WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

WINDOWS OF OPPORTUNITY: Creating Occasions for Technological Adaptation in Organizations

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WP #3309
Revised March, 1992

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Abstract

This paper examines the introduction and adaptation of technologies that support productive operations. The authors suggest that modification of new process technologies by user organizations is limited by increasing routinization that occurs with experience. 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, the technology and its context of use tend to congeal, often embedding unresolved problems into organizational practice. Further changes appear to occur in an episodic manner, triggered either by discrepant events or by new discoveries on the part of existing users. Implications for theories of technological change in production environments are discussed.

> "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)

ADAPTATION OF TECHNOLOGIES IN USE

New technologies are almost never perfect upon initial introduction. Deployment of a given technology within a specific context of application reveals numerous issues that were not apparent before introduction, but that require action to meet users' objectives or changing circumstances (Rosenberg, 1982; Dutton and Thomas, 1985). The modifications that follow can affect the technology, its physical context, or even users' basic assumptions and patterns of use (Leonard-Barton, 1988).

Modification of technologies-in-use is critical for several reasons. First, users' discovery of and adaptation to problems in operation is an important force for shaping technological development and guiding R&D activity (von Hippel, 1988; Dutton and Thomas, 1985). Second, within the user context, modification of technologies and procedures for using them is a major determinant of operating efficiency and effectiveness (Enos, 1958; Hollander, 1965; Dutton and Thomas, 1984). Third, modifications made to technologies-in-use often change the organizations and the individuals deploying them. As Van de Ven (1986:591) has pointed 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 technology is altered once it is put into use can we begin to build more complete theories of technological change in organizations.

However, we know little about the dynamics that underlie the modification of technologies-in-use. The objective of this paper is to provide an empirically grounded and theoretically informed conceptualization of how technologies are changed once introduced into specific user environments. Our research examined two questions. First, what is the pattern of technological adaptation in organizations? Specifically, do users' modifications describe a continuous and gradual accumulation of minor improvements, or is adaptive effort applied in a more discontinuous fashion? Second, to the extent that general patterns of technological adaptation are observed, what organizational forces can be found to explain them?

Our research investigated these questions by examining users' adaptation of new technologies in three organizations. We found that adaptation ceases or slows considerably after an initial period of intensive activity. It appears that new process technologies and users' behaviors congeal with ongoing use fairly rapidly after introduction. Later, modification becomes a highly discontinuous process, with users' effort and attention moving only occasionally from normal operations to experimentation and adaptation. Several organizational forces appear to contribute to this pattern, such as pressure for production and the development of routinized behaviors. This leads us to posit that users' first experience with a new technology provides a limited and valuable occasion for exploring and modifying the technology and the way it is used in the organization. Later spurts of adaptive activity appear infrequently and are interspersed among longer periods of regular use.

EXISTING LITERATURE

The adaptation of technologies-in-use has been studied by several researchers; their work demonstrates both the organizational complexity and the importance of ongoing adaptation activities. Some twenty years ago, Zaltman, Duncan and Holbeck (1973) noted that it is only through experience with a given technology that users discover all of its ramifications -- and that their discoveries include many unexpected problems. Berman and McLaughlin (1975) studied this issue in educational institutions and found that such unexpected problems required adaptation of both the new technology and users' practices and assumptions. Rogers (1983) explicitly included redefinition or restructuring as an important phase in the innovation process. During this phase, "the innovation is modified and reinvented to fit the situation of the particular organization ... and organizational structures directly relevant to the innovation are altered to accommodate [it]" (Rogers 1983: 363).

Related work (Rice and Rogers, 1980; Johnson and Rice, 1987) provided in-depth case studies of users' modification of existing technologies. These authors found that, through the process of reinvention, individual adopters became active participants in the innovation process (Rice and Rogers, 1980:512). Further, Johnson and Rice (1987) suggested that the degree of such reinvention was directly related to the success of the new technology in a given organizational context.

Leonard-Barton's (1988) work on implementation of hardware and software innovations further emphasized the importance of such ongoing modifications. She found that those organizations prepared to deal with multiple "cycles of adaptation", both large and small, were most successful at introducing and utilizing complex new production technologies. Her study documents the complementarity of modifications that address the technology, and those that affect its context of use. Thus, Leonard-Barton described the adaptation process as one of "mutual adaptation" of technology and user. Further, Leonard-Barton observed that such ongoing changes were not always initiated by users; changes were also initiated by technology developers who maintained involvement with current users.

For the sake of brevity, we will use the term "technological adaptation" to refer to adjustments and changes following initial installation of a new technology and aimed at improving its usefulness or usability in a given setting. These modifications may address physical aspects of the technology itself (e.g., hardware components or software routines), but they may also address users' procedures, assumptions, or relationships (such as, maintenance practices, operators' knowledge, or intra-firm communication patterns). Further, change efforts may involve users alone, or stem from joint efforts between current users and technology developers.

The Timing of Technological Adaptation

Curiously, none of the researchers who have most closely observed the process of technological adaptation have addressed the question of how such activities vary over time. Even when authors have explicitly mapped changes over time (Barley, 1986), they have focused on illuminating organizational differences in these changes and their outcomes, not on identifying general trends in the level of adaptations over time. A survey of the broader literature on technological change and the behavioral forces that shape it reveals conflicting assumptions about the actual pattern of technological adaptation over time. While some research approaches assume a continual process of technological adaptation, others indicate that the pattern of such modifications in organizations is likely to be far more uneven.

For example, research on experience or learning effects in production (e.g., Conway and Schultz, 1959; Alchian, 1963), showing regular productivity improvements in many industries, has prompted theorists to suggest that such "progress can be thought of as a continuous process of adaptation" (Dutton and Thomas, 1984:244). Ample empirical work supports the association between improvement and cumulative output (see Muth, 1986). However, these results are based on aggregate data from many machines, often of different ages. Further, analyses aggregate many sources of improvement in the production process, including adaptation of existing machines, introduction of new technologies, and exploitation of economies of scale. Therefore, these studies do not reveal the dynamics of adaptation around a given technology in a specific setting.

