, programmers admitted that "We often go around it [a new module of the tools]," because they were not willing to bear the cost of learning a new technique. The fact that new tools often contained system errors also induced users to stick with existing sets of CASE tools. A programmer explained:

> When things went wrong with the tools, we used to circumvent the tools left and right so that we could get on with our work.

Table 4 shows evidence of this effect across the three sites and describes the measures used.

iii. Expectations Adjust to Fit Experience

In many of the projects studied, expectations regarding the performance capabilities of a new technology changed over time. Specifically, expectations were amended to fit actual capability

Table 4: Evidence that Patterns of Use Congeal over Time

Site	Examples from Research Studies	Frequency with which the Org. Force was Mentioned in Sample[1]	
		Number	% of Total
BBA	"They had gotten used to running those parts on [that machine] and they liked it that way." "[At first] we used our existing know-how just to get the new machines up and running. The idea was that we would get back in later to do the fine tuning. But now the operators depend on the machine -- it's built in, they don't want to change. So the fact is that we have not gone back."	15 groups	37%
SCC	"We [were frustrated] during the spec. stage, as the technical developers wanted continual changes to the tools. ... So we decided that we would just continue with [our version of the tools] so that we could get on with our schedules." "When things went wrong with the tools, we used to circumvent the tools left and right so that we could get on with our work."	4 groups	80%
Tech	"I got a set of custom [settings] from [a colleague] about 4 years ago. Now they're ingrained. It's just the way I do it." One long-time user originally used a very cumbersome, daily log-in procedure for using her system. Even when informed that the complex procedure was no longer necessary, she was reluctant to change because she simply did not view her regular routine as a problem: "I'm quick and it takes less than a minute."	40 users	78%

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[1] Evidence that patterns of use congeal was identified in all three sites by analyzing interview transcripts and noting where respondents explicitly indicated that pressure to avoid or cease adaptation was internal not external. That is, statements such as "I was used to it, so I just kept it like that" were counted as instances of congealing as these reveal that the use of the technology had become habitual. Statements such as "I wanted to change it, but there was no time," were counted as instances of production pressure and considered in Table 3. Further, evidence of congealing in Tech was obtained by analyzing participants' records of customization activity over time (captured and archived automatically by the computer system).

or achievement. Therefore, as time went on, problems or opportunities often disappeared from view -- not because the technology was improved, but because standards were lowered or interpretations amended. (Table 5 shows the nature and incidence of this effect, and describes the measures used.)

For example, one project at BBA involved the introduction of an advanced precision grinding machine. The original objective of the project, according to both development engineers and original project documentation, was to develop the capability to machine all five "faces" of a particularly complex metal part. Indeed the plant manager had explained that "grinding all five faces was the key objective in this project," more important than the productivity improvements expected from the machine. Developers had demonstrated five-face grinding in the lab, but they had not been able to test whether the machine would hold required tolerances under actual plant conditions. Therefore, the project team agreed to continue development in the factory. A development engineer was assigned to the plant to work on five-face grinding.

But as time wore on development was blocked by the very success of the project on other criteria. Within several months the new machine was operating at speeds up to six times those of the equipment it had replaced, even without the addition of five-face grinding. Production personnel found they had sufficient slack to run complex parts through additional grinding machines to complete all five faces. Users soon reconstructed the original project objectives to fit this new reality. Several of those interviewed denied that five-face grinding had ever seriously been considered as a key project objective. As one engineer commented:

> We only tried doing all five faces on this machine as an experiment. It was sort of an add-on that did not work.

The supervisor in charge of the machine was even more adamant. When he was interviewed some 18 months after installation, he stated that:

> [The machine] is now doing exactly what we purchased it for -- we are getting the productivity improvements [that we wanted].

