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A Dynamic Theory for Sustaining Process Improvement Teams in Product Development

Elizabeth Krahmer Keating[1]

Rogelio Oliva[2]

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1. Sloan School of Management, Massachusetts Institute of Technology, E52-343, Cambridge, MA USA 02142. Phone (617) 253-5239; Fax: (617) 253-0603; E-Mail: ekrahmer@mit.edu.

2. Escuela de Negocios de Valparaiso, Universidad Adolfo Ibáñez, Balmaceda 1625, Recreo, Viña del Mar, Chile. Phone (56-32) 66-0211; Fax (56-32) 66-4006; E-Mail: roliva@uai.cl.

Abstract

Process improvement has become an imperative for businesses seeking competitive advantage. However, firms often experience difficulties in both gaining acceptance for improvement programs and sustaining them, particularly in product development. We describe a theory to explain the initiation and sustainability of process improvement teams in product development. The theory integrates the structural elements of the firm with the dynamics of commitment and the improvement process. Since improvement activity takes time away from design work, the short-run effect of improvement effort is an increase in work pressure and a drop in organizational performance. This *worse before better* dynamic combined with the organizational and technical complexity of product development creates unanticipated feedbacks which can lead to the failure of improvement programs, even when the teams are highly motivated. The paper integrates theories from product development, teams, performance, motivation, and process improvement literatures and is grounded in an in-depth study of a successful product development improvement initiative undertaken by a global telecommunications equipment manufacturer. Implications for theory and practice are considered.

Introduction

Process improvement has become an imperative for businesses seeking competitive advantage (Schaffer & Thomson, 1992; Takeuchi & Nanaka, 1986). However, process improvement programs, particularly in product development, often experience difficulties either in gaining initial acceptance or in sustaining the effort (Ernst and Young, 1991a and 1991b; US GAO 1990). Existing theories tend to ascribe the performance of improvement teams to motivation, incentives and aspects of team structure. Accordingly, advocates of process improvement initiatives (Deming, 1982; Ishikawa, 1985; Juran, 1974) offer numerous techniques for motivating employees and enhancing team performance, such as management support, training, promotion, and rewards.

While these factors are clearly important, they overlook the interactions between teams and other operational and organizational units of the firm, as well as the high organizational and technical complexity of product development, all of which increases the time required to realize improvement results. Both factors can create unanticipated self-reinforcing and self-correcting feedbacks that can lead to the failure of improvement programs, even when the teams are well-funded, thoroughly trained, and highly motivated.

We examine, in particular, an important structural dilemma facing process improvement teams in product development: process improvement programs create a trade-off in which investment in improvement effort today reduces current throughput but with the prospect of enhancing future productivity. Without sufficient management support and organizational commitment, employees will continue their normal day-to-day work and underinvest in improvement activities, causing process improvement initiatives to fail. On the other hand, if the employees become engaged in improvement efforts, their normal product development projects may become delayed. As a result, active process improvement programs can create a worse before better dynamic (Forrester, 1961) that can activate team and inter-departmental pressures that undermine the improvement effort. In addition, due to the long time delays between the allocation of improvement effort and the generation of results, expectations created to enlist participation and motivate product developers may outstrip actual progress, leading to disappointed teams and program failure. To overcome this problem, process improvement efforts can adopt a more understated implementation approach and also reduce the improvement delays by decomposing the development process into less complex sub-processes, each addressed by separate teams, while still maintaining coordination of the overall effort.

We present a dynamic theory of process improvement teams which augments the existing theories with: (1) feedbacks between improvement teams and the firm's physical, operational, and organizational structures; and (2) the endogenous dynamics of the improvement process. The paper integrates theories from product development, teams, and process improvement literatures and relies upon grounded, intensive case study research to extend the literature. In particular, we draw from a study of product development cycle time reduction initiative, which utilized techniques – largely overlooked by existing research – to produce substantial process improvements. While the APEX initiative can also be viewed as a valuable tool for knowledge management (Mohrman, Tenkasi, & Mohrman, 1997), we have chosen a different focus. Due to the importance of this initiative to our theory, we present a description of the Achieving Process EXcellence Teams or APEX initiative undertaken in a high-technology business unit of AT&T in a subsequent section.

Research Methodology

Overview of the Research Project and Site

The study presented in this article was conducted as part of the Designing Sustainable Improvement Programs research by the System Dynamics Group currently being done at the Sloan School of Management at MIT (Jones, Krahmer, Oliva, Repenning, Rockart, and Sterman, 1996; Sterman, Jones, Krahmer, Oliva, Repenning, and Rockart, 1996). The purpose of this project is to provide the basis for a dynamic framework through which to understand the key determinants of the success or failure of quality improvement programs. Our research involves detailed field study with four partner organizations to ground the formal models in intensive longitudinal study of important improvement programs. The models will be synthesized into a `management flight simulator' - a simulation environment in which managers and students will be able to explore the long-term dynamics of improvement programs and design more effective programs. We employ an inter-disciplinary research approach, that includes detailed longitudinal assessments of the organizations' experience with improvement programs, followed by development of hypotheses and theory grounded in data. The hypotheses are drawn from extensive field research as well as existing theory in operations management (Chase and Aquilano, 1989), quality (Deming, 1986; Juran 1969; Shiba, Graham, and Walden, 1993), and organizational theory (Cyert and March, 1963; Forrester, 1961; Lyneis, 1980).

This article describes and reflects on an innovative and successful product development cycle time reduction initiative (referred to as the Achieving Process EXcellence Teams or APEX initiative) undertaken by Bell Laboratories engineers assigned to the Transmission System Business Unit (TSBU) of AT&T, subsequently absorbed into Lucent Technologies after the 1996 trivestiture. TSBU's quality program involved all areas including manufacturing, product development, and supplier quality (McPherson, 1995). APEX was an important part of the overall initiative which culminated in the Malcolm Baldrige National Quality Award (MBNQA) for TSBU and was thus selected for study. Other studies conducted by our research group at AT&T/Lucent focus on the history of quality (McPherson, 1995) and supplier quality (Krahmer, 1997a and 1997b).

Research Method

The primary tool used to develop of the theory articulated in this paper was intensive case study research (Bonoma, 1985; Eisenhardt, 1989; Yin, 1981 and 1984). The research was retrospective; the primary initiative studied had been subsumed by another cross-project team program at the time the research was undertaken.

Data were collected through semi-structured interviews and reviews of archival data. The researchers interviewed leaders and participants in the APEX initiative, as well as other product developers, whose work was affected by the program. Most interviews were conducted at the

Merrimack Valley Works (MVW) in North Andover, MA, a major product development location which develops new transmission products, although, some APEX leaders based in New Jersey were interviewed by telephone.

Interviews were conducted according to a basic interview protocol and lasted between 45 and 90 minutes. Given the nature of the research, the interviewees were not required to stay with the standard questions. If the interviewers felt that they were pursuing a profitable avenue, the interviewee was allowed to continue in that direction. Quotes were taken from the transcription of notes taken at each interview. Several participants were contacted subsequently to elaborate on issues raised or clarify comments. The interviews were supplemented with extensive review of archival data including training books, quality improvement stories, historical performance data, and company publications.

The data are summarized in the form of a detailed case study (Krahmer & Oliva, 1995), describing the history of the initiative. The case documents were provided to participants for their feedback; participants were asked to review their quotations for accuracy but were not allowed to change the content. Participants were also asked to review the entire case for accuracy. The research was supported and enhanced by a team of corporate advisors, formed specifically for the study.

