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WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

**Exploiting Opportunities for Technological
Improvement in Organizations**

**Marcie J. Tyre
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May 1993

WP # 91-93

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*The International Center for Research
on the Management of Technology*

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Sloan WP# BPS 3581-93

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Acknowledgement

The research reported upon in this paper was funded by the International Center for Research on the Management of Technology at the MIT Sloan School of Management and the MIT Leaders for Manufacturing Program. The authors gratefully acknowledge this support.

Abstract

In recent years, managers have learned through hard experience that in order to exploit the advantages of new process technologies, they must adapt those technologies -- and their ways of using them -- to fit the organization and its strategy. But exactly how and when organizations actually make those changes is not well understood. In this paper the authors argue that technological improvement is seldom a steady process. Instead, users of new process technologies tend to alternate between short episodes of intensive change activity, and longer periods of more routine use. Data from European and U.S. firms show that adaptation to new technologies often occurs in a lumpy or episodic pattern. In these settings, the pattern appears to be a natural outgrowth of potent organizational forces that make it difficult to devote attention and energy to adaptation for long periods of time. Examination of several leading Japanese organizations reveals a similar pattern, with one important difference: managers in these operations actively exploit the episodic pattern of adaptation around a given technology. Drawing on these observations, the authors suggest that managing an uneven pace of adaptation can yield important benefits to firms pursuing both efficiency and change.

We often hear that companies must learn to embrace change. This is particularly true of companies that are striving to apply advanced technologies as a way of improving their competitive position. The full advantages of such technologies cannot simply be purchased off the shelf; they are won by patiently and carefully tailoring the technology to fit a given firm's organizational and strategic context. At the same time, organizational skills, procedures, and assumptions within the firm need to be adapted to fit the new technology (Leonard-Barton, 1988; Van de Ven, 1986).

However, little is known about how organizations actually go about modifying new process technologies, or how they adapt their own practices in response to technological change. Most of the existing research on this topic has assumed that users learn about and modify new technologies in a gradual fashion over time. These assumptions have been built into our theories and images about technological adaptation -- such as the familiar learning curve, which implies a highly regular accretion of improvements over time. The same assumptions are built into the prescriptions offered to management. Many researchers exhort managers to "allow plenty of time" to digest new process technologies, and to strive for "continuous improvement" over time. This view is illustrated in Figure 1 (below).

Yet most of the research on which these assumptions are based was performed at the aggregate level. Certainly, an entire firm or factory must strive for continuous improvement. But, at the level of a particular new technology, the process of learning about and modifying a new process may not be continuous at all. Indeed, our research suggests that when one examines an individual new technology, the pattern of adaptation is often a decidedly "lumpy" or episodic

one, as illustrated in Figure 2 (below). In general, it appears that the introduction of a new technology into an operating environment triggers an initial burst of adaptive activity, as users explore the new technology and resolve unexpected problems. However this activity is often short-lived, with effort and attention declining dramatically after the first few months of use. In effect, the technology as well as the habits and assumptions surrounding it tend to become "taken for granted" and built into standard operating procedures. This initiates a period of stability, where attention focuses more on regular production tasks than on further adaptation. Later on, users often refocus their attention on unresolved problems or new challenges, creating additional spurts of adaptive activity. In many cases, this episodic pattern continues over time, with brief periods of adaptation followed by longer periods of relatively stable use.

In this paper, we discuss the evidence for such an episodic process of adaptation. The evidence comes both from our own research in U.S. and European companies, as well as from analysis of existing research on the practices of successful Japanese companies. After presenting this evidence, we also discuss reasons why such an episodic pattern -- provided it is understood and managed -- may actually be an effective and powerful way to pursue ongoing improvement of new process technologies.

Recent Research: Explicating the pattern of adaptation over time

In a recent research study (Tyre and Orlikowski, forthcoming), we investigated the adaptation of new process technologies in three manufacturing and service organizations in the U.S. and Europe. The first site was BBA,¹ a

¹ Names of all organizations have been disguised.

leading manufacturer of precision metal components, where we studied 41 projects involving the introduction of new capital equipment in European and U.S. factories. The second site was SCC, a multi-national software developer of custom-built computer applications, where we examined the introduction of computer-aided software engineering (CASE) tools in three U.S. offices. The third site was Tech, a research university in the U.S., where we examined modifications made to user-customizable computer tools such as text editors and electronic mail utilities.

Our main findings are consistent with the pattern described in Figure 2. First, we found that installation of a new process technology was followed by an immediate and relatively brief burst of adaptation efforts. Thereafter, such efforts fell off precipitously. Thus, experimentation was more likely to occur and significant changes more apt to be implemented immediately following introduction than at any later time. This rapid fall-off of adaptive activity was apparently not a simple "learning curve" phenomenon, as it occurred even when outstanding problems had not been fully addressed.

However, the initial period was not the only time when important modifications were made. In each company, events sometimes triggered new episodes of intensive adaptation effort. These later episodes were also short-lived, but they were critical because they enabled users to tackle outstanding problems and to apply the additional insights they had gained through use over time. Thus, the cycle of intensive improvement followed by relatively stable operations tended to repeat itself.

The timing of adaptation at BBA illustrates this pattern. As shown in Figure 3 (below), we found that most of the adaptations made were accomplished within a very short time after implementation -- on average, 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 was remarkably consistent across all of the projects analyzed; the episode of adaptation that seemed to accompany initial implementation lasted about the same time (approximately three months) whether the project involved five people or 50, and whether the technology was familiar or a departure from current procedures. Further, it was clear that adaptation efforts were not falling off simply because all problems were resolved within this period; on average, respondents reported five significant problems still outstanding at the time when initial adaptation efforts were curtailed. Indeed, most of the new technologies were not considered “production worthy” for many months.

Following the initial burst of activity, most of the technologies entered a phase of regular use as a part of the overall production process. On the other hand, possible improvements to new technologies were not completely ignored after the initial period of adaptation. In most projects, participants regrouped and refocused attention on modifications some time later, again in a concentrated manner and for a short period (two to three months). Three-quarters of all projects in BBA showed a second spurt of adaptive activity. On average, this episode began about 11 months after initial installation, and it accounted for an average of 23% of all reported adaptive activities. Further, in several of the projects, there was a third such spurt of adaptive activity about six to 12 months after the second episode.

Similar patterns emerged at the other two firms studied (see Table 1). At SCC, a large amount of adjustment and modification took place directly following initial installation of CASE tools into a new project site. In each project, the tools had to be fitted to the particular client organization. However, once application programmers (i.e., the users responsible for the actual production of new application software) were brought onto the project and began using the CASE

tools as process technology, further changes to the tools were halted. These tool users required their process technology to be stable and reliable to facilitate production work. Thus, further refinement of the tools declined very sharply after the initial spurt of adaptive activity.