Studies of industry evolution also make important assumptions about the modification of technologies over time at an aggregate level. For example, Dosi (1982), Abernathy and Utterback (1978), and Tushman and Anderson (1986) argue that modifications to an existing technical base are made on an ongoing basis. These authors 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, "radical" shifts in technology are seen as extraordinary and rare events (Abernathy and Clark, 1985; Tushman and Anderson, 1986).

Another important 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 a gradual effort. Rogers (1983) stated 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). Rosenberg (1982) argued that "learning by using" following initial installation of new equipment is a long-term process because "the underlying problems may not even declare themselves for a few years" (1982:137). Similarly, Hughes (1971:152) suggested that "trying to force the pace" of improvement and adaptation would be counterproductive because "the greatest uncertainties connected with [new technologies] arise from problems that may not show up until the [technologies] have been in operation for a few years." Hage and Aiken (1970:106) argue that managers must leave time for "trial and error" to deal with unexpected problems, and they note that, "There is some probability that the longer the elite allow this period of trial and error to continue, the greater the chances of the new program achieving its intended objectives."

Other scholars argue that adaptive change should be a continuous activity. For example, Johnson and Rice (1987) suggest that organizations must constantly attend to the modification and adaptation of technologies-in-use if satisfaction and effectiveness are to be maximized. This theme has been enthusiastically embraced by practitioners; recent popular works describe "continuously improving" organizations and exhort managers to undertake continuous change around new technologies as in other arenas (e.g., Goldratt and Cox, 1986; Imai, 1986).

As attractive as this notion of continuous technological adaptation is, it is not fully convincing. Comparison with behavioral theory at the level of organizations, groups, and individuals, presents several important challenges. 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 considered salient and the manner in which information about events 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). 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 a given approach has been used, the greater the rigidity (Allen, 1966).

At the individual level, it has been shown 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 adaptations 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 points to Barley's (1986) data to argue 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, Weick (1990) 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 unevenly applied over time. They suggest that the initial period following installation may represent a critical, formative period for making changes to a new technology and the way it is used within an organization. After that, further adaptation may be difficult unless a surprise or interruption refocuses attention on established routines and assumptions.

Behavioral theory thus predicts a very different pattern of technological adaptation from that portrayed in the innovation literature. This paper confronts the conflicting characterizations of technological adaptation emerging from these different conceptual perspectives, and develops a more integrative theory that takes into account both technological and behavioral aspects of the adaptation process. The study described here examined group and individual users' adaptations to new process technologies installed in specific organizational settings. The data reveal common patterns in the time trend of adaptation activity across projects and organizational settings. Further, the study identified forces operating at the organizational, group, and individual levels as reasons for these patterns. The next section of the paper describes the study and research methodology employed. The following section presents the results of the research. The final section discusses implications for a temporal theory of technological adaptation.

RESEARCH STUDIES AND METHODS

Research Studies

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 a single organization, and examined multiple projects or users facing changes in the way production work was accomplished. The sites were matched on four dimensions to ensure comparability across technologies and organizations (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 failure 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 a new version or generation of process technology until full and regular use was achieved.

The first study investigated the introduction of new capital equipment in BBA,[1] a leading manufacturer of precision metal components. The study examined changes undertaken in eight factories in Europe and the U.S. The second study examined the introduction 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. Once implemented, these tools are the primary means through which production work -- writing software -- is accomplished in SCC. The third study investigated the introduction of user-customizable software in an information systems support department at Tech, a research university in the U.S. The study examined technical changes made by users as they modified their computer work environments.

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, 1990:316). The technologies studied 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 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, is specifically designed to allow adaptation during use. Most users at Tech are technically trained, and many of those interviewed were involved in the initial development of the technology they were using.

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[1] Names of all organizations have been disguised.

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 and analytical techniques. At the same time, all three of the studies included in-depth field research, ensuring that the concepts and patterns we 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 research studies are described below and summarized in Table 1.

see Table 1, next page

Research Site and Method at BBA

BBA is a European-based manufacturer of precision metal components; it is a world leader in market share and product quality. BBA is organized geographically, with operations in different countries run as separate divisions under local management. The study was carried out in three major divisions--Italy, West Germany, and the United States--and involved eight different plants. Forty-eight projects were studied (four to eight in each plant) for a total of 48 process technology introductions. 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 and reached completion before or at the time of the study; (ii) they represented an investment of more than $50,000 per project; and (iii) they involved personnel who were available for

Table 1: Sites and Data Collection Methods across Research Studies

	BBA	SCC	Tech
Nature of Site	• Manufacturer of precision metal components • Three divisions in Italy, West 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
Sample	• 41 projects • Process Technology: production equipment, e.g., machining cell	• 5 projects • Process Technology: computer aided software engineering tools, e.g., program code generators	• 51 users • Process Technology: centrally administered personal computing environment, e.g., text editors
Informants	• 89	• 119	• 51
Time frame	• Retrospective	• Longitudinal (8 months)	• Longitudinal (4 months)
Methods	• Semi-structured interviews • Questionnaires • Review of company and plant documents	• Unstructured and semi-structured interviews • Observation • Review of company, project and technology documents	• Semi-structured interviews • Questionnaires • Automatic collection and analysis of customization activity

participation in the study. 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 frequently supplemented by multi-participant discussions. 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). To clarify their responses, participants were interviewed both before and after they completed questionnaires. In most cases, respondents made heavy use of project documentation in completing questionnaires. In addition, the researcher had access to historical data in 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 application systems that clients use to support their major administrative activities. SCC's operations are organized by project, with project teams varying from around ten to over a hundred personnel, and projects extending from a few months to a number of years in duration. SCC recently constructed and deployed process technology--known as Computer-Aided Software Engineering (CASE) technology--in all its projects to automate the software production process. The research consisted of an in-depth field study conducted over eight months in three SCC offices located in the northeast U.S. 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 was collected via on-site observation of participants, unstructured and semi-structured interviews, documentation review, and informal social contact with the participants. Participants spanned SCC's hierarchic levels from the most junior consultants and programmers, to senior project managers. Other key informants were identified and sought out both within and outside SCC, such as the director of research and development, senior recruiting officers, sales directors, major client managers, and former SCC employees. Approximately one hundred and twenty interviews were conducted, each lasting an average of an hour and a half. (For further details, see Orlikowski (1992).)