The theory is articulated with the aid of causal-loop diagrams (Forrester, 1961; Mausch, 1985; Richardson and Pugh, 1981; Richardson, 1991; Weick, 1979). Causal-loop diagrams provide a compact and precise representation of the interdependencies in a system and are useful in portraying the feedback structure of systems. Particular causal linkages and feedback relationships are substantiated through APEX interview data, existing academic theory and discussions with the research advisory group.

The causal loop diagrams should not be interpreted as precise mathematical specifications of the relationships, which may be linear or non-linear. In subsequent work, the theory will be converted into formal mathematical models, that will permit identification of critical interactions between quality programs and other organizational structures, allow the theory to be tested against data for a wide range of quality programs, and aid in policy design (for examples of formal feedback models of quality improvement programs, see Repenning, 1996; Sterman, Repenning and Kofman, 1997).

The following section offers background regarding the APEX initiative. The case highlights the rationale for the cycle time reduction initiative, the failure of earlier cycle time programs, the factors underlying the initial and medium term success of the APEX teams and the dynamics associated with its eventual termination. The APEX case along with existing theories are then employed to develop an integrated dynamic theory for sustaining product development process improvement teams.

The Achieving Process EXcellence Teams (APEX) Initiative

Recognizing the Importance of Quality and Cycle Time

Responding to the Divestiture and Increased Competition

After the 1984 divestiture of the Regional Bell Operating Companies (RBOCs), AT&T faced new and fierce competition for the telephony equipment market. To become more responsive to the new competition, AT&T re-organized its business operations in 1989, combining the transmission-related manufacturing facilities of Western Electric and the associated product development expertise of Bell Laboratories into a new division, the Transmission System Business Unit (TSBU) which immediately committed to addressing several key business issues through the use of quality and process improvement programs.

The focus on quality was not new to the employees in the TSBU. The programs prior to reorganization often emphasized quick fixes, provided little training, lacked careful implementation strategies, and generated more frustration than change (see McPherson, 1995 for case history of MVW's TQM initiatives). Given the previous quality improvement attempts, developing employee support for new quality efforts became a management concern. In late 1989 and early 1990, two events helped galvanize support for quality improvements. The first was the release of the first customer *report card*. To the surprise of many, price was not the top customer concern; rather quality/reliability and features/functionality were paramount. One interviewee described the latter concern as, “The customers wanted what they wanted, and they wanted it when they wanted it.” A developer noted:

> We needed to compete with the Japanese. Bell Labs had the latest technology, but it was no good if the customer did not see it. AT&T was not perceived as having the latest stuff. To recapture the RBOC customers, such as BellAtlantic, BellSouth, and Pacific Telesis, TSBU’s quality needed to be enhanced and time to market reduced.

A mock Malcolm Baldrige National Quality Award (MBNQA) application process generated a second source of momentum behind quality improvement efforts. The new President, Pete Fenner brought in certified national MBNQA examiners to train TSBU managers on the award criteria and evaluation process. On the last day, a MBNQA examiner scored the mock application and provided extensive feedback. One attendee at this session remarked: “Fenner sent his executives the message that he wanted TSBU to obtain the award in four years.”

Early Attempts to Reduce Cycle Time

Following these events, Fenner held his Leadership Team to their commitments to pursue change. One effort, led by Bell Labs Vice President, Bill McCurdy, focused on time-to-market as a critical competitive advantage for TSBU. McCurdy vowed to reduce the Product Realization Process (PRP) interval – the time from specifications of conceptual designs until release to manufacturing – by 50% in three years (1989-92). Although the lack of precise and uniform PRP interval data was a significant problem, they estimated that the development of a full system was averaging 39 months. Reducing the interval from 39 to 19 months by 1992 (three years) became the goal of the interval reduction initiative. As one interval reduction champion recalled:

> The interval data was imprecise and not complete. The 39 month estimate may not have been a pure or certified number, but I thought it was a pretty good number, and we needed to put a stake in the ground.

The early attempts to reduce cycle time failed, as a leader noted:

> The 1,600 research developers in TSBU in the ten product areas communicated infrequently, and projects tended to be run as fiefdoms. An attitude prevailed that “we do

> not do it that way in our area." In this environment, improvements needed to be your fiefdom's idea to be worthwhile.

After two false starts that lasted into early 1990, McCurdy's project director, Al Hofmann, began work with Luis Boza of QUEST[1] Consulting to conceive of a new approach. Hofmann recognized the need for a structured methodology to guide the teams. He selected Process Quality Management and Improvement (PQMI), a methodology already used in the company which focuses on identification and analysis of processes and provides techniques for shortening process intervals. One interviewee described the two-to-three day PQMI training: "At the PQMI workshop, you had to grapple with what is a process and how do you make an improvement. Many people did not realize before that what they were doing was a process."

The new initiative differed from the previous efforts, not only in methodology, but also in team purpose and organization. Hofmann and Boza studied the key subprocesses within product development interval and decided to establish a team for each major sub-process: Integrated Circuits, Circuit Packs, Software, Front-End Process, System Verification, and Wired Equipment. They planned that each team would consist of well-regarded specialists in that particular sub-process. To overcome the fiefdom mentality, the team members would be drawn from all current product development projects.

Finally, Hofmann selected leaders who were well-known, high visibility "hot shots." Some were project managers, while others were functional experts. Hofmann wanted people "who were recognized as having their heads screwed on straight." The groups of specialist, focusing on sub-process improvements through PQMI became known as Achieving Process EXcellence (APEX) teams. Hofmann explained how they elaborated upon this team design concept:

> Luis and I brainstormed for days on how to get traction given the sociology of the environment. We were having to think like social workers. ... We felt it was important to bring together the people that did the actual work from all the different projects.

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[1] QUEST Consulting is an AT&T internal consulting firm that offers extended training, facilitation, and project management services to AT&T business units.

The Initial APEX Efforts

In the first quarter of 1990, the first pilot APEX team was launched in the area of Integrated Circuits (IC). Hofmann indicated that he *rigged the game* by selecting the PREP project manager who had conducted the original subject matter expert meetings. He explained: "I intentionally did not create all of the teams at once. I started with one and invested a lot of time in making sure it was a success." In the following quarter, two additional teams were formed, with a total of six teams formed by the third quarter of 1990.

Based on PQMI methodology, the APEX teams adopted a process approach to addressing interval problems. For most teams, the first task involved documenting local best practices. Specifically, they analyzed the current situation by describing in detail the key subprocesses within their domain and determining the associated intervals. Accordingly, each APEX member collected information on his/her project to identify and rank improvement opportunities. One APEX leader reported that his team spent most of the first year documenting the development practices within TSBU and credited the PQMI training and methodology as helping with that task.

Interviewees reported several important benefits from the study of local best practices: While the APEX members had initial difficulties understanding the different "language and customs" of members from other projects, they soon became stimulated by interacting with people with similar functional expertise and work challenges. The APEX meetings became colloquia for comparing processes. One QUEST facilitator described the benefits of bringing together people from different projects but with similar expertise:

> The exchange of ideas between people that did the same job was valuable. Each person brought a different perspective. It was amazing the number of novel ideas that were generated by people talking about their processes with other experts. Everyone was able to come away with some new ideas.