Users at Tech also displayed a variety of ways in which experience with a new technology affected their perception of potential problems and opportunities. For example, one user explained that he had tried to use a special feature of the software called Zephyr when his system was new,

Table 5: Evidence that Expectations adjust to fit Experience[1]

Site	Examples from Research Studies	Frequency with which the Org. Force was Mentioned/Observed in Sample[2]	
		Number	% of Total
BBA	A new grinding machine was purchased to do "five face" grinding, but after one year this had not been achieved. Productivity, however, was high. Users' assessment was that: "This machine is doing exactly what we purchased it for." In a project involving a high-end precision grinder, users were having trouble getting correct dimensional finishes. The project engineer explained: "But once we decided that the finish was okay as it was, then we figured that we need not and in fact could not improve beyond what we were getting!" "The fact that this is an optimized system was proved by the corporate post-project audit -- it showed that we are getting 138% payback!" In contrast to this project manager's assessment, engineers pointed out that many issues had not been attended to, most notably the automated tool changing system--considered a major feature of the new tool--had not been debugged and was not in use.	10 groups	24%
SCC	Programmers adjust to the limited functionality of the CASE tools they are given to work with. One observed: "it's like playing with a pack of cards. You have to pick a card out of the 52 available; you can't pick the 53rd." According to a technical manager: "They [the application programmers] would patch things in the places where they couldn't get the tools to work. So over time ... use of the tools would atrophy."	2 groups	40%
Tech	"I spent two days on Zephyr and it never worked. ... Once burned off, I don't come back unless it's a real pain." One user was especially keen on a certain function, but it failed early on. He assumed it had failed for good, and never thought to ask if it had been repaired and reinstated. In fact, it had been fixed and was in working order, and was being applied by other users.	9 users	18%

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[1] Since initial expectations are often not made explicit, many examples of this change in expectations are invisible to users and researchers alike. Hence, the number of instances where this organizational force was detected is likely to be a conservative estimate of its actual occurrence.

[2] Evidence of this organizational force was obtained in BBA and SCC from project documentation (e.g., financial justification, schedules, and spec. sheets) and interviews with project managers and technology developers. Evidence in Tech was obtained from user interviews which yielded comments about resignation and rationalization.

and that he had failed to get the feature working satisfactorily in his first two days of trying. Months later, he explained that he had no interest in trying Zephyr again: "Once burned off, I don't come back..." In another case, a manager noted that one of the software functions he used most had failed some time ago and was no longer available. In fact, the function had been repaired and was again available (other users were employing it at the time), but since this user's expectations had already adjusted, he had not thought to inquire whether the problem had been corrected.

iv. Erosion of Team Membership and Enthusiasm

Another barrier to adaptation was that when projects bogged down, the relevant teams tended to dissolve and lose momentum. (Table 6 shows the nature and incidence of this effect, and describes the measures used.) For instance, one project at BBA involved the introduction of a novel thermal-forming approach for producing complex metal parts. The lead project engineer explained that:

> Our approach was to create a team consisting of a manufacturing engineer, a service technician, and a skilled operator to put the machine into production. But the slow rate of production start-up was a problem. Each time the machine went down, we had to disband the team and send the people to other activities while we waited for new parts or tools. We got the people back in when we received the new tools, then sent them out when the new tools broke. That really hampered our learning. And, you do not always get the team members back. We strove to keep the group together, but sometimes individual people became involved in other, more urgent projects that were not dragging on as much.

Furthermore, as another project manager stated, it was difficult to keep the team focused:

> It's easy to get plant engineers to start working on large projects, but it's extremely difficult to keep attention focused on the details over time. People tend to drift away to other problems when the work is only half done.

On another BBA project, modifications to the technology-in-use stopped once the engineers returned to their normal assignments. A project participant noted:

> For the first three months, we had a really intensive effort -- the engineers [assigned to the project] were 100% on. But after that, well ...