Research Site and Method at Tech

Tech is a research university in the northeast U.S. It includes a department responsible for providing a variety of technical and administrative computing services to the university. In function, this department's activities resemble those of a corporate information systems department. Users in several areas--administration, education, operations, systems development, user services, and video applications--rely heavily on computer software tools, such as electronic mail, graphics, spreadsheets, and word processing, to perform their various duties. The study focused on how various users (managers, secretaries, technical specialists, support staff) in these areas customized new versions of their software tools. Tech differs from the other sites in that individuals rather than teams make adaptations, and in that individuals' modifications rarely affect others' computing environments. Hence, there are fewer opportunities for conflicts to constrain adaptive behavior. Tech is thus an extreme case where continuous -- or at least extensive -- adaptation may be most likely.

The research was longitudinal and included a mixture of data collection methods, such as interviews, questionnaires, and automatic records of customization activity. Three sets of semi-structured interviews were conducted with 51 users over a period of four months, beginning shortly after installation of the new technology. Interviews explored users' customization strategies, their customization decisions, and the factors that facilitated or hindered customization. Questionnaires were filled out before and after interviews and included questions on the type of customization activities undertaken. The computer system was programmed to capture data on participants' customization activity, and this data was used to highlight critical instances of customization activity. These key instances were used in conjunction with a critical incident technique (Chapanis, 1969) which allowed probing of participants' specific customization activities during interview sessions. (For further details, see Mackay (1990).)

Definition and Measurement of Adaptation Activities

At BBA, adaptation activities were defined as those activities involving efforts 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 of machine operators, or development of 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 its hardware, software, or context.

As part of the written questionnaire, respondents were asked to rate the level of effort devoted to adaptive activities such as modification of machine software or change in factory procedures. Activities were rated as high, medium, low, or none/not significant. 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 total of all such activities that were mentioned as taking place 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", and date when the new equipment was considered fully integrated (i.e., satisfactory efficiency and quality achieved; operating parameters fully defined). 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 modify, customize, extend, or otherwise enhance 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 descriptions 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" (i.e., modifications) of their software-based personal computing environments. Customizations involve changes 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 if no permanent changes were made to the work environment. Data on the occurrence of customizations over time was collected as described above.

Method of Analysis

Each of the research projects yielded rich data on users' adoptions of and modifications to new process technologies over time. We analyzed this data using the interpretive lens of our research questions on technological adaptation. 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 patterns characterizing the introduction, adaptation, and use of new process 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 resolved. Third, having identified some patterns we searched for the underlying reasons that would account for the termination of adaptation activity and the persistence of technological problems. As Eisenhardt (1989:542) suggests, this step of deriving the underlying reasons for relationships is critical to establishing the validity of the findings. We were able to articulate and categorize a number of organizational forces that appeared to influence these patterns. Finally, we compared the patterns and organizational forces we had identified across the three sites and determined similarities and differences.

Our findings are strengthened by the fact that evidence from one study was corroborated by evidence from the others (Eisenhardt, 1989:541), and that these findings were generated from data collected by multiple investigators using multiple data collection methods (Eisenhardt, 1989:546). This increases the likelihood that the patterns of adaptation we found across the technologies and settings are intrinsic to the generic process of technological adaptation rather than consequences of a specific implementation approach or particular type of technology.

RESULTS

Temporal Pattern of Technological Adaptation

A striking finding across the three research sites was that adaptation efforts appeared to fall off abruptly after a short initial introduction period. The 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 operating environments studied. Experimentation was more likely to occur and significant changes more apt to be implemented immediately 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 modification took place immediately 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 support members, who had designed and constructed the CASE tools. Following such initial adaptation of the tools, application programmers (who were responsible for the actual production of new applications software) were brought onto the project. Once these programmers began using the CASE tools as process technology, they halted further changes to the tools. That is, they insisted that the process technology be stable and reliable to facilitate their production work. Only under extreme conditions (such as a breakdown in the software) 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 users found that, once the equipment was installed and operating in the plant, 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.

Developers commented that, after several months of work at the plant:

> 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 shortly 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 following initial implementation. Instead, users settled on a system 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.

Table 2 shows the incidence of the temporal pattern of adaptation in all three sites.

see Table 2, next page

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 adaptive activity undertaken over time for 32 projects.[2] To derive the curve, we first calculated for each project the percent of all adaptive activity completed during the first, second, etc., months of the project. Results by month were then averaged across projects. For example, we see that on average 28% of all of the 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. This pattern of adaptations is distinctly non-linear; it is much better described by a geometrically decreasing (quadratic) function than a simple linear one (see Table 3). Further, the time period of this initial window[3] was remarkably stable: 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. There was no relationship between the size of the project (as measured by dollar investment) and the duration of intensive adaptation efforts (r= .06, ns).

see Figure 1 (page 21) and
Table 3 (page 22)

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[2] Nine projects were deleted from this calculation because their total time to full integration was less than twelve months. Including these shorter projects would have skewed the results, since adaptation would necessarily cease early when the project is short.