After the review of local best practices, the APEX team members identified opportunities for reducing the development interval and suggested improvements in their individual projects. Benchmarking outside firms and other AT&T operations then became the next APEX focus. The APEX leadership approached firms with similar processes, some of which were competitors, to request permission to tour their facilities. Prior to the first off-site visits, a couple of teams received benchmarking training through QUEST. The Circuit Pack APEX team conducted one of the first external benchmarking programs. They examined six outside firms and eight other AT&T operations in 1990. One APEX leader described the response to the first outside benchmarking trips:

> The APEX members were generally more willing to consider ideas that did not originate at Bell Labs, but they were still shocked to discover how significantly AT&T lagged behind best industry practices in some areas.

As a result of the internal and external benchmarking work, the APEX members' analytical competencies and in-depth knowledge of their subprocesses grew and, as one interviewee mentioned, "APEX became a process for not only identifying best practices but also the conditions under which the best practices could be achieved."

Developing Ongoing Commitment to APEX

The extensive time commitment and persistence of Al Hofmann and members of the APEX leadership helped the APEX effort develop momentum. Hofmann made numerous phone calls to his peers and his superiors to procure funding and time off from other responsibilities for the APEX team members. He regularly sent notes of appreciation to APEX participants and encouraged managers to recognize their staffs for their APEX work. One APEX member recalled:

> At first, people were *volunteered* for teams by their managers, and people felt that APEX was a flavor of the month project ... Hofmann put in a huge amount of personal time. He was committed to spend one-third of his time, but he often spent more. He worked hard to show that management cared. People then believed that management was serious.

In addition, APEX effort benefited from the full-time facilitation support of QUEST. The four to five facilitators were funded by a roughly $1 million tax on all development projects, representing less than 1% of the annual TSBU product development budget. One QUEST facilitator recounted:

Over the first year, APEX teams developed regular working arrangements with many teams holding full-day monthly meetings with people from MVW as well as New Jersey and other research locations traveling to a common site. A QUEST facilitator estimated that the APEX leaders and members spent on average 20% of their time on APEX issues. However, the APEX teams still faced resistance from some managers and product developers. Management encouraged people to work on APEX, yet they were still expected to do their core job as normal. One APEX leader recalled: “Many people worked evenings and weekends to catch up on either their development work or APEX. Some organizations did allocate an hour a week for APEX, but that was not enough.” Another APEX leader explained the pressures that APEX leaders were experiencing from more senior management:

> This APEX stuff is hard for Corporate America. It is a hard sell, especially when people are under pressure to fulfill their development responsibilities.

Despite the competing work pressures, new team members continued to join APEX for a variety of reasons. As indicated by APEX and non-APEX product developers, people were primarily motivated to join APEX teams for career advancement reasons, but teamwork and comradeship were also a key factor. In addition, as a result of the growing success of APEX, people started to self-identify themselves for teams.

APEX Project Reviews

Over time, APEX teams developed new methods of diffusing lessons gained by individual teams to the entire research and development community. One prominent practice, <u>APEX Project Reviews</u>, entailed having APEX teams conduct examinations of ongoing development projects. Hofmann explained:

> I was talking to my boss about one of my development projects. He suggested having one of the APEX teams audit my process. I approached one of my project leaders, who was also an APEX leader. I told him to rally his engineers. I wanted the audit of his project to be a resounding success. The Circuit Pack APEX team conducted the review in November 1990. The project staff felt the review was beneficial and agreed to institutionalize 30% of the recommendations.... The review helped [the project leader] get his project done with a remarkable interval of only 15 months. I heavily promoted this success; it was really a win-win across the board.

After the first review, Hofmann encouraged APEX members to invite other APEX teams to review their projects and make recommendations. A procedure developed whereby a project could request a review from the Front-End Process APEX team early in its development process and subsequent reviews by other teams, such as integrated circuits, software, and/or system verification. The review format eventually constituted six to eight APEX members spending one or two days examining the project using an APEX Project Review Checklist. The teams designed the checklists to include the best current practices. The review teams would use their collective backgrounds and previous benchmarking experience to develop recommendations. Project staff would respond to each recommendation by deciding whether or not to accept the proposed change and developing an implementation plan.

An APEX leader characterized the review process as peer consultation with project and APEX team members sharing ideas and concerns. In the view of several APEX participants, the project staffs generally appreciated the advice they received from experienced APEX practitioners:

> It was not like a dreaded audit. People were excited to be reviewed. It was like having the top coaches and players auditing the Celtics. ... The reviewers actually knew what they were doing and could give useful suggestions for improvements. ... An advantage of the APEX reviews was that people were given advice by peers rather than by supervisors. Hence, people were not defensive regarding their work, but open to suggestions for improvement.

The APEX reviews became a widely used practice within product development. Their number increased from 10 in 1991 to 23 in 1992, and to about 60 in 1993. However, the reviews did not always live up to their reputation, as one technical supervisor reported:

> It was a good idea, but there was weak follow-up, and it did not necessarily identify significant problems. In my case, I received a favorable audit, but I later got into schedule difficulties. The project took a lot longer than expected.

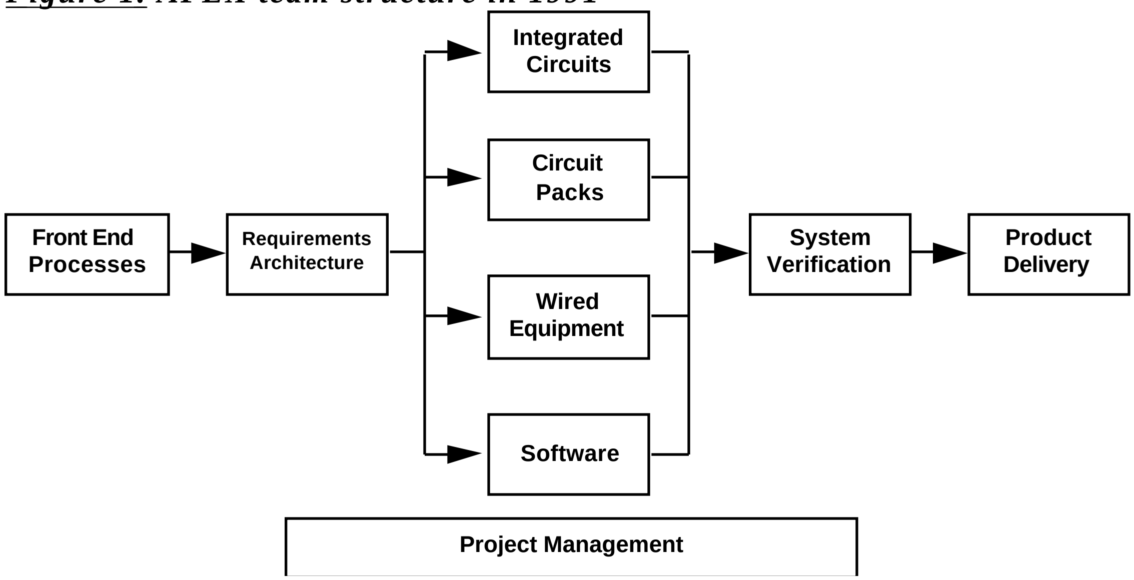
Expanding the Divide and Conquer Approach

By 1991, several APEX leaders recognized a need for additional teams in order to better *divide and conquer* the interval problem. The new teams would allow the APEX effort to address subprocesses, such as product delivery, documentation and customer support services, that were not addressed by existing APEX teams. An APEX leader highlighted the mentality that the APEX leadership wanted to overcome with the supplemental teams:

> Before the divestiture, Bell Labs really ran the place. The Transmission Business Unit had $3 billion in revenues and spent $400 million [13%] in research and development. The product managers would first worry about funding the R&D for the product and worried about other issues later. As a result, logistics elements, such as documentation on the product, would not be available on time, resulting in products shipping to customers without documentation. Final products would often become generally available, lacking logistical support elements, such as ordering, delivery, installation, and training.