As at BBA, however, a significant surprise or major breakdown later in the project could turn users' attention back to the need for ongoing improvements. At these times, technical support personnel were reassigned to undertake a new round of adaptations.

Table 1: Episodic Pattern of Adaptation

SITE	<u>Early focus on adaptation was quickly subsumed by routine use</u>		<u>Later on, routine use was broken by occasional episodes of further adaptation</u>	
	NUMBER	%	NUMBER	%
BBA	34	86%	31	75%
SCC	4	80%	1	25%
Tech	33	65%	49	96%

At Tech, too, users' adaptation of their computer tools fell off abruptly soon after initial implementation. 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 tried to maintain its stability. As one Tech employee explained, few people even thought about making changes once they had become comfortable with the software:

It's just the way I do it. ... It's not that [further changes would be] hard, it's just that it's not worth the effort.

Yet most users at Tech (49 of 51) did note that specific events did occasionally refocus their attention on the software and trigger further customizations; thus, further adaptations did occur, and these tended to cluster in relatively brief spurts that interspersed periods of routine use of the technology.

In short, all three of these very different organizations displayed a distinctly discontinuous pattern in the way they adapted new process technologies. Significantly, this did not seem to be a conscious management policy in any of the companies. Quite the contrary: managers (and users) frequently stated that they recognized the need for continuous ongoing changes to new technologies, but that it was difficult to keep people focused on this sort of modification activity for more than a short time. Thus, once users became familiar with a new technology, it tended to become a "taken-for-granted" part of normal operations.

The forces for stability and routinization, however, were occasionally disrupted by events that forced -- or allowed -- technology users to ask new questions and to reexamine old problems. Typically, the events that created additional opportunities for adaptation were new developments that somehow interrupted routine operations. At BBA, for instance, the new episodes of adaptation reported were generally associated with events that placed new demands on existing operations. These events also created a pause in the normal production schedule. For example, when new machines were added to the production line where the technology was being used, they often created increased demands for high-precision or high-speed processing that had not yet been achieved. At the same time, the installation of these new machines imposed a temporary line shutdown. Users in our study often took advantage of this time to address old problems and to initiate new adaptations to their technology.

Similarly, the introduction of new products or product requirements, the imposition of new production procedures, or occasional breakdowns of the new technology, also were ways that the need for improvement became apparent, while providing a brief and sanctioned stop in the action. Similarly, at Tech, the release of new versions of computer software forced users to interrupt their normal routines; these events accounted for almost one third (28%) of all later episodes of adaptation observed there. Users at Tech also reported that they occasionally returned their attention to making software modifications when existing procedures became too frustrating, or when they were exposed to new ways to make their routines more efficient.

Examining the Findings: Regularity, or Pathology?

Several aspects of our findings are notable when compared to the conventional wisdom about technological adaptation. First, improvement is episodic, not continuous. That is, the initial burst of adaptation as well as later episodes are limited in duration, quickly giving way to longer periods of relatively routine operation. Second, these periods of adaptation tend to be occasioned by some unusual event that interrupts normal productive operations, or at least that triggers users to begin to ask new questions. The contrary nature of these results raised a number of questions. Did these results suggest a new way of understanding the adaptation process, or were they simply the result of mismanagement at the companies we studied?

In order to answer these questions, we examined several detailed accounts of how some successful firms in other industries and national settings absorb and modify new technologies. In particular, we were interested in Japanese firms known to embrace “continuous improvement” at the level of the overall operation. We asked whether the pattern of adaptations around a specific new

technology in such firms is in fact gradual and continuous over time, or whether it more nearly resembles the episodic pattern that we observed in our data.

We discovered that the successful Japanese operations do not invite or expect continuous adaptations to specific new technologies. Instead, we found a discontinuous model of adaptation that basically resembled our findings. An important difference, however, was that the timing of adaptations appeared to be consciously and carefully managed in the Japanese firms. Managers in these organizations apparently create *and exploit* the very episodic pattern that we described above. Specifically, managers in these companies do three things. First, they aggressively utilize the introduction period to adapt new technologies. That is, they identify and make the maximum number of modifications as early as possible. Then, following this period, they impose routine on the use of new technologies, *and* they exploit routine for what it can teach them. Third, they consciously and periodically create new opportunities for further adaptations.

Below, we describe these three aspects of such technological management in more detail. We then present reasons why exploiting the episodic pattern of technological adaptation can be a particularly *effective* (and attainable) approach to learning and improving over time.

Initial Introduction Period: Aggressively adapting the new technology.

The Japanese operations we examined truly exploit the initial period of technology introduction. They do not build in a great deal of extra time for debugging a new technology before moving into full production schedules. Rather, they develop very demanding, early production commitments for new technologies -- and then they take steps to ensure that the new process technology will be ready. The ability to do this stems partly from careful early design of new products and processes, as has been well documented elsewhere

(Wheelwright and Clark, 1992). What is less widely understood is that meeting tight production deadlines in Japanese operations also stems from “the intensity of revisions on the spot during start-up” (Hall, 1983:197). At Toyota, for instance, there is “a direct engineering assault to correct [problems] in the beginning, [which] prevents the need to dribble a constant stream of engineering changes through the formal system over a long period of time” (Hall, 1983:199).

This early spurt of activity is often not apparent to outsiders. For example, U.S. observers who toured a successful Japanese electronics operation reported that “the Japanese can simply 'flick a switch'” to start up new process technologies at high yield. In reality, successful introduction required three months of intensive, exhausting effort by a team of engineers. These engineers knew that there would be problems, but they also knew that these problems had to be resolved during the brief ramp-up period. Production commitments were absolutely firm, and the firm's profitability depended on meeting them (Langowitz, 1986).

In the automobile industry, for example, Clark and Fujimoto (1991) describe the Japanese approach to managing initial ramp-up of new technologies as far more intense than normal problem solving activities -- in fact, they label it “the Japanese 'war time' approach” (page 202). They find that while U.S. and European automobile manufacturers typically allow close to one year after the start of production to meet their target level of quality on a new line, the Japanese allow only one to two months. The idea behind this Japanese strategy, explains Hall (1983:60), is to “work through as many engineering changes as possible when a new model starts into production so that, at the close of start-up, it is ready to run smoothly.” This idea is backed up with significant resource commitments. For example, at Toyota, “design engineers, manufacturing engineers, production control personnel, quality managers and anyone else who is

necessary live on the production floor during start-up. [Time losses are minimized because] engineering changes are made on the spot."

Periods of Regular Use: Imposing and exploiting routine.