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

Table 2: Evidence of an Initial Window of Opportunity

Site	Examples from Research Studies	% of Sample where Pattern was Observed or Mentioned
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."	86% N = 34
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." "[The technical developers] do not want to release stuff until it is perfect. But we would rather they give us something to walk with, and then they can enhance it later to give us a racing car. But right now 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."	80% N = 4
Tech	"I used to customize ... [but even though] replacing software is smoother now, I'm so tired, I'm not adventurous anymore."	65% N = 33

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

(N = 32 projects)

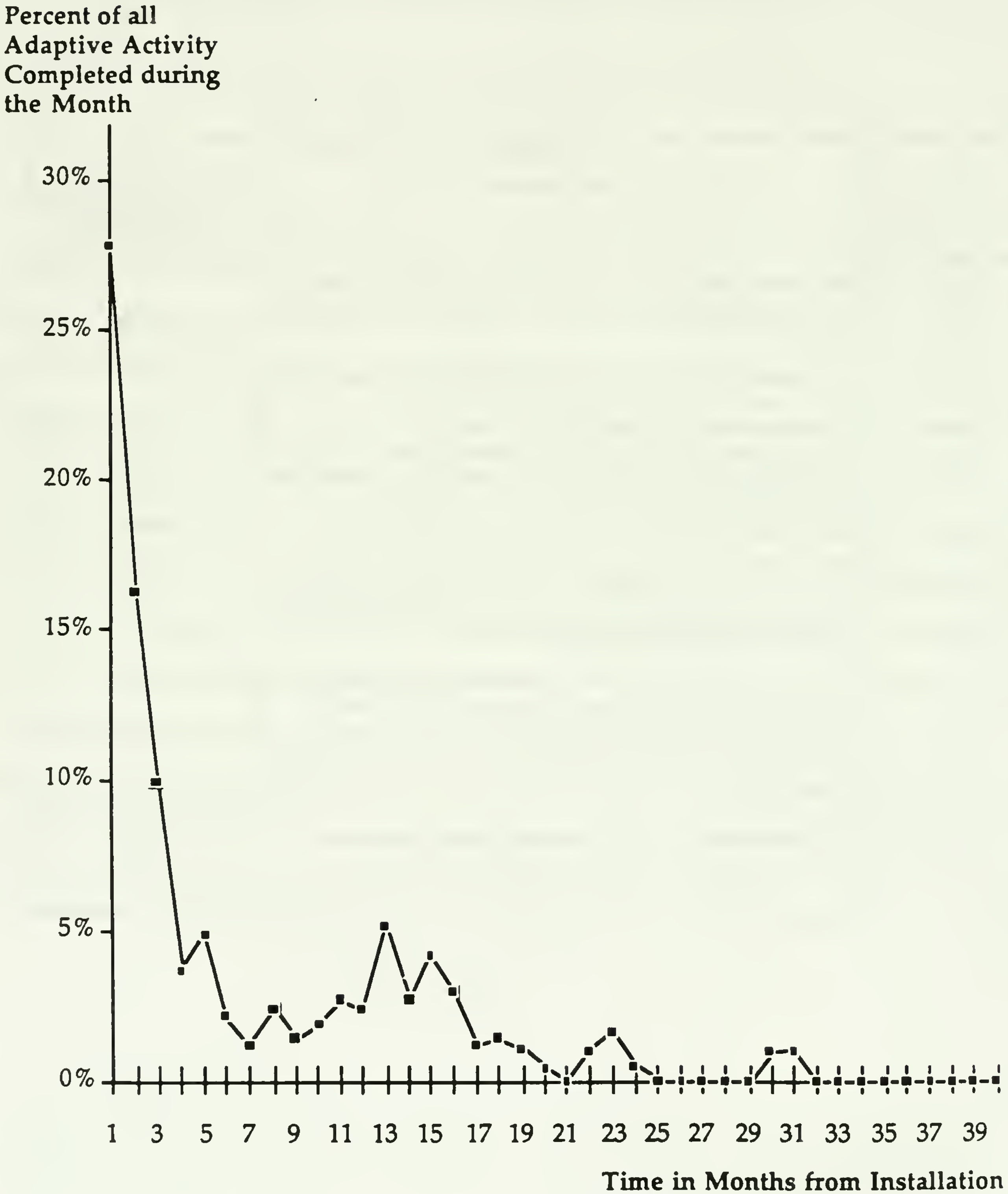


Table 3: Linear and Quadratic Models of Adaptive Activity in BBA over Time

Model	Intercept	Month	$Month^2$	R^2	d.f.	F
Linear	.0624•• (.0105)	-.0015•• (.0003)	-	.29	52	23.0
Quadratic	.1111•• (.0136)	-.0068•• (.0011)	.0001•• (.0000)	.50	51	27.3

•• $p < 0.01$; Numbers in parentheses are standard errors.

A possible explanation of 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 case. On average, the new technologies took almost 14 months to be considered production-worthy, and they required another eight months to be fully integrated into the production process. In addition, respondents' reports revealed that there were an average of five problems still outstanding at the end of the first wave of intensive adaptation. In most cases these were significant issues, including inconsistent or unreliable operations, software problems, tooling or procedures that were not yet defined, and manual operations in place of automatic features that had not yet been mastered. In several cases, respondents reported that attention to problem solving fell off even though the machines remained inoperative. In some cases, events prompted later, but also short-lived phases of adaptation. These new windows for change and their characteristics are discussed more fully below.

In sum, evidence from all three sites reveals a similar pattern of adaptive activity over time -- beginning with a short, intensive burst and followed by smaller, infrequent episodes. In the following section we examine evidence relating to the organizational forces that shape this pattern of adaptation. Four forces were consistently mentioned or observed in all three sites: (i) the tension between production requirements and adaptive activities, (ii) the constraining effect of habits and procedures once they are developed, (iii) the modification of expectations based on experience, and (iv) the erosion of team membership and enthusiasm over time.