To confront deployment and integration issues that were not effectively dealt with by existing APEX teams or by the existing cross-functional project work structure, three more teams were created: Requirements and Architecture, Product Delivery, and Project Management. Hofmann and other APEX leaders also established the Super Team in April 1991 to coordinate the efforts of the individual teams. It was chaired by Hofmann and composed of the team leaders, QUEST facilitators and a few other active APEX members. In mid-1991, the team structure had expanded to the structure shown in

Figure 1. ***APEX team structure in 1991***



Source: TSBU APEX Superteam Quality Improvement Story 1993, pg. 7

Incorporating Quality Improvement Teams

In addition to APEX, TSBU managers received three-day training from Qualtec, a training arm of Florida Power & Light (FPL), which had recently become the first non-Japanese firm to win the Deming Prize, Japan's top quality award. Two concepts from this training took hold at TSBU: Quality Improvement Stories and Policy Deployment. The Quality Improvement methodology (QI story) is a seven-step process that permits a team of workers to analyze a problem and identify countermeasures in a highly structured fashion. Policy Deployment is a management process aimed at planning and executing significant improvements in business performance by cascading key business and customer priorities down through the organization, breaking them down into increasingly detailed tasks, so that the worker on the shop floor knows how his or her job fits into the overall corporate mission.

While the Qualtec training translated into an active and successful program in the manufacturing operations at MVW (McPherson, 1995), the reception to the training in product development was mixed. A product developer characterized the overall response:

> There were those that embraced the QI story enthusiastically. There were also a lot of people, probably the largest portion, who were interested in the stuff as time permitted. The last group were cynical. ... The overall impact is that we became more attentive to the product development process.

After the Qualtec training, the product development staff became aware of the need to participate on QI teams. While not officially a job requirement, product developers were informed by management that they were expected to have a QI story on their list of annual personal accomplishments. Technical supervisors reported feeling pressure from senior management to promote QI teams among their staff. QI teams proliferated; participation rates in product development were estimated at between 50% and 85% in 1991-92. Some product developers were displeased with the QI methodology: “We had to participate on QI teams. One can not be against QI around here. It is sacrosanct. It is like being against motherhood and apple pie.” They were also displeased with the heavy emphasis placed on QI teams by management: “To the Bell Labs people, frankly, it was insulting. We had structured, organized thinking already. We did not need a 5th grade system to drive a logical process.”

After TSBU received the Malcolm Baldrige National Quality Award, participation in QI teams waned in 1993 with interviewees stating that QI teams were being misapplied and work pressures were too high. One APEX member provided another reason:

> I guess the QI story was dropped because management paid less attention to them. The QI discipline was not natural. On the other hand, APEX ended up having a life of its own. It had its own terms and discipline.

APEX Responds to the QI Story

As part of the roll-out of the QI initiative, QUEST facilitators attended Qualtec training in

February, 1991. Several APEX members noted that the QI initiative provided direct gains through the QI teams, but also offered important indirect benefits through its impact on APEX teams. Since senior management strongly encouraged employees to utilize the QI Story methodology to analyze problems and identify countermeasures, Hofmann requested that the work of APEX teams be translated from the PQMI to the QI Story format. Although the approaches were similar, PQMI had a heavier focus on process identification and analysis, while the QI Story emphasized problem-solving and implementation. One QUEST facilitator characterized the transition:

> It fell on the QUEST facilitators to retrofit the existing APEX effort into the QI story format. It was not easy; the steps did not exactly match up. The work did help us identify some things that we had skipped using PQMI. Once the QI stories were developed, it was easy to use the QI story format moving forward.

The QUEST facilitators also tied the APEX teams into the Policy Deployment Matrix under the interval reduction goal. In addition, they developed a QI story for the Super Team and each individual team; each story detailed the past, present and anticipated future activities of a team. While the APEX teams shifted to the QI story methodology, the teams did not adhere fully to the rigid QI story format. Over time, some APEX and QI teams began to work together as people recognized the relative strengths of the two efforts. QI Teams were used to address specific problems, often within a single development project and were disbanded once they completed their narrow task. In contrast, APEX operated like a think-tank, studying a complex issue in detail and then suggesting both immediate and longer term countermeasures to shorten interval or ameliorate process problems.

Sustaining the Momentum of APEX Teams

Achieving the Original Goals

In 1992, TSBU received three honors recognizing its quality accomplishments: ISO-9000 certification[2], the Massachusetts Quality Award, and the Malcolm Baldrige National Quality Award. APEX played a significant role in achieving ISO-9000 in under one year by providing documentation on existing local practices. In addition, APEX teams were cited an important contributor to the Baldrige Award. An excerpt from the Baldrige Award feedback stated:

> Nine APEX teams address improvement of design and product introduction processes using Quality Improvement Stories, process performance data, and benchmarking information. All major business projects are represented on these teams. "Super teams" make sure these efforts are integrated. Results in reduction of interval are excellent.

The APEX teams also reached another significant milestone in 1992; they succeeded in achieving their three-year goal by reducing interval on full systems from 39 to 20 months despite the increased complexity of the products developed – the number of interconnections per square inch of circuit board has grown at an average annual rate of 6.4% since 1980. When questioned whether interval reduction arose from better processes due to APEX or QI teams or from greater development work intensity, one APEX leader conceded:

> That question is like trying to figure out if it is helpful to send your children to a good school so that they have a better life. You do not want to take the risk. We brought the interval down, but we do not know if it came down due to competitive pressure or APEX work.

According to Hofmann, the APEX leaders and QUEST facilitators had increasingly become the driving forces behind the APEX effort by late 1991; their leadership permitted Hofmann to switch to a more supportive and responsive style of management. By late 1992, Hofmann indicated that he had successfully initiated and nurtured the APEX teams, and APEX members took pride in their accomplishments. The teams were essentially self-directed, and Hofmann was feeling overloaded by his other job commitments. He requested that his APEX responsibilities be turned over to others; two new co-leaders were selected in May 1993.

Setting New Objectives

Reducing the product development cycle time had been the rallying cry of the APEX teams for its first three years. After the teams achieved their primary goal, they developed their next three-

[2] ISO-9000 series originated as a certification required to sell products in European Union countries and is now required

year goal. In early 1993, the APEX leadership had decided to revise the definition of interval. Rather than using the date that the first product was produced in the factory, the new interval measurement extended the end of project to the date that target manufacturing yields were achieved. The APEX managers estimated that these changes in measurement added five months to the interval so adjusted the current estimate of interval from 19 to 24 months. In August 1993, the APEX leadership agreed to reduce interval by 50% for the three-year period, using the new interval measurement. The new goal became to *Break the One Year Barrier.* An APEX manager explained the rationale behind the one-year target, “This new goal was quite compelling. Not only was it psychologically appealing, but it also permits a project to be completed within a single annual budget cycle.”