Similarly at SCC, once projects reached a stage where the CASE technology had been installed and programmers began using the technology to do their production work, many of the technical developers requested assignment to other projects with "more interesting" work. One technical developer commented:

Table 6: Evidence of Team Erosion over Time

		Frequency with which the Org. Force was Mentioned/Observed in Sample[1]	
Site	Examples from Research Studies	Number	% of Total
BBA	"We strove to keep the group together, but ... people became involved in other, more urgent projects that were not dragging on as much." "Since the major problems were solved, there was no impetus for engineering support to help on other improvements.. and once [they] left, a lot of effort just never got done." "Once [the laboratory engineer] left, it was much harder to make changes on our own." Once the key engineers leave the project team, "they always plan to get back in [to deal with unfinished issues], but the problem is, they <u>don't</u> go back."	22 groups	54%
SCC	"I got transferred to another part of the project as all the creative work had been done there, and we knew they [the tools] basically worked. ... So I got involved in developing the front-end to [the product] which is much more interesting and challenging for me." "The more stable the development environment is then the less technical support the development team needs, and the less technical developers I need on the project."	4 groups	80%
Tech	not applicable -- individual users only; no teams		

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[1] Evidence that teams dissolve over time was identified in BBA and SCC by analyzing interview transcripts and noting where respondents made explicit, voluntary reference to the difficulties associated with the turnover of production personnel, a change in project management, or the transfer of engineers/technical support staff to other projects. Further information in BBA was obtained through questionnaire responses, by analyzing answers to the open-ended questionnaire item "what factors were most detrimental to progress [in this project]?" and by seeking clarification of questionnaire responses such as "this project was a frustrating experience." Further information was obtained in SCC through observation, where the actual turnover of personnel (most usually technical developers) was directly observed.

> I got transferred to another part of the project as all the creative work had been done, and we knew they [the tools] basically worked. ... So I got involved in developing the front-end to [the product] which is much more interesting and challenging for me.

Another issue was that technical developers were reassigned to production tasks on the project once the process technology was sufficiently stable. Their new task assignment effectively precluded further work on the process technology. For example:

> [The project manager] is pushing to disperse us [the technical developers] across the application teams to help with ... code production.

Such tendencies blocked the implementation of detailed process technology changes after the initial period of installation and adjustment.

Timing of Subsequent Technological Adaptations

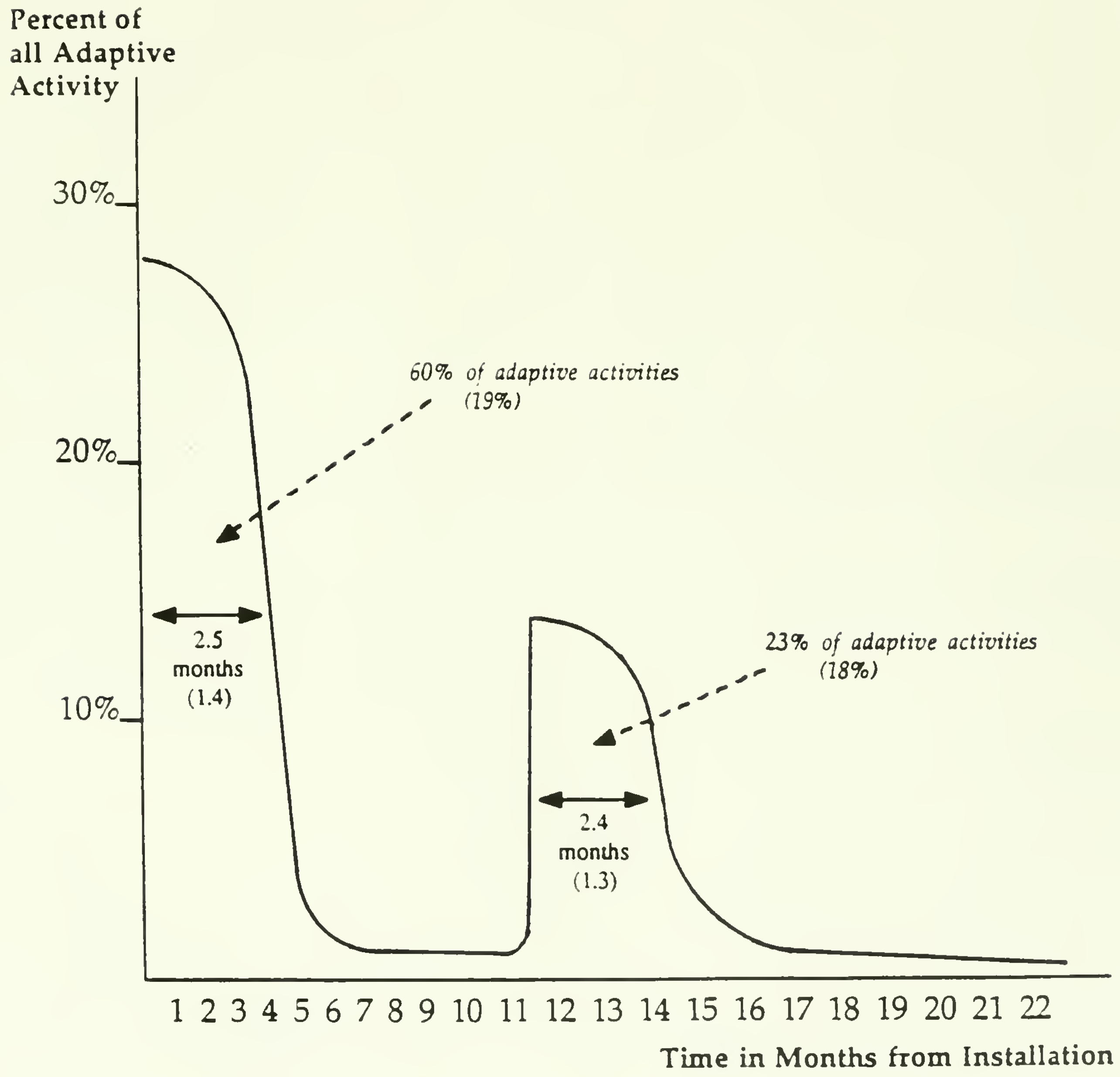
The data presented above suggest that adaptation becomes increasingly difficult as process technologies become more thoroughly embedded and routinized in the user environment. Regular use of the technologies we studied was not consistent with the kind of mental and physical effort required to develop and implement new ideas. Yet, paradoxically, routine use was also <u>necessary</u> for ongoing adaptation; it provided the raw data that, if utilized, could lead to improvements in the technology or the way it was applied in the local context.