Organizational Forces Influencing Technological Adaptation

i. Production Requirements Versus Adaptation Opportunities

Data from all three studies suggest that one of the most powerful forces behind the failure of continuous ongoing modification was the incompatibility between the requirements for production and those for adaptation (see Table 4). Productivity demands quickly drove out opportunities for identifying and solving new problems once technology was put into use.

see Table 4, next page

At SCC, for example, both programmers and technical support members were acutely aware that making changes to the tools or experimenting with different technology options meant time away 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 other typical users:

> [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 [production work].
>
> I hate to stop [working] long enough to get set up [with new features].

In part, these 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. As one user explained, "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:

> So I gave up [on customization]. I'm a conservative guy. 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 expressed the conflict between production and adaptation in the following terms:

Table 4: Evidence that Production Pressure Impedes Adaptation

Site	Examples from Research Studies	% of Sample where Factor was Observed or Mentioned
BBA	"Success tends to be measured by production. Now production loves [this machine] so engineering can't get in to play. There is lots [sic] of experimentation and further improvements that are possible, but we can't get 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 <u>small</u> changes, attend to <u>small</u> problems."	40% N = 16
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."	60% N = 3
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 [customization]." "I like things to be predictable and out of the box -- I don't like customizing."	63% N = 32

> 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

In all three operating settings, users adapted themselves fairly quickly to their new process technologies. They established norms and routines for using the technology shortly after their initial experiences with it. These patterns of use supported short-term productivity goals but constrained further exploration and adaptation. This proved to be a major barrier to ongoing change, apparently stunting the "learning" process that was expected by many managers.

In SCC, CASE technology was introduced to leverage the technical skills of its personnel. Indeed, as users gained experience with CASE tools their productivity increased, but so did their dependence on the technology in its current form. Users therefore resisted ideas for improvements or adjustments to their tools because these threatened to destabilize developed capabilities. When such changes were occasionally introduced, users often tried to ignore them by bypassing the new versions to work with the original system. A project manager noted that:

> We found a lot of frustration among the programmers during the spec stage, as the technical developers wanted continual changes to the tools... But that meant we couldn't get on with our [production] work. So we decided that we would just continue with [our version of the tools] so that we could get on with our schedules.

A programmer commented that this practice of bypassing new changes to tools was a common occurrence in projects:

> 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.

The constraining effects of increased experience were also 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 system. 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 to users, they were extremely resistant to change. To illustrate, when new software versions were installed, users very often simply retrofitted the new versions to mimic functions of the familiar, original version. In one 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 purposefully avoids making major changes to his software because "Now that I know things, I have learned the [existing] commands, I'm happier."

Table 5 shows evidence of this issue across the three sites.

see Table 5, next page

Table 5: Evidence that Patterns Congeal over Time

Site	Examples from Research Studies	% of Sample where Factor was Observed or Mentioned
BBA	"They had gotten used to running those parts on [that machine] and they liked it that way."	37% N = 15
SCC	"We found a lot of frustration among the application programmers during the spec stage, as the technical developers wanted continual changes to the tools ... But that meant we couldn't get on with our [production] work. 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."	100% N = 5
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."	78% N = 40

iii. Expectations Adjust to Fit Experience or Knowledge

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 achievement or capability. 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 (see Table 6).

see Table 6, next page

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:

Table 6: Evidence that Expectations adjust to fit Experience[1]

Site	Examples from Research Studies
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."
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."
Tech	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.

[1] Since initial expectations are seldom made explicit, many examples of this change in expectations are invisible to users and researchers alike. Hence we do not display the number of cases where this change was observed, as such a count would be misleading.

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 displayed a variety of ways in which experience with a new technology affected their perception of potential problems and opportunities. One of the features of the user-customizable software installed at Tech was the capability to develop a personalized log-in procedure so that the software would automatically attach relevant directories, set up a specified set of screens, and so on. One experienced manager explained that, even though she knew that it was possible to set up an automatic log-in procedure, she had not bothered to do so. Over time, she noted that she had developed her speed at manual log-in; "I'm quick and it takes less than a minute to log in." So, even though she acknowledged that it was cumbersome and "wastes mental attention," she indicated that at this point she simply did not consider it a problem.

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 congealed, he had never thought to inquire whether the problem had been corrected.

iv. Enthusiasm Degrades and Teams Dissolve Over Time

Another barrier to adaptation was that when projects bogged down, the relevant teams tended to dissolve and lose momentum (see Table 7). 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.

In general, explained one project manager:

> 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.

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 support personnel requested assignment to other projects with "more interesting" work. One technical developer commented:

> 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. 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 implementation of detailed process technology changes after the initial window of installation and adjustment.

see Table 7, next page

Evidence of Subsequent Windows of Opportunity

The data presented above suggest that ongoing adaptive change 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 later in the project life cycle. At

Table 7: Evidence that Teams Dissolve over Time

Site	Examples from Research Studies	% of Sample where Factor was Observed or Mentioned
BBA	"We strove to keep the group together, but ... people became involved in other, more urgent projects that were not dragging on as much." "The 'main situation' is when we start up. We can all work closely together; we are all very close. After that it is hard. It takes a long time to make any real progress." "Engineers are always excited at the beginning of the project. But, after a while, they lose enthusiasm for doing all the detailed changes that spell the difference between success and failure in an innovation project."	54% N = 22
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."	80% N = 4
Tech	not applicable -- individual users only; no teams	

BBA, 31 of the 41 projects studied demonstrated a later spurt of activity. In four of these cases more than one later spurt of activity was reported.

Later windows for change were, like the initial window, of limited duration. At BBA these later spurts of activity lasted for an average of 2.4 months (compared to an initial window 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 an average of 23% of all reported adaptive activities occurred during this second window for change.