While many Japanese firms are known for their pursuit of "continuous improvement," this does not mean that a newly implemented technology is subjected to a constant stream of changes. Instead, it is understood that before any improvement can be undertaken, "it is essential that the current standards be stabilized" and institutionalized (Imai, 1986:63). In the Kaizen philosophy, "there can be no improvement where there are no standards" (p. 74). This means that standards and measures must be imposed, "and it is management's job to see that everyone work in accordance with the established standards" (Imai, 1986:75).

Specifically, in the case of new process technologies, once the initial episode of debugging and modifying the technology is completed, standard operating routines are developed and enforced. Operators are not expected and not allowed to introduce modifications on an informal, everyday basis.

Jaikumar provides a vivid example; in his sample of FMS users in Japan, operations were so smooth that production planning took only one hour per week, and unexpected downtime was virtually nil. With such predictability in operations, there was no need, and "no allowances for in-the-line, people-intensive adjustments" (Jaikumar, 1986:76). Even the appropriate recovery routine for each possible failure mode had been codified and provided to operators (Clark, Henderson and Jaikumar, 1989).

This does not mean that ongoing improvements are neglected -- only that the changes actually implemented are tightly controlled. Operators in Japanese operations perform considerable off-line experimentation, but they do not make

unauthorized changes to production technology (Schonberger, 1982). Except for urgent corrections, adaptations to the technology or production practices are permitted only at designated times (Hall, 1983; Schonberger, 1982).

This emphasis on routinization is echoed in nonmanufacturing operations in Japan. In Japan's new software factories, there is rigid adherence to existing standards and little allowance for individuals to make changes as they go along during the production of new software systems, (Cusumano, 1991). Managers in Hitachi's software works, for example, realized that creating standardized procedures not only helped them to improve programming efficiency and productivity, but also "helped them identify best practices within the company and within the industry for dissemination to all projects and departments" (Cusumano, 1992:468).

The Cycle Repeats: Periodically, creating new opportunities for adaptation

Descriptions of technological adaptation in Japanese firms reveal that, at the level of a given technology, "continuous change" really involves repeated cycles of change and stability. Imposing the discipline of routine procedures ensures that the timing of further changes is carefully managed. Whenever possible, modifications are grouped together systematically and implemented in one intensive episode of adaptation.

Very often these episodes are timed to coincide with other major changes, such as product-model changeovers, releases of new software versions, or yearly factory shutdowns. For example, Hall (1983:200) explains that the most efficient manufacturing companies "generally plan engineering changes one to two months before the effective date. The effective dates of most changes are timed to occur at schedule-change times." Similarly, in Japanese software factories, development methods, tools, and products are generally held steady during a given project, but

are periodically and systematically upgraded or revised. Cusumano's review of Hitachi's software factory, for example, shows that Hitachi managers knew that the procedures they initially created would not be perfect; they "clearly recognized that these procedures and standards would have to evolve as personnel and technology changed, and they made provisions to revise performance standards annually" (Cusumano, 1992: 468).

In short, by creating distinct episodes of adaptation, managers provide the operation with both the benefits of routine, and the vitality of ongoing change.

Challenging the Received Wisdom: Why a Discontinuous Pattern of Change can be Effective

One way of interpreting the evidence from our research and the Japanese studies is to suggest that successful companies take the naturally "lumpy" pattern of adaptation and exploit it. That is, managers in the firms cited above achieve maximum benefit from their adaptation efforts by carefully managing both spurts of adaptation and periods of routine operation. Indeed, there is evidence that such a *discontinuous* pattern of modification can yield important benefits. First, there appears to be a natural surge of energy at the start of projects, and smart managers exploit this to the fullest. Second, both learning and efficiency goals can be enhanced by imposing (and using) periods of routine operation in between periods of rapid change. And third, revisiting the adaptation agenda at intervals can make problems more tractable and can render change more attractive. Below, we discuss each of these issues.

1. The Importance of Beginnings: Utilizing the Initial Window of Opportunity

The period immediately following initial introduction of a new technology provides a special "window of opportunity" for adaptation. At the start of the

project, the level of energy is high. The novelty of the situation helps people to focus on the new technology, and to see it as a distinct and malleable tool. As Weick (1990:21-2) argues, "The point at which technology is introduced is the point at which it is most susceptible to influence. Beginnings are of special importance because they constrain what is learned about the technology and how fast it is learned."

In the three organizations we studied, we noticed powerful organizational forces that underscored the importance of beginnings. In many cases, the motivation to change and to achieve targets was highest at the start of the introduction period. Challenging project objectives had a catalyzing effect at the start that often faded over time. For example, when one of the BBA plants began using an advanced precision grinding cell, the plant manager explained that "grinding all five faces [is] the key objective in this project." Productivity improvements were viewed as less challenging and were simply assumed. Yet 18 months later, when users still had not achieved five-face grinding, the motivating power of these objectives had faded. One engineer simply dismissed the earlier objective, commenting that:

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

Thus in this case, as in others we observed, people slowly lost sight of their aggressive original objectives as they became accustomed to the level of performance actually achieved.

Another powerful factor is that modification and improvements are much easier to implement at the beginning of the introduction effort. Successful implementation means that, over time, the technology becomes increasingly integrated into the production process. The new technology gets physically interconnected with the rest of the production process, and users learn to rely on

it for production needs. Thus, after the initial period, further adaptation threatens to disrupt the physical flow of goods or services. Later modifications also threaten to destroy the routines and procedures for using the technology that users establish over time. For example, one engineer at BBA explained that it was hard to get production people to agree to further adaptation because "now the operators depend on the machine -- it's built in, they don't want to change." Even at Tech, where there were few system constraints on the changes that individuals made to their personal computing environments, users admitted that their own routines or habits tended to constrain further change. One user stated, "I got a set of custom [settings] from [a colleague] about four years ago. Now they're ingrained."

Another reason why beginnings are so potent is that as time goes on, key project personnel are often needed for other assignments. Thus, they are not available to help with continued fine-tuning and modification of the new technology over time. Even where team members are not reassigned, teams tend to lose enthusiasm over time. At a BBA plant in Germany, an engineering manager commented,

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.

Research on human behavior suggests that these tendencies are not just a function of mismanagement or short-term thinking in Western companies, but rather are normal aspects of human task performance. Psychological studies have shown that people's motivation to engage in effortful problem solving is partly a function of time: with extended exposure to a given phenomenon, people tend to become less alert and to notice fewer details than they do up front (e.g., Newtonson, 1973; Kruglanski and Freund, 1983). Familiarity also makes people less willing

to invest time and effort in difficult problem-solving (Langer and Imber, 1979). Sustaining such motivation over long periods is difficult.