In each of the sites studied there was evidence that users did, at least occasionally, reexamine existing technology and make important modifications after gaining additional experience. At BBA, 31 of the 41 projects studied demonstrated a later spurt of adaptive activity. In four of these cases more than one later spurt of activity was reported.

Later episodes of adaptive activity, like the initial episode, were of limited duration. At BBA these later spurts of activity lasted for an average of 2.4 months (similar to the initial period of 2.5 months, or 2.8 months for the 32 longer projects), and there was little variation across projects (there were only two instances where the episode lasted longer than three months). Figure 2 shows the general pattern of adaptation observed at BBA. As shown, the second spurt of activity began, on average, about 11 months after initial installation, and accounted for an average of 23% of all reported adaptive activities.

Figure 2: Episodes of Adaptation in BBA

(Schematic graph showing average timing of adaptive activity)
(N = 41 projects)



Note: Standard Deviations in Parentheses

In almost every case, the existence of a later spurt of adaptive activity at BBA was associated with a specific, disruptive event in the project life cycle (see Table 7 for evidence and a description of the measures used). Most often, respondents reported that attention was refocused on the technology and its mode of use by the addition of new machines or tools to the same cell or line. In other cases, new project requirements or changed factory procedures forced participants to revisit decisions made earlier and to improve technical capabilities or procedures. In a few cases, a new episode of adaptation was induced by an unusual but not disruptive event, as in two cases where the arrival of new, unassigned technical personnel provided extra resources for handling outstanding problems with the process technology. Management action also triggered some new adaptive activity. This was generally linked to the arrival of new managers at the company or local level. For example, one new machine was plagued with problems for more than two years because users were unable to reconfigure the technology on the shop floor. As the factory-level project leader explained:

> We wasted a huge amount of time ... We would make some small adjustment but then, due to difficulties at a more basic level, something else would happen or a tool would break... The whole process accomplished very little until we were able to rethink some of the early choices and assumptions.

Significantly, the opportunity to "rethink" early choices came about only once a new group of divisional managers took over and focused attention on the troubled project. In only one case did existing managers explicitly instigate further adaptation efforts.