The APEX leadership also decided to expand the objectives of APEX to address concerns of customer and employee satisfaction. The QI stories documented an increased emphasis on providing *The Right Feature Set for the Customer*. In addition, the results of the 1992 employee survey, in which AT&T personnel expressed lower job satisfaction than the highest employee-rated companies. The APEX leadership responded by emphasizing *Getting It Right the First Time* product design. An APEX leader explained the new emphasis:

> If we did not do it right the first time, then there was rework and that increases interval. We had been in the habit of designing a device and then testing it to find the flaws rather than trying to figure out what we really wanted in the design and make it that way to begin with. It is actually very demotivating for people to do work, have it be wrong and then have to redo it. Get it right the first time helps by reducing interval and increasing job satisfaction.

In addition, APEX teams adopted a goal of reducing manufactured product cost, which included cutting total R&D expenses. In 1992, they announced a goal of cutting R&D costs by 5% in TSBU, and they continued the focus in subsequent years. One APEX member commented: “TSBU started questioning whether we could afford our R&D, so we focused on trying to cut costs and eliminate redundancies.” Shortening development interval could result in significant cost savings. In addition, faster time-to-market provided another financial benefit of preventing AT&T

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in other overseas markets. The ISO-9000 series demand that corporate processes be well-defined and documented and that these written procedures are followed.

from losing sales to competitors.

The QI stories developed by the individual APEX teams and interview data indicates that the teams also supplemented the primary interval reduction goal with team-specific objectives. An APEX leader and a QI story indicated a concern that developers were *throwing the designs over the* wall, leaving flaws to be discovered later in the process. Both the Integrated Circuit and Circuit Pack Teams addressed the concern by setting yield improvement objectives. For these two groups, test yield in the factory was a metric that was as – if not more – important than product development interval.

Expanding APEX's Role

By late 1993, the environment had shifted again. AT&T senior management announced a reorganization that would combine TSBU with the much larger Switching Systems Business Unit (SSBU) and Operations Systems Business Units (OSBU) to form a Global Public Network (GPN) organization. A new marketing approach was adopted that emphasized products built on generic platforms that could be readily customized. While early APEX process improvements involved converting to best industry practices, the new strategy demanded that the product development process be redesigned, common product platforms be developed, and more emphasis placed on re-use of existing work or multiple use of new work. The multiple use activity entailed having developers from several projects co-produce a new design for use in several projects. With the lack of communication between fiefdoms prior to APEX, reuse had not been practiced. Multi-use did occur but was not the norm. Due to the APEX teams, multi-use could more readily be adopted, and development project teams became more aware of opportunities for reuse.

To prepare for the new marketing strategy, the APEX teams focused on the issues of cross-functional integration and long-term planning that affected multiple projects, spawning several new initiatives and APEX teams and subteams. The Super Team formed the Glue Team, indicating its new focus on the connections between the subprocesses. The Glue Team's mission was to take a "systems level view of APEX" and to confront the issues that crossed APEX team boundaries. To better integrate processes, the APEX leadership looked at *Closing the Loop* in the product development process by using more feedback from customers to guide the front-end process. In addition, a new Product Integrity team was created to examine product documentation, customer training, ordering, installation, operations, and technical support.

To achieve re-use and multi-use, integration of several similar process management and documentation tools within TSBU became essential. Up to this time, three initiatives – the new interval measurement process, ISO-9000, and the requirement and architecture APEX work – had exhibited some synergies: As noted, APEX members felt that the rapid ISO certification would not have been possible without the prior process documentation done by APEX teams. Similarly, one product developer stated that the ISO-9000 emphasis on documentation had helped them avoid shipping defective products. The APEX leadership perceived that even more gains could be realized from greater integration of the processes.

A new Policy Statement initiative was spawned out of the APEX Project Review process that assisted in the integration effort. Under the project reviews, APEX team members would update their Project Review Checklist to reflect new improvements. By 1993, they would identify major policy changes and submit them to the Super Team for endorsement and dissemination to the individual projects. The Super Team would then issue a policy statement requesting that the new procedures be adopted on all new product development projects. Some technologies or processes were designated as the default, forcing a project to justify a decision to use an alternative. APEX teams monitored the projects for compliance. In two separate interviews, one APEX leader explained:

> For APEX members, the ability to set business unit wide policy gave them a sense of power and recognition ... If a project design got into difficulties, it was okay if the project used the APEX policies. If not, the projects could be in trouble. ... The value of the policies is that they cause people to talk about the consequences of design choices early in the product realization process. This stimulates a meaningful discussion between manufacturing and design that had not happened before.

A final significant integration thrust was the globalization of APEX. In October 1992, Transmission Systems operations in Europe created an APEX structure. Four sister teams were developed in Europe in the areas of software, system verification, hardware, and integrated circuits. The European teams participated on the Glue Team and also met with the US teams once a year to share information and techniques.

The End of the APEX Era

Despite the enthusiasm of the APEX leaders for their new initiatives in 1994, there was a growing sense among several members of the APEX leadership that "we are not getting anywhere." The distribution of work within the teams became more lop-sided with a few people taking on large quantities of work and more and more people “riding along as passengers." It became harder to find replacements when people stepped down from teams. APEX leaders offered differing reasons for the slowdown:

> This was a volunteer effort. After a while, the glitter had tarnished for some. They felt that trying to create change in a sea of resistance was overwhelming. Some got burned out. Others bowed out due to excessive work loads in their primary jobs. However, that was not all bad since it resulted in new people, new ideas, new directions.
>
> APEX participants became demoralized by seeing APEX leaders removed from their positions when their development projects ran into difficulties.
>
> APEX had simply bitten off more than it could chew when it took on the integration initiatives. The final projects were too much for everyone’s good for anyone to work on them.
>
> The new leaders were not as strong or committed as Hofmann.

The APEX teams were associated with a period of significant reduction in product development interval. Most of the interviewees commented that APEX had bettered their individual and project work processes although at least one person felt that APEX made no noticeable difference in processes or environment. Some APEX members reported greater job satisfaction as they spent less time redoing work and more time on high level issues. In addition, APEX members reported benefiting from having earned respect from their peers and access to selected high level management. For some, the work had resulted in better performance appraisals and may have long term career benefits. Figure 2 depicts the trend in product development interval for both incremental and full systems, commencing in 1988.

***Figure 2.* Interval reduction from 1988 to 1994**

Source: Adapted from Internal AT&T document. The figure depicts the product development interval for both full and incremental systems for the first and second half of each year. PDI is defined as the time from GATE III (Project Definition) to GATE V (Deployment). Since the GATE process was introduced in 1992, the PDI data from prior years was recomputed to match the GATE criteria by AT&T QUEST facilitators.

The APEX teams were disbanded in December 1994, when TSBU became part of Global Public Network. Some teams were merged into Functional Excellence Teams (FETs), a new structure that sought to combine APEX teams with Process Management Teams, a team approach used in the larger Switching Systems Business Unit. Several APEX members expressed regret, stating that the FETs closely resembled PMTs, which were more short-term oriented and ill-suited to address the longer-term, more complex issues that product development was confronting. A QUEST facilitator observed that the APEX and Process Management teams reflected their respective organizations. TSBU had a diverse product line and promoted autonomy, experimentation, and creativity, while Switching Systems, with its one large development effort, valued standardization and hierarchical managerial control. One APEX team member lamented:

> There was no strong leadership that could weld the various FETs into an integrated, coordinated activity. As such, groups reverted to the old paradigm of focusing in on their individual functional nested interest rather than trying to optimize the delivery of the whole.

Other former APEX members expressed optimism about the future. Another product developer observed that the nature of the FETs has been changing and that they are starting to resemble APEX teams in nature. He smiled and commented: “There is a mating dance still going on.”