Finally, identifying and resolving problems during the initial introduction period is often easier because there are fewer competing demands on people's time. Later on, production issues tend to dominate the list of priorities, simply because urgent problems have the power to drive out attention to more important, but less urgent, issues. One project manager we interviewed stated,

The basic operating fact is that you need to produce good parts every day. [Even if] these people [the project team members] see a problem or get an idea and want to try it, some days you just can't.

Some project managers in our study imagined that they could continue to modify the technology on a gradual basis "as we went along," but found that production and adaptation did not mix well. As one project engineer explained,

On this project, we tried to mix production and engineering work. But once we really got into production, time to do important engineering work was squeezed out by everyday work with the machine and operators. The sheer volume of work made it impossible to search very far for new solutions, or to examine and test ideas before they went on line. There was plenty of money, but no time -- we only had Saturdays for testing new solutions. The result? Lots of grey hair!

The difficulty of simultaneously tackling production and adaptation were not unique to Western firms. One Japanese engineer faced with this problem is quoted by Ogawa (1991:185-6) as saying,

The production quota was high at that time. Even when team members gathered at the operation room on time to do an experiment, we were often kept waiting until the production quota was filled. Experiments often started at midnight. These circumstances deteriorated the efficiency of the work significantly. Consequently, it took longer to fix the problems than we had expected. This experience taught us the importance of finding the potential bottlenecks as soon as possible. The later the problems are found, the more it becomes difficult to solve them.

2. The Benefits of Institutionalization: Learning from Routine Use

Once an initial set of modifications has been identified and implemented, there are several reasons to hold the technology (relatively) constant for a period of time. First, there are obvious efficiency benefits to allowing the operation to run for some time in a stable fashion without imposing frequent, disruptive changes. Hayes and Clark (1985) have shown that plants that are not subject to high levels of "confusion" from frequent changes in their tasks and technology show superior growth in productivity relative to "higher confusion" environments. Hall's (1983) study of Toyota argues that "dribbling a constant stream of changes" into the operating system can seriously compromise operating effectiveness.

Second, routine operations are an important test bed; if constant and uncontrolled changes are being made, it will be very difficult to assess the effectiveness of previous modifications (Imai, 1986). Especially in "noisy," complex environments, where signals may be misleading or difficult to interpret, problem solvers need to observe the system over relatively long periods of time before defining further adaptations (Levinthal and March, 1981).

Periods of routine operation also provide users with opportunities to explore a new technology, and to learn from their own reactions (Weick, 1983; Etzioni, 1989). Sometimes, extended use is needed to identify features that are inconvenient, or that cannot meet the evolving daily demands of a particular operating environment (von Hippel and Tyre, 1993). Thus, as Imai explains, progress can only occur when one "institutionalizes [a given] improvement as a new practice to improve on" (1986:62).

3. *The Value of Periodic Episodes of Adaptation: Reopening the Window of Opportunity*

There are several reasons why it makes sense to return to the adaptation agenda in short but intensive spurts, rather than to try for a more gradual pattern of change around a given technology. First, short but intensive episodes of adaptive activity exploit “economies of scale” in problem solving. Diverse resources are required for resolving many of the problems that affect a new technology. Managers, engineers, and users must create a cross-functional team, call in outside experts, set up experimental apparatus, develop prototypes, etc. Frequently, regular operations must come to a halt. Gathering these resources only *once* to attack a number of issues is obviously more efficient than gathering them each time a single issue arises.

Changes are also less disruptive to ongoing operations if they are bundled together than if they are trickled out piecemeal to operations (Hall, 1983; Clark and Fujimoto, 1990). Indeed some problems simply cannot be solved -- or cannot be solved effectively -- unless they are examined as part of a complex set of interdependent issues. When problems are dealt with *en mass*, instead of one-by-one, these interdependencies can be identified and utilized.

There are also motivational economies of scale associated with brief, intensive spurts of adaptive activity. It is easier to motivate a team (or even an individual) to devote attention and energy when the goal is large and obviously significant (resolving many problems) than when it is small and apparently unimportant (solving just one issue). Similarly, the rewards and satisfaction that come from resolving a significant set of issues can be an important motivator for team and individual efforts.

Finally, episodic cycling between short spurts of change and longer periods of regular use makes it possible to revisit problems or issues as knowledge is

gained with experience. Multiple cycles make it possible to respond to changes in the operating environment that occur long after initial implementation of a new system -- whether these are exogenous developments, or shifts in users' preferences and expectations (von Hippel and Tyre, 1993). By moving occasionally into adaptation mode, problems that eluded understanding during one phase can be reframed and perhaps approached more successfully after a break in the action.

Management of Attention and Effort over Time

These arguments suggest that a "lumpy" pattern of adaptation around a specific new technology may not be such a bad thing. Instead, relatively long periods of routine use, coupled with occasional but intensive episodes of adaptation, may be a powerful combination. Reaping the joint benefits of short episodes of adaptation and longer periods of regular use, however, is not automatic. It requires explicit management of the attention and effort applied in both phases.

Managing cycles of change and routine use of technologies demands a way of thinking that is unfamiliar to many Western managers. Users in all three of our research sites noted that management very seldom took explicit action to create episodes of adaptation. For example, management seldom intervened in a specific project to raise performance expectations, nor did they require regular project audits that might have helped to focus attention on persistent performance shortfalls. Indeed, our interviews with managers showed that while they were concerned with the way their organizations were introducing and using new process technologies, they were not sure how to manage the process. None of the people we interviewed seemed aware of the need to create or take advantage of discrete windows of opportunity for technological adaptation.

Our findings suggest that managers must consider how to create opportunities for adaptation, how to utilize those opportunities, and how to exploit periods of regular use of technologies for generating new insights and ideas. We cannot offer a recipe for doing this. However, we can suggest some ideas for moving toward a more conscious management of opportunities for technological improvement.

Creating opportunities for adaptation.

Sometimes, events outside of managers' direct control create new challenges or expose users to new ideas. We showed above that at BBA, the imposition of new products and additional new equipment often created renewed opportunities to focus on problems with process technology. On the other hand, we found few cases where managers actively created new opportunities, even though they could have. For example, requesting post-project audits of new process technology is one way of helping users refocus on original project objectives, and to compare those with current operations. Managers can also precipitate "minicrises" within the operating environment that push users to stretch existing capabilities -- for example, managers can declare a target of zero defects during a given week. Taking a different approach, managers can inject new resources for problem solving on a temporary basis. For example, during a period when orders are low, plant managers may call a "problem-solving day" when no production takes place, and each person is expected to suggest and work at implementing improvements.