At Tech, users were generally reluctant to alter software systems once a serviceable configuration had been found. Yet most users (49 out of 51) did note that specific events could refocus their attention on the software and trigger further customizations. As at BBA, triggers were often disruptive or aberrant events, such as the release of a new system or the breakdown of an existing one (see Table 8 on page 32). For example, in one case an experienced user was given a special assignment that required him to process greatly increased amounts of data in a very short time. To cope with the resulting crisis, he created a new set of program rules that automatically sorted, labeled, and routed his electronic messages. Once the special assignment was completed, he discovered that these new rules significantly improved his effectiveness even under

Table 7: Subsequent Windows of Opportunity--Triggering further Adaptation at BBA

# of Instances	% of all Instances[1]	Trigger
14	40%	New machines or tools added
6	17%	New product requirements
6	17%	New management action (intervention by new plant or senior management)
3	9%	New factory procedures
3	9%	New personnel or break in schedule create slack resources
2	6%	Machine breakdown
1	3%	Existing management request action

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[1] Identification of triggers was based on interviews and users' designation of critical events on the questionnaire timeline. New episodes were defined as beginning when recorded adaptive activity increased by more than 100%, or began again after a period of no such reported activity. Episodes were defined as ending when the month-to-month change in the level of adaptive activity was negative and greater than 50%.

Table 8: Subsequent Windows of Opportunity--Triggering further Adaptation at Tech

# Times Mentioned	% of all Users Mentioning this Issue[1]	Trigger
34	68%	New system release or changes to existing systems
22	43%	Saw an opportunity to automate commonly-used routines
21	41%	Existing system becomes too annoying or frustrating
20	39%	Exposure to other users' ideas
15	29%	Problems with existing systems
11	22%	Thought of something new

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[1] Identification of triggers was based on users' responses to an open-ended interview question about what provokes subsequent adaptation activity. Specifically, users were asked "What are the circumstances under which you choose to modify your work environment?" This column adds to more than 100% because each user listed more than one trigger (the average number of triggers mentioned per user was 4.4) Additional triggers were mentioned but are not listed here as they were noted fewer than ten times each

normal circumstances. In another instance, a user who normally did not travel went on an extended trip. Upon returning, he was overwhelmed with accumulated electronic mail messages, and he quickly developed new rules to deal with the situation. He soon discovered that these modifications proved useful additions to his regular work routine.

In other cases at Tech, opportunities for change were created when normal workflow and thought patterns were interrupted by outsiders. For example, when a visitor asked whether the electronic mail system routed messages reliably, some non-technical users expressed surprise and concern that the technology might not work correctly. As a result of this interruption, they began to undertake new experiments with their technology. Sometimes the impetus for further adaptation effort was internal. A significant number of users modified their system when they thought of new ideas, or when old procedures simply became too frustrating.

Disruptive events or new ideas, however, did not always trigger changes that advanced the technology. As noted earlier, the most common form of adaptation at Tech following new system releases was a retrofit that enabled users to continue to operate as if no change had occurred.

At SCC there was evidence of only one incident of technological adaptation during a later phase of a project. This is not surprising given that formal procedures explicitly dictated that the CASE tools be defined at the beginning of the project and then held stable. Even after projects were complete, there were few opportunities to revisit questions about the technology and its mode of use. A senior consultant commented that once projects were finished:

> We are never asked to reflect on the problems we've had... No one asks how are these tools used after their time so we can fine-tune the process or correct and eliminate the problems.

Yet even at SCC, a crisis could create an opportunity to rethink earlier choices. In the one project where users did seek to modify the process technology later in the project cycle, they did so because the existing CASE tools had ceased to produce useful output. Many production requirements had changed over time, and the CASE tools in use no longer reflected the current requirements. Eventually, project management recognized that the tools had become inadequate to the task, and technical personnel were called in to help modify the existing technology.