Theoretical Framework

Improvement programs are initiated for a variety of reasons. The Transmission Systems Business Unit’s (TSBU) rationale for undertaking improvement initiatives – raising customer satisfaction by improving quality and time-to-market – was consistent with that of other firms actively engaged in process improvement. While the motivation of TSBU management conformed to conventional process improvement thinking, several attributes of the APEX initiative would be expected to create adverse conditions for sustainable improvement. Advocates of process improvement initiatives (Deming, 1982; Juran, 1974; Ishikawa 1985) emphasize techniques for motivating employees and enhancing team performance, such as management support, training, promotion and rewards. Specifically, the APEX initiative varied from traditional TQM implementations in that it was limited in: (1) the direct support from senior management for improvement, (2) the backing from local managers, and (3) extrinsic incentives for the participants of the improvement effort, yet APEX yielded significant improvement results in a complex product development environment over a three-year period.

Drawing from the APEX experience, we developed a dynamic theory to explain the initiation and sustainability of process improvement teams in product development. Product development, teams, and process improvement literature, as well as the APEX initiative, are the basis for the causal linkages that compose the theory. The theory is presented in causal loop diagrams and it explains how structural elements of the organization created the observed improvement dynamics. The emphasis on structural elements permits the theory to be more readily transferable to other settings and improvement efforts. We identify both endogenous, self-reinforcing feedbacks that can sustain the effectiveness of process improvement teams as well as self-correcting feedbacks that undermine not only newly created but also established improvement programs. In addition, the theory reveals innovative strategies that can be employed to support improvement teams through their inception and sustain them on an on-going basis. Our integrated theory is presented in the following order: In the next sub-section we articulate the operational limitations of and the rationale for self-improvement initiatives. We then explore the motivational dimension of improvement teams and the implications of focusing improvement on cycle time. The generic structure of improvement initiatives is used as a platform to explain the early success of APEX specific strategies and to identify the late-failure modes that brought its demise. The theory section concludes with a summary of the theory's key elements.

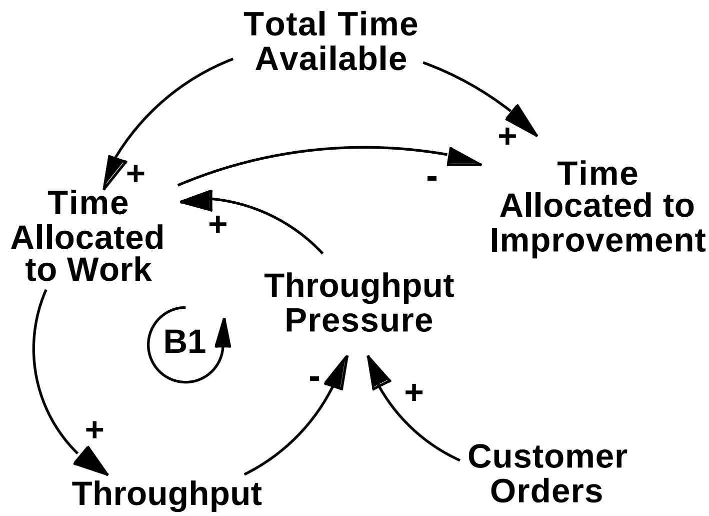
The Self-Improvement Dilemma

The Conflict Between Daily Throughput Work and Improvement Effort

APEX, like other improvement strategies relied on the employees responsible for performing the day-to-day operational activities — product development engineers — as the main source of improvement direction and effort. The rationale behind this strategy is twofold: First, employees doing the job are well informed on the current status of the system, thus reducing data collection and diagnosis time. Second, they have a strong interest and motivation for implementing the proposed changes.

The self-improvement strategy, however, has certain tradeoffs. As the employees increase the *Time Allocated to Improvement*, the *Time Available for Work* decreases, resulting in lower *Throughput.* By devoting more time to improvement, already busy employees then experience increased *Throughput Pressure* from their supervisors and managers to generate normal day-to-day development work. The competing work and improvement pressures place employees in a difficult *self-improvement trap*, as the total throughput and improvement activities are constrained by the *Total Time Available* to employees to accomplish their work. If *Throughput Pressure* rises above the normal level employees may respond by working harder during the day or working overtime. Should the pressure continue – since throughput is privileged as the main source of revenue – team members may begin allocating more and more time to normal tasks, at the expense of the improvement effort (Homer, 1985; Oliva, 1996). Figure 3 captures this time limitation and the selfregulating mechanism (depicted as B1) that ensures continuity of throughput.

***Figure 3.* Self-improvement dilemma**



Arrows indicate the direction of causality: Signs ("+" and "-") at arrowheads indicate the polarity of relationships: a "+" denotes that an increase in the independent variable causes the dependent variable to increase above what it would have been, ceteris paribus (and a decrease causes a decrease beyond what it would have been). Similarly, a "-" indicates that an increase in the independent variable causes the dependent variable to decrease. Double hash marks ("//" or "=") indicate that an increase or decrease in the independent variable will generate a time delayed response in the dependent variable. A balancing loop (denoted by B in the loop identifier) indicates a regulating (negative) feedback process. A reinforcing (R) loop indicates a self-reinforcing (positive) feedback process.

Unless the organization creates sufficient slack time for its improvement teams, efforts to improve will reduce throughput in the short run. If employees devote time to improvement activities, the development work will build, throughput pressure will rise, and people will be forced to abandon improvement efforts. To overcome the quandary, the process improvement advocates recommend that managers avoid setting numerical throughput goals (Deming, 1976) and encourage employees to allocate a portion of their normal workday to improvement effort. An alternative strategy is to schedule the improvement efforts during periods of low customer demand.

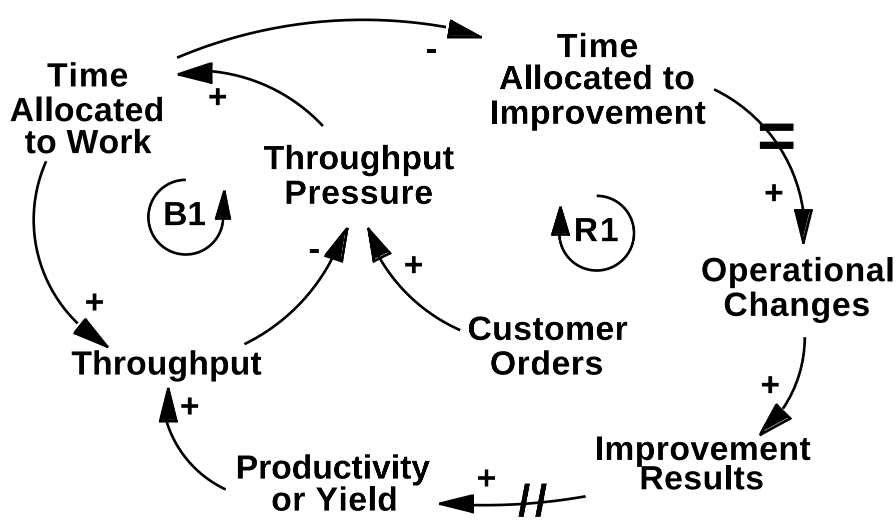
In the APEX case, once the Bell Labs engineers found the APEX initiative appealing, they were able to dedicate substantial time to the improvement effort due to the fortuitous timing of the APEX initiative: First, the previous monopoly environment had permitted AT&T to operate with a well-qualified and ample staffing. Second, a decline of customer orders had allowed *Throughput*

Pressure to remain relatively constant even though pressure to bring products to market faster had increased. The product development engineers, therefore, had excess time to devote to improvement efforts.