Rotating people between assignments is another way to generate opportunities for change. We know that new project team members tend to bring fresh ideas, and to pose questions that existing team members have ceased asking (Katz, 1982). New team members also represent additional resources that are

often needed to undertake modification activities. For example, we noticed that at BBA new episodes of adaptation were sometimes triggered simply by the addition of a new, unattached engineer into the factory environment. Likewise, existing team members who spend time in another setting or in a different function may return with new ideas to put into practice, or a new perspective for assessing performance.

In creating windows of opportunity, it is important to realize that simply knowing that there are problems (or that better alternatives exist) is not enough. Somehow, management must provide the incentive to undertake improvements, the resources necessary to accomplish this, and the chance to halt normal production rhythms for at least a short time. New product introductions, new quality requirements, or special assignments are events that often provide these -- but not always. If operations are too chaotic, or if additional requirements place too great a burden on existing resources, it will be difficult to focus on potential new improvements at the same time.

Besides the specific actions taken, the way these actions are framed is also important. A new or unexpected event is too often interpreted as a threat (which produces insecurity and rigidity), when it could be seen as a welcome opportunity for change (Meyer, 1982; Dutton and Jackson, 1987; Weick, 1990). The words used, the rewards implied, and the actions displayed by managers all affect such framing. To recognize a new development as an opportunity, employees need to believe that the situation holds the potential for meaningful gain, and that they will have access to the competencies and resources necessary to develop that potential (Jackson and Dutton, 1988). Consider, for example, the manager who requests a post-project audit. This can easily become just one more onerous reporting requirement, where considerable effort is spent in justifying actions already taken. Such audits may present opportunities for real exploration if they

are framed differently. For example, managers can ask users to skip the economic justification, asking them instead to identify three objectives that have not yet been fulfilled, or have not been fulfilled as well as they could be, and to outline plans for improvement.

An interesting question is whether new windows of opportunity must be surprising or unexpected events. Some organizations seem to turn very regular events, such as yearly plant shutdowns, new product introductions, scheduled technology upgrades, or maintenance reviews into successful episodes of adaptation (Hall, 1983; Jaikumar, 1986). Yet there are also many cases where the element of surprise is important for jolting people out of entrenched routines and assumptions. In a well-known study, Meyer (1982) showed how a potentially-crippling doctors' strike provided opportunities for some hospitals to undertake new organizational experiments, to restructure operations, and to redefine internal power relationships. Examples are also common in everyday life; an extreme one was the case of the San Francisco earthquake in 1989. Following the quake, some computer users lost the information they had saved on disks. While experiencing a loss, they were also released from past constraints, and some people used this as an opportunity to reconfigure their workspaces both electronically and physically. Whether or not such a disruptive event is necessary to create new opportunities for adaptation may depend on how deeply entrenched existing routines have become.

Exploiting windows of opportunity for adaptation.

At least three factors influence the ability of the organization to exploit opportunities for adaptation: the organizational capability to act rapidly during a limited time window; the knowledge to select and undertake useful adaptations; and the choice of objectives to guide activities during this period.

The ability to act rapidly following a surprise, disruption, or halt in normal operations is critical if windows of opportunity are inherently brief. This ability is also rare, because it requires that the operation be organized for fast response. One important aspect of fast response capability is what has been called “information turn-around time” (Bohn, 1988); that is, the time required to collect data (by observing regular operations or by running special tests), analyze them, and make decisions about next steps. If test results are obsolete before action can be taken, then modifications will be both slow and, often, misdirected. One plant engineer we interviewed explained that:

We could work on this [mold] to improve it, but we'd have to send it out to the lab [for evaluation after each trial], and the lab lead time is one week. You can't develop a process like that! So, we just decided to consider this part "done".

Similarly, the responsiveness of support functions is critical to maximizing the limited time for adaptation. Very often, modifications require the input of technicians, development engineers, systems analysts, programmers, maintenance personnel, etc. If users find it difficult and time-consuming to get the attention of support personnel, and if weeks elapse before users' requests are responded to, then the opportunities to undertake modifications will dissolve rapidly.

One of the Italian project teams we studied created an innovative solution to this problem. Plant managers realized the necessity for fast response to the problems arising with a new process technology. They created a special workstation near the new process, called “pronto intervento,” which housed dedicated maintenance personnel and other resources (such as extra tooling and machine parts) to be sure that problems could be dealt with immediately. Similarly, rapid response from external part or tool vendors, combined with smooth functioning of internal purchasing and receiving units, can be critical.

It is important to note that the organization's ability for rapid response is highly systemic. If project deadlines are habitually allowed to lengthen because of outstanding problems, then key personnel will be perpetually busy, and unable to respond to special requests for assistance with modifications. Worse, these commitments will be unpredictable, and so the whole system will suffer increasingly from lags and unresponsiveness (Bradac, Perry and Votta, 1993).

This illustrates the self-reinforcing quality of rigid project deadlines and limited windows of opportunity: when project deadlines are respected, key personnel are freed up to respond to new opportunities for improvement in other parts of the operation. When episodes of adaptation are short but intense, such personnel can devote their full attention to the work involved, yet still be able to return to other projects in a short time.

Similarly, a strict deadline can help focus energy on needed adaptations. When tasks are bounded in time by definite deadlines, this often helps to focus attention and to increase the chance that people will actively work on the problems facing them. Especially when people are working in groups, deadlines help to keep individual efforts aligned and to maintain motivation (Hackman, 1990). Awareness of tight time limits helps groups to assess their progress and to develop new approaches when existing ones are not working (Gersick, 1988).

Of course, deadlines can also become dysfunctional if they are unrealistic or too rigid to accommodate unanticipated contingencies. Remembering that new windows of opportunity can be opened in the future for further work may help managers set more reasonable deadlines and expectations for the period immediately following installation of a new technology.

Perhaps the most serious problem that distracts personnel from attending to technological adaptation is the need for continuous fire-fighting just to maintain normal operations. When operations are out of control to begin with,

introducing new (and advanced) technology only creates confusion and chaos (Hayes and Clark, 1986). Similarly, introducing technology that is itself very immature can swamp the operation with crises, and divert attention from genuine improvement efforts. As one of the engineers involved in a disappointing project at BBA explained:

There were so many machine and quality problems at first that we had to change so many things...once we got into these problems, I couldn't do any more [significant improvements]; only try to attend to the little problems. The result was a lot of frustration.

The more that problems can be resolved *before* introducing the new technology, the more users can exploit windows of opportunity for making improvements, rather than simply for keeping their heads above water (cf. Tyre and Hauptman, 1992).