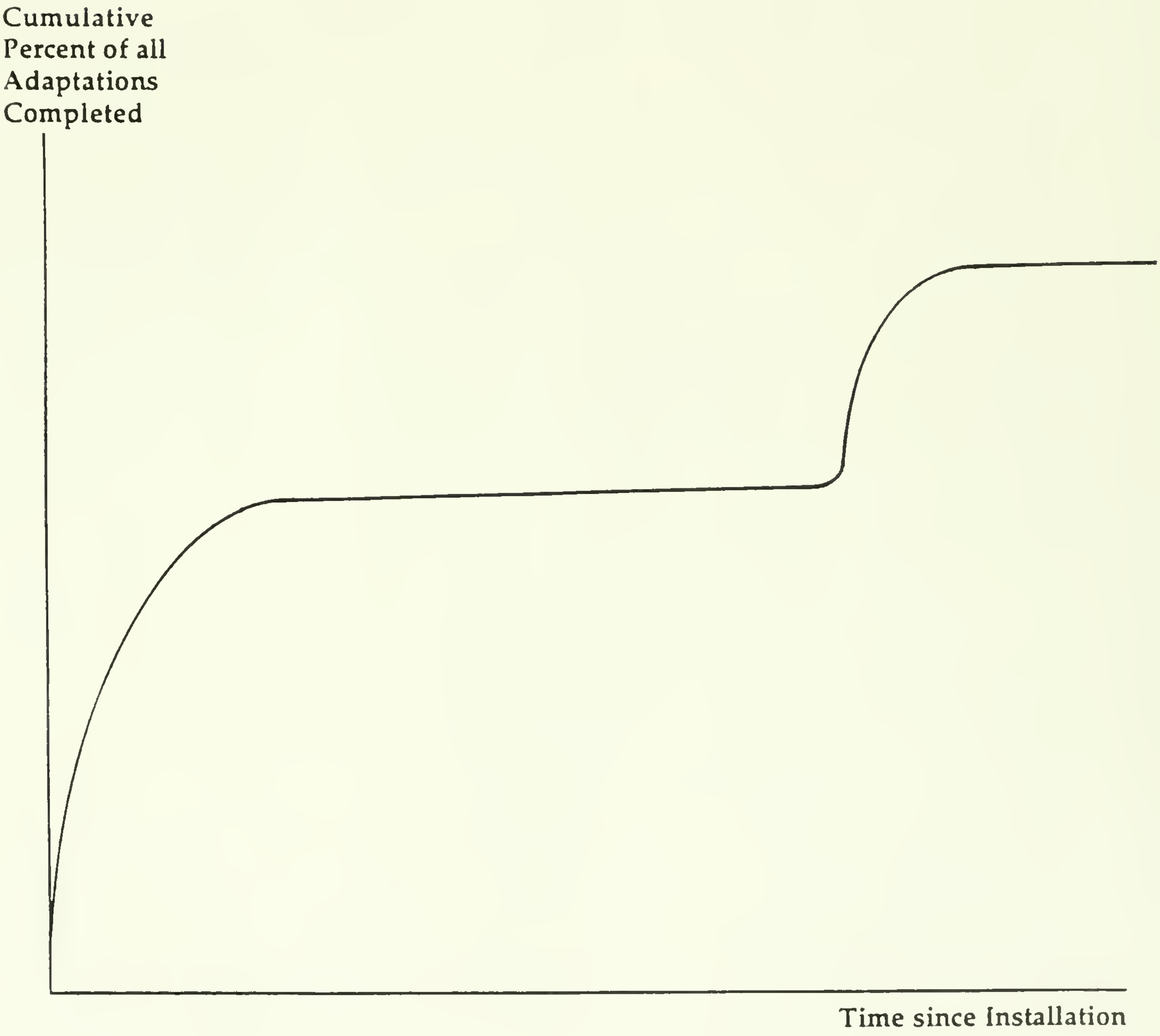
DISCUSSION AND IMPLICATIONS FOR THEORY

This research has confronted an apparent conflict in the literature over the timing of technological adaptation in organizations. While innovation research describes a gradual, continuous process of modification, behavioral theory indicates that the process may be much more discontinuous. Our results reveal a pattern of adaptation that is distinctly discontinuous, or episodic, as illustrated in Figure 3. While full integration of a new technology may take several years, adaptation attention and effort are not applied consistently over that period, nor do they taper off gradually. Rather, they are concentrated in short spurts during the period. This finding suggests that what appears, at an aggregate level, to be "continuous improvement" may more accurately be described as the sum of discrete episodes of adaptive activity carried out at different times and applied to different technologies.