Productivity – the Long Term Solution to the Self-Improvement Dilemma

An important rationale for engaging in process improvement efforts is the long term productivity gains that enable the organization to produce more goods with less resources (time, personnel, raw materials, etc.). Specifically, *Improvement Results* are thought to create greater *Product Development Productivity,* which enables product development work to be completed with less development effort. If the higher *Product Development Productivity* is realized, then more goods or designs are produced, *Throughput* increases and *Throughput Pressure* is relieved, allowing more time to become available for improvement efforts. The improvement activities then further enhance the efficiency of product development processes, thereby establishing a self-sustaining, continuous improvement mechanism (see Mausch, 1985; Richardson, 1991; Weick, 1979 for other examples of reinforcing feedback processes). Figure 4 depicts the self-perpetuating productivity gains from allocating time to improvement (Loop R1).

<u>Figure 4.</u> Productivity - the long term solution to the self-improvement tradeoff



While the self-improvement programs enhance productivity, these benefits are not realized immediately. Significant delays exist between the initial improvement activities (diagnosis and planning meetings) and when these efforts yield higher productivity. As a result, a worse before better dynamic is experienced (Forrester, 1961). The improvement program designed to increase product development productivity actually causes a short term drop in throughput before eventually producing productivity gains that permit higher than original rates of throughput.

In the case of product development improvement efforts at TSBU, the cycle time reduction leaders were unsuccessful in their pre-APEX attempts to overcome the self-improvement dilemma due to inadequate training, an undeveloped implementation strategy, and a quick fix problem-solving approach. Without the productivity gains from improvement, there was no relief of throughput pressure, hence, no additional time could be allocated to improvement.

Upon first examination, the APEX initiative appears poorly designed to overcome the self-improvement problem. First, while a few managers allocated one to two hours a week to participate on APEX teams, most managers provided no time allocation for their staff. Second, the stated goal of reducing product development interval (PDI) by 50% from 1989 to 1992, while serving as a source of inspiration for the improvement effort, also placed additional throughput pressure on product development engineers to complete development work in a shorter time period. As the three-year deadline approached, the product development engineers felt compelled to increase overtime and allocate more time to normal development work to complete development projects quickly, rather than to sustain improvement efforts. Despite these seemingly adverse conditions, the APEX members voluntarily worked about 20% of their normal day and substantial overtime to achieve both the desired throughput and improvement results.

Commitment to Improvement

Given the inherent trade-offs and the *worse before better* dynamics involved in self-improvement programs, the real challenge for management is to design a set of structural characteristics that allow the improvement process to get started and be sustained over time. Essentially, TQM theories suggest that team commitment can be employed to produce virtuous cycles of improvement that can help sustain the improvement initiative during the period of low throughput until the productivity gains are realized. In addition, other non-commitment-related factors can be used to encourage improvement efforts during the interim before commitment is developed (see the Work Smarter dynamics described in Repenning & Sterman, 1997). In the APEX case, however, the need to improve product quality and lower time to market in order to boost customer orders was a compelling motivation to start improvement efforts.

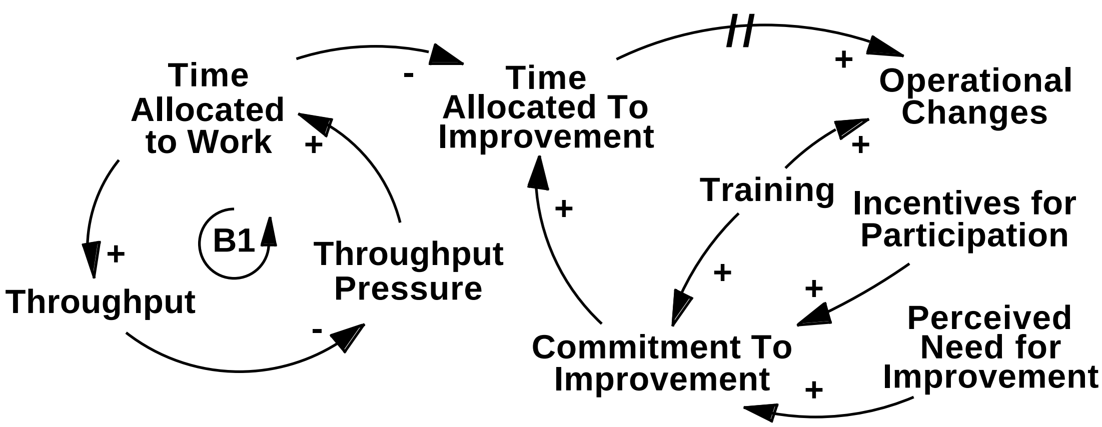
Commitment can be generated from a variety of sources. Shiba et al. (1993) make a useful distinction between two sources of commitment for improvement programs: managerial *push* and employee *pull* for improvement. Managerial *push* refers to the incentives available to management to promote the improvement effort. The employee *pull* refers to the motivation that arises from understanding the benefits as well as seeing the tangible results from the improvement programs (Schaffer and Thomson, 1992; Shiba et al., 1993). This view of commitment sources is consistent with the expectancy/valence theory of motivation (Hackman & Porter, 1968; Lawler, 1973; Vroom, 1964). According to Vroom (1964), motivation is the product of three factors: how much one wants a reward (valence), one's estimate of the probability that effort will result in successful performance (expectancy), and one's estimate that performance will result in receiving the reward (instrumentality). Expectancy/valance theory recommends that managers motivate employees to value improvement results in order to activate an improvement program (push). Commitment or motivation is perpetuated once employees have high valence and have confidence that their improvement efforts and associated operational changes will yield the desired results (pull). The remainder of the section uses this distinction to describe the commitment mechanisms used by the APEX improvement initiative.

Management's Push for Improvement

The process improvement literature (Crosby, 1979; Deming, 1982; Juran, 1969; Shiba et al., 1993) stresses the pivotal role of senior management in initiating new process improvement programs, through the use of training and promotional activities. Similarly, organizational theorists (Nadler and Tushman, 1987; Tichy, 1983) argue that large-scale organizational change must be managed by top management. There are three basic levers (depicted in Figure 5) that management has available to jump start a process improvement program.

First, management can instill in employees a *Perceived Need for Improvement* and help employees more quickly perceive the merits of the improvement program and the results of particular operational changes. Second, by providing *Training* and selecting appropriate improvement techniques, management can not only generate greater commitment to improvement but also ensure that employees will be effective in detecting improvement opportunities and capitalizing their improvement efforts. Finally, management can motivate employees by providing *Incentives for Participation* in improvement activities.

***Figure 5.* Management's push for improvement**



Managerial commitment to the APEX improvement activities was manifested through the multiple efforts that were being deployed in the manufacturing side of the organization as a result of Fenner's initiatives. During the roll-out of these initiatives, it became evident to many product development engineers that without significant changes in product features, quality, and time-to-market, ultimately their job security would be threatened, thus they perceived the need for improvement and were encouraged to participate in process improvement efforts.

The APEX initiative, unlike its interval reduction predecessors, relied on training to stimulate commitment. APEX team members attended the PQMI process mapping workshop, while some participated in a benchmarking seminar early in the initiative. The training helped team members understand the potential benefits from improvement and provided them with the skills to identify and implement changes. Later, they underwent the QI story training with similar results.