Besides availability of physical and support resources, users need considerable technical capability if they are to take advantage of opportunities to improve operating technologies. Thus, technical training of users of new process technologies is critical. However, many conventional training programs ignore the fact that opportunities for learning, like technological adaptation, may also be episodic or cyclical over time. Traditionally, user training occurs before installation of a new process technology. Indeed, most systems development processes schedule user training as one of the last phases before hand off of the system to the users. Certainly, some basic-level skills are needed at this installation point. However, just as all problems with a new technology do not show up immediately, so users cannot absorb all that they need to understand at the outset. As they gain experience with the new technology, they gain insights and increase their "absorptive capacity" (Cohen and Levinthal, 1990) for further formal training. With increasing comfort with the new technology, and a greater

understanding of their own operating requirements, users are better able to exploit educational opportunities on more advanced topics.

Moving away from the “one-shot training” approach would be particularly valuable in software where complex features and functionality simply cannot be explored or appreciated without a certain experience of the technology. One company we know has specifically implemented a two-tier training program for its personal computer users. Here, the second tier is not seen as “optional” training, as many advanced courses often are. Rather, it is presented as the continuation of the training course begun six months earlier.

Other users are another source of insight for utilizing opportunities to adapt new process technologies. For instance, at Tech a large number of software modifications were suggested by or borrowed from other users of the computer tools (see also Mackay, 1991). However, physical and organizational boundaries often prevent users from visiting other sites or from borrowing ideas from other users. This is unfortunate, because such visits and face-to-face exchanges can sometimes trigger new opportunities for adaptation. They can also help users to make more informed choices about the adaptations they pursue.

Finally, perhaps the most critical determinant of whether or not organizations exploit opportunities for technological adaptation is the objectives they apply. Many people see the period immediately following initial installation of a new process technology as a time to get the system “up and running” smoothly. Thus, the objective is to resolve problems that will interfere with full assimilation of the new technology. A different and more aggressive approach is to view this period as a time to surface as many problems as possible. The reasoning here is that if problems are not identified early, it may be difficult to focus on (or even to recognize) these issues later. Yet, such unresolved issues may compromise performance of the technology over the long term. With the

alternative approach, the objective of the initial start-up period is not just a working technology, but also new understanding about how the technology can be most fully exploited in a given operating environment.

A very interesting proposal in this regard is presented by Ogawa (1991), who studied new technology introductions in the Japanese steel industry. He argues that many managers hold a mistaken view of the test period. They assume that the purpose of this period is to enable operators to get accustomed to the new equipment, to set operating parameters, and to get product samples approved by customers. In fact, Ogawa argues that the best Japanese managers also see the test period as a time to surface all major problems with the new technology. They reason that the new equipment should be placed under unusually severe demands as early as possible. Ogawa calls this the “rapid max” strategy. Under “rapid max,” the new system is quickly but temporarily brought up to maximum operating rates during the startup and test period. The point with “rapid max” is not to reach stabilization rapidly, since this can lead to stabilization of suboptimal routines, or even to “false stabilization.” Rather, the objective is to experience rapidly a full range of issues and to uncover problems that would be difficult to deal with later.

Employing a “rapid max” strategy to new process start-ups would be a bold move for managers in most Western settings. The approach employs the same counter-intuitive logic as the “kan-ban” system, which tells managers to decrease inventory in order to make their problems more obvious. Yet, if we recognize that experience brings with it inevitable forces for routinization, this strategy appears to be a powerful learning tool that can contribute to long-term effectiveness.

Exploiting periods of regular use of process technology.

We argued above that periods of sustained regular use can be complementary to episodes of adaptation. Periods of regular use provide data on how the technology is working, on whether previous changes are yielding positive results, and what new problems (or opportunities) need to be addressed. Thus, the key to utilizing periods of regular use is careful observation of operations and collection of data about them.

This is not a simple task. Especially in Western settings, users of technology often perceive a conflict between production goals and data gathering activities. As one user at Tech remarked, she often runs into a certain problem with her software, but when this occurs she is typically “too busy” to carefully log the circumstances surrounding the error as a base for future analysis.

One solution may be for managers to make data collection part of users' regular responsibilities. For example, Jaikumar (1986) reports that in Japanese FMS installations, operators spend almost one third of their time observing system behavior, examining statistics on system performance, or running tests to generate new data about the system.

Managers can also make data-gathering easier. A number of automated methods could be used. For example, if software users feel “too busy” to log the occurrence of errors and the circumstances surrounding them, it may be possible to create an automatic “log-it” function, where the system captures relevant data when problems occur. Another idea is to utilize an electronic mail message system that lets users send ideas and remarks about system problems to a central person. That individual could then collate and categorize such comments. Additionally, automatic tracking of operations (e.g., as part of statistical process control systems) is often available in manufacturing settings; the data could be gathered and used to track performance variations over time. Existing records of

repairs or service calls made, or of engineering change orders filed, could also be culled as sources of data on problems and opportunities. At the very least, users could keep electronic journals of observations (including things they like or do not like) at the individual level. Whatever the mechanism, it is important to note that useful data include both well-structured information on predetermined topics (e.g., level of defects, nature of defects), as well as unstructured observations and ideas that may occur to users as they interact with the new technology.

Non-electronic innovations can be equally powerful. For example, one of our colleagues noted that he keeps a manila file of ideas from students or others about ways to improve his course. Instead of turning off whenever a suggestion is made -- because he knows he is too busy to deal with it -- he simply jots it down and files it. Then, once a year (when he revises his syllabus over the summer), he examines the contents and acts on those ideas that have been made repeatedly over the past year.

Framing the data-gathering effort by setting appropriate objectives is also important. When using regular operations to support further adaptations, the point is not only to pinpoint unresolved problems or to test past solutions, but for users to also increase their understanding of the new technology. Thus, next time they find an opportunity to focus on adaptations, users would be able to investigate problems at a deeper level, and to tackle more challenging types of change. In this way, repeated cycles of adaptation should offer the chance for something better than just ongoing modification. It should create opportunities to identify increasingly subtle problems, or to set increasingly challenging objectives for the technology (and its users) over time.

Conclusion

While virtually everyone agrees that process technologies must be modified and improved over time, very few people have examined the process in detail. In this paper, we have described a central paradox that affects the implementation and later use of new process technologies. On the one hand, ongoing adaptation is an important success factor for implementing and using many new process technologies -- and such adaptation takes time and experience. On the other hand, the more experience that users gain with a new technology, the more they rely on established routines and habits. Over time, their sharp focus on the technology as a separate and malleable object fades; thus, both the technology and the way it is used become taken for granted.