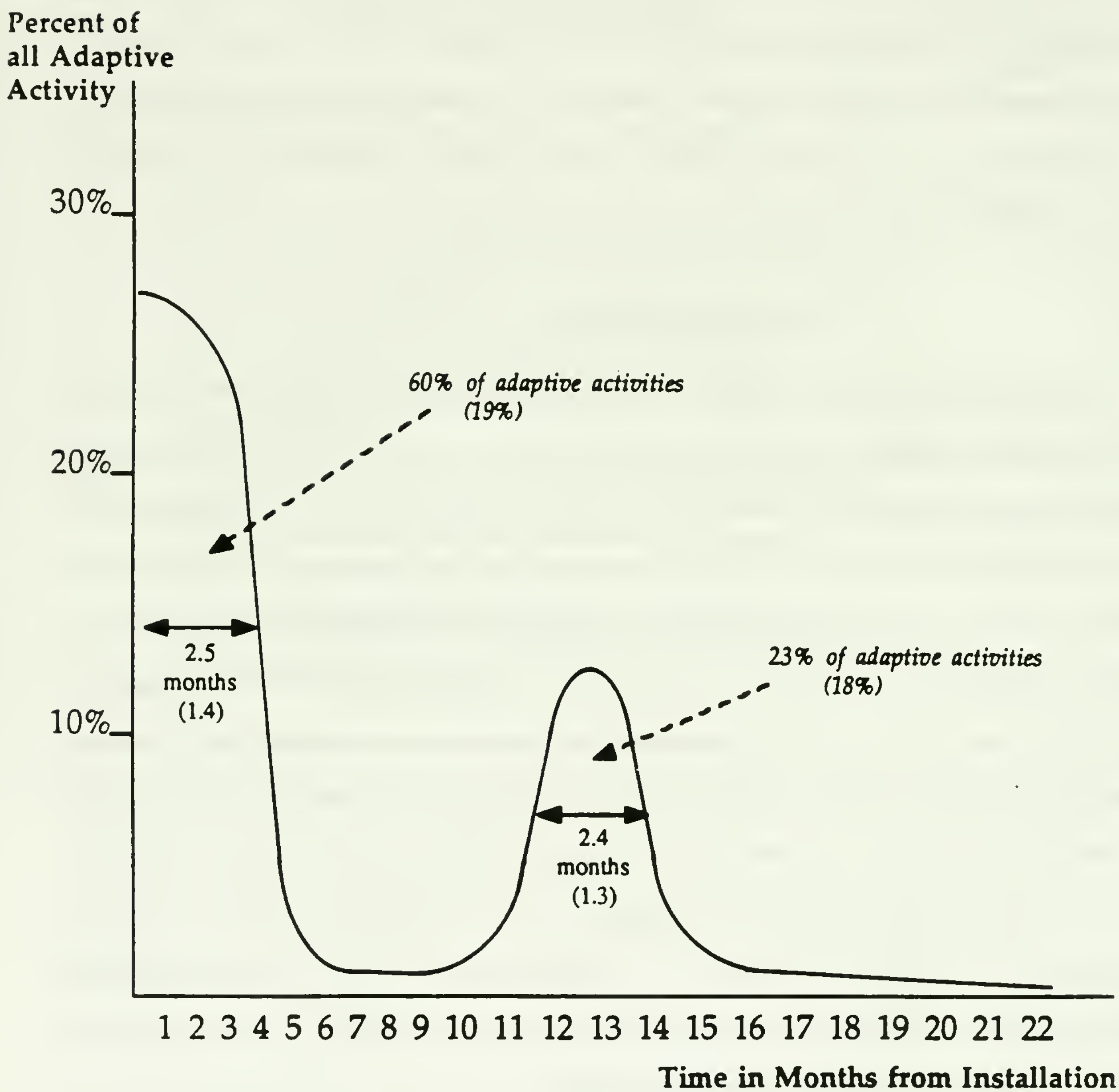
see Figure 2, next page

In almost every case the existence of a later spurt of adaptive activity at BBA could be traced to a specific, disruptive event in the project life cycle (see Table 8). Most often, attention was refocused on the technology and its mode of use by a subsequent 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 their own procedures. In a few cases, a new window for change was opened by an unusual but not disruptive event, as in two cases where the entry of new, unassigned technical personnel into the plant provided extra resources for dealing with outstanding problems with the new equipment. Management action also created some new windows for change, however, this was generally linked to the arrival of new plant-level management or the intervention of senior company management into a problematic project. 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.

Figure 2: Episodes of Adaptive Activities in BBA

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



Note: Standard Deviations in Parentheses

Significantly, the opportunity to "rethink" early choices came about only once a new group of divisional managers took over and made the troubled project an initial focal issue of their tenure. In only one case did existing local management explicitly refocus attention on an existing machine and the need for further modifications.

see Table 8, next page

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 modifications. As at BBA, triggers were often disruptive or aberrant events, such as the release of a new system or the breakdown of an existing system (see Table 9). 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 normal circumstances. In another instance, a user who normally did not travel went on an extended trip. Upon returning he found that he was overwhelmed with electronic mail that had accumulated in his absence; the new rules he developed to deal with the situation proved useful additions to his regular work routines.

In other cases at Tech opportunities for change were created when normal workflow and thought patterns were interrupted by outsiders. For instance, when a visitor asked whether their electronic mail system succeeded in routing their messages reliably, some non-technical users expressed surprise and concern. They had never thought the technology might not work correctly. As a result of this interruption, they began to undertake new experiments with their technology.

Table 8: Triggers that Open Subsequent Windows of Opportunity at BBA

# of Instances in Sample of 41 projects	% of all Instances that opened Subsequent Windows	Trigger
14	40%	New machines or tools added
6	18%	New product requirements
6	18%	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

Yet disruptive events did not always trigger changes that advanced the technology or its utility. The most common form of adaptation following new system releases was a retrofit that enabled users to continue to operate as if no change had occurred.