We find that the initial episode of adaptation is especially important. The decisions and directions taken during a short period following initial installation--a period that may be as brief as two to three months--are major determinants of how the technology will be used by the organization over the longer term. Indeed, it appears that further adaptation is rare unless some sort of unusual event or discovery (such as a breakdown in the technology, the entry of more new technology, a managerial intervention, or the culmination of users' own frustrations) triggers subsequent episodes of adaptive activity.

We have called the initial period following installation a window of opportunity. It is a window in the sense that, for a time, users can view the new technology as a distinct artifact. Initial experiences yield insights about the technology and its relationship to the context of use. Later, users' views are obscured by integration of the technology into a complex production system, and by the habitual behaviors that sustain it. The initial period also represents a window because during this limited time users (often assisted by technical experts) can reach into the technology to change it. Once the new technology is assimilated into the larger production process, change threatens to disrupt the habits and procedures that support productive work. The production process and the

Figure 3: Relationship between Time and Users' Adaptation of Technology



specific technology used to support it congeal, and the window of opportunity is closed. Subsequent episodes of adaptation occur only occasionally, and typically last only a short time.

While more work is needed to corroborate these findings, we suggest that the episodic pattern of adaptation observed in this study may be inherent in users' efforts to deal with new technologies, and not just a function of a given managerial approach. Our results find support in existing research on the management of attention and sensemaking among individuals and groups in organizations. For example, our findings coincide with Weick's proposal that "beginnings are of special importance" in determining the way that users make sense of new technologies and the problems that arise (Weick, 1990:21). Weick points to Barley's (1986) work to support his argument, and indeed the metaphor of windows of opportunity may be helpful in explaining the divergent responses to CT technology that Barley observed in two hospitals. From our perspective, the window of opportunity immediately following installation of new technology was exploited at Suburban Hospital: within two months of receiving the CT, a new mode of operating and interacting had been established. At Urban Hospital, by contrast, there was little change within the first two months following installation. Although later adaptations occurred in both settings, the presence or absence of an initial episode of adaptation may have fueled Suburban's more dramatic reconfiguration, and made change at Urban slower and less significant.

At a more general level, this study addresses the question of how organizational actors allocate attention to regular production work as opposed to the development and improvement of technologies and procedures. Our study contributes to this issue in several ways. First, it supports previous findings that the assumptions, behavior patterns, and practices governing the execution of production tasks are defined early and congeal quickly. This pattern has been detected among organizations (Hedberg, Nystrom and Starbuck, 1976), groups (Gersick, 1988; Bettenhausen and Murninghan, 1985) and individuals (Luchins, 1942; Langer and Imber, 1979). Second, our study highlights the importance of interruptions in the form of problems or surprises. Interruptions create opportunities for organizational actors to mobilize their accumulated experience in-order to redefine their task, their approach, or the tools applied. A number of researchers have

pointed to the power of such interruptions. For example, Gersick finds that groups working under deadlines often radically revise their approach when they have used up half their time, because "the midpoint appears to work like an alarm clock" (1988: 34) that interrupts the routine flow of work and encourages reexamination of the process. By contrast, groups that do not have such a built-in alarm can get stuck in unproductive work patterns; it is more difficult for them to turn their negative experiences into usable insights (Hackman, 1990). Bettenhausen and Murninghan (1985) find that when group members threaten or challenge group norms, they create an opportunity to consider new alternatives and to build a new, stronger consensus. At the individual level, unexpected events have been shown to occasion revision of habits and assumptions (Langer and Piper, 1987; Pyszczynski and Greenberg, 1981; Louis and Sutton, 1991).