Given these tendencies, is it possible to pursue ongoing improvement while enjoying the benefits of stable, routine operations? We suggest that it is, but that achieving both objectives requires careful management of time and attention. At the level of a specific technology, there are important benefits to applying adaptation efforts in an uneven, episodic manner, rather than on a gradual, continuous basis. The episodic pattern described in this paper allows users to rely on stable production routines most of the time, but also provides discrete "windows of opportunity" to reexamine and change those routines. Short but intensive episodes of adaptation make it possible for team members to devote their attention to adaptation efforts without undue distraction from -- or interference with -- ongoing operations. Such brief, intensive periods of adaptation also make it possible to exploit economies of scale by attending to many small problems at once.

Unfortunately, many companies (and this may be more common in Western ones) neither recognize nor manage these episodic cycles of change and stability. Managers typically exhort employees to seek out problems and to

pursue improvements on a continuous basis. Yet we suggest that managers could exploit a more discontinuous pattern to good effect, by: (i) aggressively exploiting the opportunities for change that accompany the initial introduction of a new technology into the organization; (ii) mining subsequent periods of regular, routine use for new data and new insights into technological problems and opportunities; and (iii) periodically creating and utilizing new opportunities for further adaptation. This last point may be the most challenging. It involves both focusing users' attention on the need for change, and providing the resources and capabilities needed to act quickly -- before the window of opportunity closes once again.