Sometimes, the impetus for further adaptive change was internal. A significant number of users modified their system when they thought of new ideas, or when old procedures simply became too frustrating.

see Table 9, next page

At SCC there were few occurrences of adaptations during later phases of the projects; formal procedures explicitly dictated that software 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. One 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.

However, even at SCC a crisis could create an opportunity to rethink earlier choices. In one project at SCC where users did seek to modify the CASE technology much later in the project cycle, they did so because the existing process technology had broken down. Many system requirements had been changed over time, yet these changes in product specifications were not reflected in the existing CASE technology. Eventually, available tools became completely inadequate to the task. Technical personnel were called in, and a modification of the existing process technology was undertaken.

Table 9: Triggers that Open Subsequent Windows of Opportunity at Tech

# Times Mentioned	% of all Users Mentioning this Issue[2]	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

[2] Derived from users' responses to open-ended questions about what factors triggered subsequent adaptation activity. This column adds to more than 100% because each user listed more than one triggering factor (the average number of triggering factors mentioned per user was 4.4). Additional triggers were mentioned but are not listed here as they were noted fewer than 10 times each.

DISCUSSION AND IMPLICATIONS FOR THEORY

This paper was motivated by the recognition that, while literature on the management of innovation has demonstrated the importance of users' adaptation of technologies-in-use, researchers have not examined the persistence of such adaptive activities over time. Several authors have documented the role of adaptation in the initial introduction of new process technologies, and have further argued that such modification should be an ongoing, continuous activity within organizations (Johnson and Rice, 1987; Leonard-Barton, 1988; Tyre, 1991). Yet studies of individual and organizational behavior have shown that active information processing tends to erode over time. This raises serious questions about the likelihood of sustaining high levels of adaptive attention and effort over very long periods of time.

The results of our investigation suggest that adaptation to new process technologies is not a smooth, ongoing process but a distinctly intermittent one. First, in each of the settings studied there was a pronounced, early period of relatively intensive adaptive activity. We found that users' first experience with new technologies provides an important window for change -- that is, a limited and valuable occasion for observing, exploring, and changing the technology and the way it is used in the organization. This period is a window in the sense that, for a time, users have a clear view of the new technology as a discrete artifact. Initial experiences yield new 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 introduction 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 specific technology used to support it congeal, and the window for change is closed.

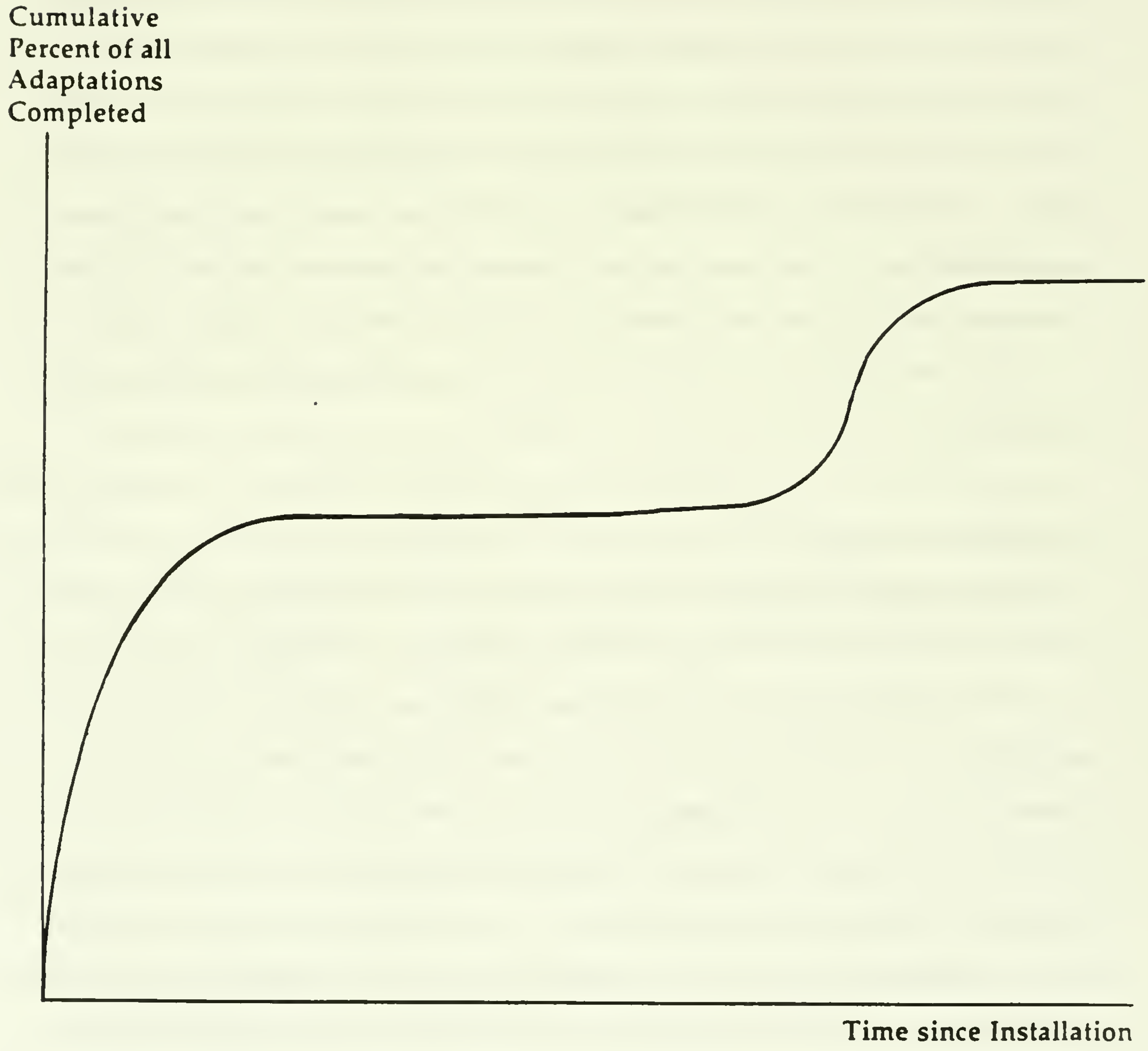
Despite these tendencies, we also found that later spurts of adaptive activity did occur. These events were important because they enabled users to revisit problems in light of their accumulated experience, and even to revise basic choices about the technology and their relationship with it. Yet, indications are that these later windows for change occur only occasionally, and last only a short time.