Thus, it appears that interruptions can serve an important role by triggering actors to review and revise their procedures or processes. Nonetheless, an interruption provides only a window of opportunity; the opportunity must also be exploited. We noted that when discrepant events were evaluated from a production-oriented perspective, they often appeared to be useless disruptions which users strove to ignore. Research at the individual (Luchins, 1942; Langer, 1983; Langer and Piper, 1987) and organizational (Dutton and Jackson, 1987; Meyer, 1982; Weick, 1990) levels shows that how an unexpected event is framed or introduced helps to determine whether it is interpreted within existing routines or used to create new ways of understanding. Likewise, managers may be more likely to encourage adaptation when they frame interruptions and surprises as noteworthy and potentially informative. Unfortunately, managers seldom take advantage of this fact. In our study, for example, there were few instances where managers actively intervened to turn unusual events into opportunities for change.

It is important to note that our research was carried out exclusively in Western organizations, which may manage adaptation differently from other (e.g., Asian) organizations. Therefore, it is interesting that our findings are consistent with descriptions of several "best-practice" Japanese approaches. For example, in a study of production practices at Toyota, Hall (1983:199) notes that when a new machine or process is first installed, the factory makes "a direct

engineering assault ... [that] prevents the need to dribble a constant stream of engineering changes through the formal system over a long time." Further, Clark and Fujimoto (1991: 189) found that in Japanese automobile companies, "pilot runs are relatively short, and the pilot run periods are compressed." Similarly, Ogawa's (1991) study of a leading Japanese steel company points out that the test period should be seen as a limited opportunity to surface all major problems with new technology, since incremental changes can be hard to implement later.

These authors report that in the Japanese companies they studied, adaptation during normal production is carefully controlled to stay within prescribed limits. Most of the time, the new process is run in a relatively stable fashion. Modifications are "lumped" into special periods marked by plant shutdowns, model changeovers, or the imposition of new operating standards (Hall, 1983; Imai, 1986; Clark and Fujimoto, 1991). Thus, conflict between production and adaptation objectives is explicitly managed and even exploited -- it is not ignored or obscured.

A Final Note

Our findings on the pattern of technological adaptation are remarkably consistent across both groups and individuals, and across different organizational and technological settings. An intriguing possibility is that these findings reflect relatively pervasive aspects of human behavior. Indeed, several examples from outside of the studies discussed above suggest that the same patterns of behavior occur even in informal task settings without sophisticated process technologies. These examples suggest that, in the immediate aftermath of a major change or disruption, participants are often able and willing to revise, adapt, and critically evaluate their new situation. The lack of an established routine, combined with the necessary (and necessarily temporary) suspension of normal performance demands, appears to open the way for a period of experimentation, reflection, and modification. However, as pent-up performance demands resurface, and as modifications succeed in enabling participants to turn their attention to these demands, the openness to further adaptation diminishes rapidly.

A simple anecdote illustrates this point. During the drafting of this paper, both authors coincidentally moved households. At the start of previous moves, both authors had made solemn resolutions to be better organized at home. Yet when they began packing this time, each discovered that any box that had not been unpacked within approximately two weeks following the previous move had remained untouched. It had simply become part of the landscape, or been lost in the rubble of a back closet, or had become a constant but low-level irritation that was never severe enough to act upon. Consequently, this time both authors have resolved to attack the problem of unpacking and organizing **immediately** following installation in their respective new residences. Even when the technology is as simple as boxes of books in a room, we have found that patterns of behavior congeal all too rapidly.

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APPENDIX

Measurement of Variables at BBA

(N = 41 projects)

VARIABLE	SOURCE	MEAN	RANGE	S.D.
Adaptive Activity - Total per project - Per month per project	Questionnaire: Ratings of 10 activities and time-line	19.10 .91	3 - 42 0 - 14	10.14 1.75
Time from installation until new technology is "production worthy"	Questionnaire: Time-line	13.7 months	2 - 41 months	8.2 months
Time from installation to full integration of new technology	Questionnaire: Time-line	22.2 months	2 - 55 months	13.3 months
Dollar investment in new technology	Questionnaire and Project Documents	1,156.7 ($000)	80 - 5,600 ($000)	1,318.3 ($000)

Correlation Matrix

	Time to Full Integration	Size of Project ($ investment)
Adaptive Activity (total per project)	.47	.30
Time to Full Integration	-	.11
Size of Project ($ investment)	-	-