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FIGURE 1

**A CONTINUOUS PATTERN OF
TECHNOLOGICAL ADAPTATION**

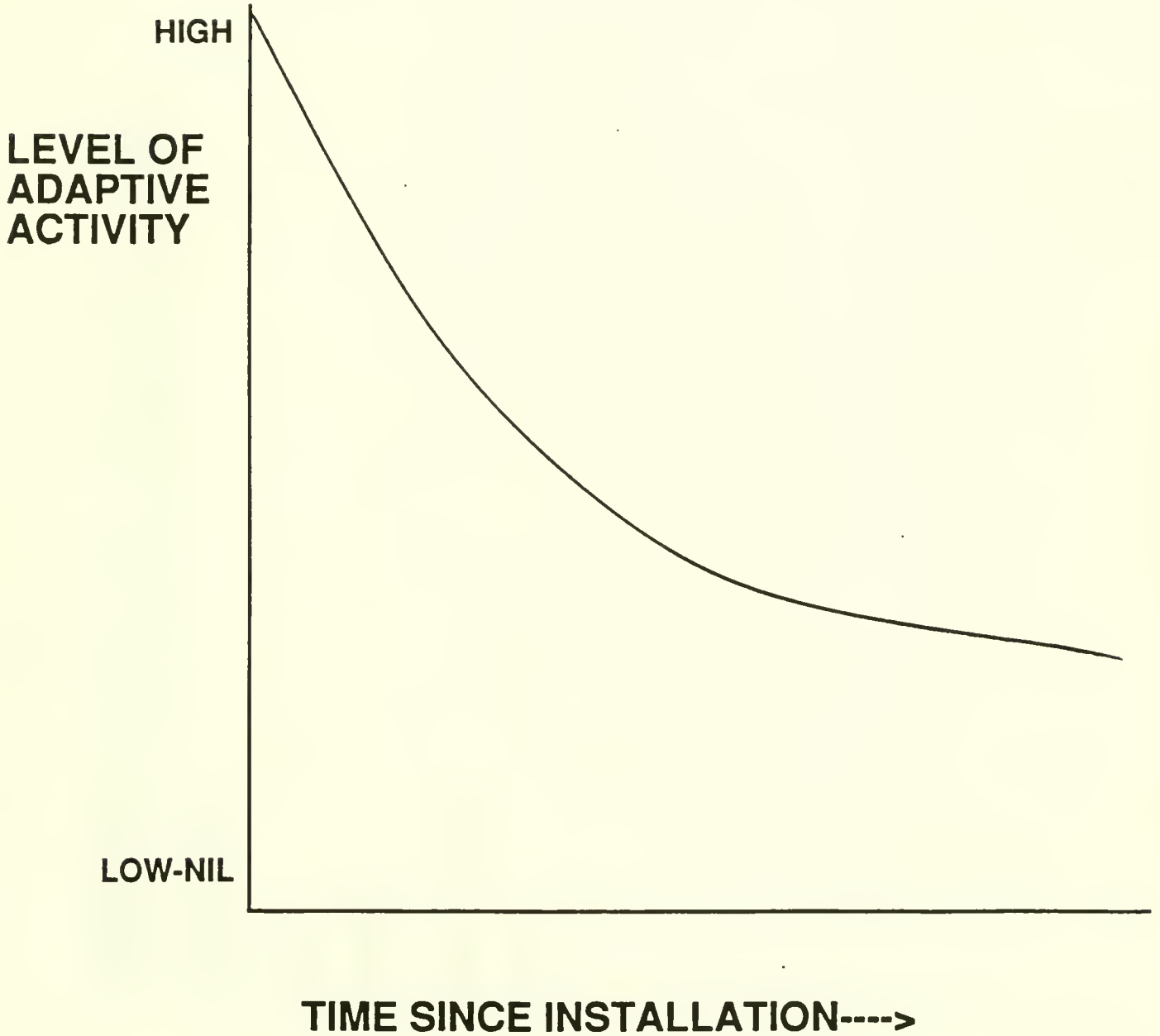


FIGURE 2

**A LUMPY OR "EPISODIC" PATTERN OF
TECHNOLOGICAL ADAPTATION**

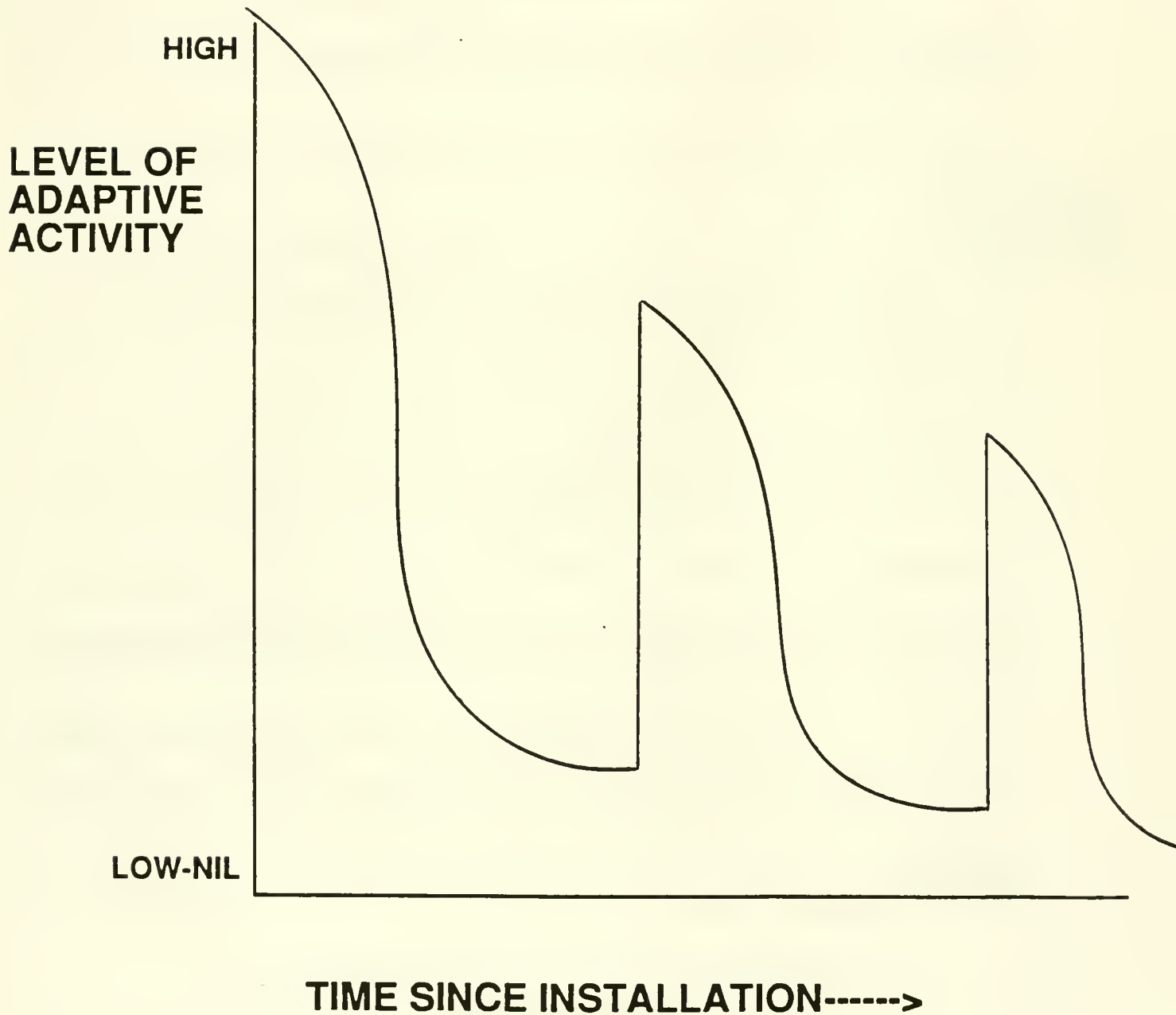
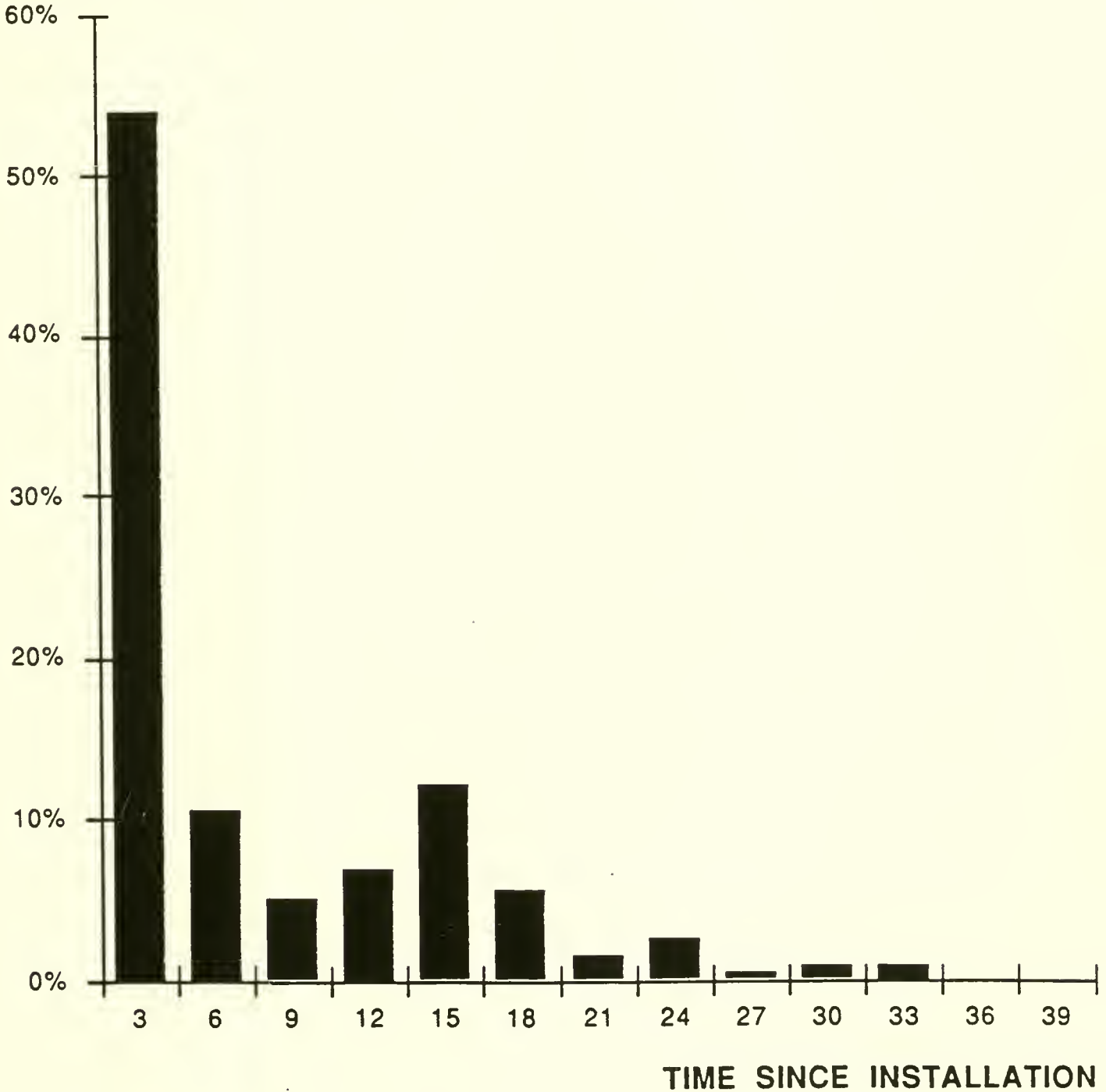


FIGURE 3

TIMING OF TECHNOLOGICAL ADAPTATION AT BBA

**PERCENT OF ALL
ADAPTIVE ACTIVITY**



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