We, thus, suggest that the actual pattern of technological adaptation in organizations is not continuous but episodic, as illustrated in Figure 3. While there is often a considerable elapsed time between initial installation and full integration of a new technology, adaptive attention and effort are concentrated in short spurts during that period. The initial episode of adaptation is especially important. The decisions and directions taken during a very short period following initial installation--a period that may be as brief as two to three months--are very significant determinants of how the technology will be used by the organization over the longer term. Indeed, it appears that further adaptations are rare unless some sort of unusual event (such as a breakdown in the technology, the entry of more new technology, a managerial intervention, or the culmination of users' own frustration) triggers further adaptive effort.

see Figure 3, next page

While our study of the issue is still preliminary, we suggest that the episodic pattern of adaptation observed in this study may be inherent to users' efforts to deal with new technologies, and not just a function of a given managerial approach. Our empirical work finds 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). Our findings are also consistent with the idea that surprising or unusual stimuli can trigger renewed, higher levels of attention to tasks or situations normally regarded as routine (Newtson, 1973; Louis and Sutton, 1991).

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



These findings pose many interesting questions for future research. In particular, if the initial window of opportunity for adaptation is necessarily of limited duration, how can organizations best take advantage of that opportunity? Further, if subsequent periods of adaptive effort occur episodically, separated by periods of regular operations, is there a necessary relationship between these two modes of operation? For example, does a period of stability provide the wherewithal (new insights, renewed resources) for organizational actors to reexamine and revise the new technology? And finally, what sort of events trigger a subsequent episode of adaptive activity following a period of normal operations? Specifically, how frequently do such triggers take the form of exogenous events, and how often they stem from users' own discoveries or frustrations? Under what conditions might we observe these different kinds of "triggers" at work? Further empirical research examining activities at the project level will be needed to address these questions.

Implications for Action

Our findings have potentially major implications for the management of technological change in the production process. Many scholars and practitioners, citing successful Japanese practices, are calling for "continuous improvement" efforts around the technologies applied to productive work. Our findings suggest that framing the need for adaptation in this way may be misleading. What appears, at an aggregate level, to be "continuous improvement" may in fact be the sum of distinct episodes of adaptation. In this case, a more powerful strategy for managing the improvement of new process technologies might be to create and exploit specific episodes of intensive adaptive activity. For instance, following initial installation, managers could encourage aggressive testing, modification, and ramp-up. Later, once activities have subsided and users have experienced a period of more normal operations, managers could "reopen the window" for ongoing change. This might be done by introducing new challenges, new technology, or new people into the regular production process. Indeed, it may be more effective to create intensive but occasional spurts of attention and action, instead of trying to maintain a constant level of adaptive activity.

Interestingly, such an approach is consistent with descriptions of some "best-practice" Japanese approaches. In a study of production practices at Toyota, Hall (1983:199) notes that at the time of initial introduction of a new machine or process, the factory makes "a direct engineering assault ... [This] prevents the need to dribble a constant stream of engineering changes through the formal system over a long time." Similarly, Clark and Fujimoto (1991:189) found that in Japanese automobile companies, "pilot runs are relatively short, and the pilot run periods are compressed." Ogawa's (1991) study of a leading Japanese steel company points out that the test period should be seen as a limited period 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.

These examples, combined with our own findings, suggest that pursuing discontinuous modification of process technologies may be a powerful strategy. However, we also find evidence that managing a discontinuous process of adaptation is not easy. For example, occurrence of discrepant events does not guarantee that new windows for change will be opened. We noted above that when such events were evaluated from a production-oriented perspective, they often appeared to be useless disruptions which users strove to ignore. Yet in other cases users adopted a different perspective: they embraced unusual events as opportunities to make useful changes to their tools and techniques. Research at the individual (Langer, 1983; Langer and Piper, 1987) and organizational (Dutton and Jackson, 1987) levels shows that how an 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 create windows for change when they frame discrepant events as noteworthy and potentially informative. Unfortunately, in our study there were few instances where managers actively managed users' perceptions, or where they intervened to turn unusual events into opportunities for change.

A Final Note

Our findings on the pattern of technological adaptation are remarkably consistent across three different companies with divergent industrial, technological, and managerial characteristics. This suggests that the forces identified here are likely to be present in many productive contexts -- even small-scale operations that do not rely on complex technologies in their production systems.

A simple anecdote serves to illustrate this point. During the drafting of this paper, both authors coincidentally moved households. In the process of gathering and packing their possessions, both authors found that the window for change in everyday life is remarkably narrow. 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.

ACKNOWLEDGEMENTS

The authors are grateful for helpful comments from colleagues, and for constructive suggestions from three anonymous reviewers and the senior editor. The research was funded by the MIT Center for Information Systems Research, the MIT Leaders for Manufacturing Program, and the Harvard Business School Division of Research. Their assistance is gratefully acknowledged.

APPENDIX

Measurement of Variables at BBA

(n=41)

VARIABLE	SOURCE	MEAN	RANGE	S.D.
Adaptation 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)
Duration of initial episode of adaptation activities	Computed from above	2.5 months	1 - 7 months	1.4 months
Duration of second episode of adaptation activities	Computed from above	2.4 months	1 - 7 months	1.3 months
Duration of initial episode as a % of time to full integration of technology	Computed from above	15%	4 - 43%	10.2%

Correlation Matrix

(n=41)

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

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