However, the management roll-out strategy for the APEX initiative, in several important regards, deviated from the recommended process improvement phase-in described above. Although the impetus for the interval reduction effort emanated from top management (Pete Fenner) and the Vision Quest meeting, the APEX effort was not presented to the product development engineers by senior management as a top priority nor did senior management pressure the product development engineers to allocate time to the APEX initiative. Instead it was driven by the commitment of time and effort from one director, a few senior managers as well as the full-time work of three to five QUEST facilitators. Rather than encouraging participation by executive mandate, promotional activities, incentives or potential for high profile recognition, APEX attracted new members, at first, by intensive personal persuasion by Hofmann.

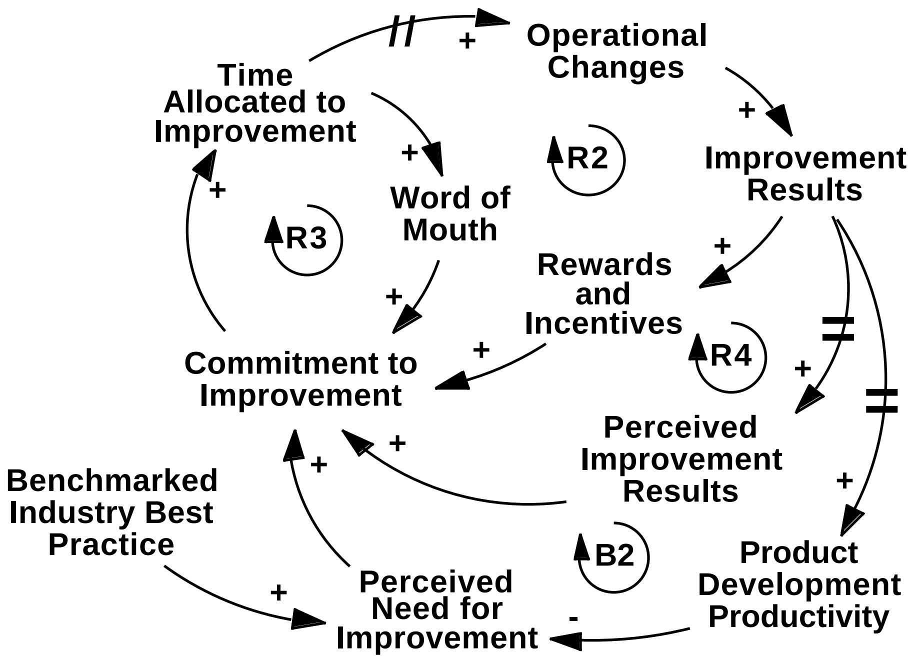
The Pull Toward Improvement

While managerial push serves an important role in activating process improvement programs, these factors are insufficient to sustain a program as employees' willingness to participate will decline if the program fails to generate the improvement results and productivity gains promised by management. In order for a program to move beyond inception, team members need to value improvement themselves or become committed out of self-interest. From the APEX initiative, we identified four employee pull mechanisms that can sustain process improvement teams.

First, rewards and compensation are recommended by the process improvement experts (Crosby, 1979; Ishikawa, 1985; Juran, 1969) since they create a valuable reinforcing mechanism as employees are rewarded for *Improvement Results*. Although extrinsic rewards and incentives were notably absent from management's support of the APEX initiative; the APEX members derived the intrinsic rewards of peer recognition and job satisfaction from their teamwork. While the APEX members initially obtained only notes of appreciation from Al Hofmann, APEX participants later received recognition in the form of respect from fellow project members as well as peers on other projects. The APEX members felt appreciated by other product developers, who benefited from the sharing of experiences and benchmarking information provided at APEX meetings as well as the insights provided during APEX project reviews. The APEX experience is consistent with other research indicating that knowledge workers are motivated by intrinsic rewards while extrinsic rewards interfere with performance (Jordan, 1986).

Other product development engineers' attributes help to explain their initial enthusiasm for the process improvement initiative. Because of the nature of their work, which entails developing products that will be delivered to the market in one to three years, product development engineers have a better sense than most of the long term perspective and are more willing to make the initial investment in process improvement without seeing immediate results. Product development engineers are analytical problem-solvers. Job satisfaction increases when people have interesting problems to address. Examining their own processes and reducing inefficiencies and rework was an appealing and natural challenge for product development engineers.

Figure 6. ***Pull to improvement***



In the APEX case, as *Improvement Results* were generated, the product development engineers received *Rewards and Incentives* in the form of peer recognition and job satisfaction. The *Rewards and Incentives* helped nourish *Commitment to Improvement* that encouraged continuing the improvement activities through maintaining the *Time Allocated to Improvement*

(Loop R2 in Figure 6).

Second, the early emphasis on data collection and analysis enabled Hofmann and other leaders to gain credibility from participants by providing information on the state of current processes and not through promises of future benefits. As team members documented local best practices and benchmarked outside firms, they became “shocked to discover how significantly AT&T lagged behind best industry practice.” As a result, the prevalent *not invented here* mentality weakened. Similar to other improvement implementations studied by Shiba et al. (1993), the APEX members became aware of the weaknesses in their development process and developed a sense of urgency in correcting their shortcomings. Essentially, by comparing *their Benchmarked Industry Best Practice* to their *Product Development Productivity*, the APEX leaders and team members increased their *Perceived Need for Improvement*, which strengthened their *Commitment to Improvement.* This self-correcting *information fosters commitment* process (Loop B2) provided the APEX members with the impetus for improvement as long as their operations lagged behind the industry.

Third, the APEX initiative also benefited from Hofmann’s low-key roll-out strategy. He had carefully rigged the game by selecting members and team leaders he knew to be more receptive to change and intentionally started with just one team that had a high likelihood of success. Through this approach, Hofmann was able to activate a fast-acting *word-of-mouth* dynamic within a single team. The team members, who had been drawn from all of the major product development projects, then communicated their enthusiasm and insights to their project co-workers. Through the positive word-of-mouth, interest developed among other product developers in the APEX initiative, and new teams were formed. Although many developers were originally skeptical about APEX, viewing it as a *flavor of the month* project, once the early teams were able to return to their development projects with ideas for change that were successfully implemented, then a word-of-mouth process was activated. By seeding the process, Hofmann could rely on the self-sustaining momentum of word-of-mouth (Loop R3) to attract additional participants to his grassroots effort.

The effects of word-of-mouth are also documented in the product development team literature (Ancona & Caldwell, 1992; Cooper & Kleinschmidt, 1994) and in previous process improvement studies (Sterman et al., 1997). Ancona and Caldwell report that functional diversity in groups was found to cause more communications outside the team boundary, and that greater communication led to higher the managerial ratings for innovation. By relying on cross-project teams and a gradual information dissemination process, the APEX teams were able to achieve a similar result.

Finally, the pulls from rewards and incentives, information, and word-of-mouth enabled APEX teams to become committed to the initiative despite the limited managerial push. In addition, these pulls kept the team members engaged in improvement long enough to generate *Improvement Results*. Once the program produced *Perceived Improvement Results*, a more powerful pull toward commitment arose (Schaffer and Thomson, 1992; Shiba et al., 1993). The team members' *Commitment to Improvement* increased as the *Perceived Improvement Results* were seen, and team members continued their *Time Allocated to Improvement.* The renewed *Commitment to Improvement* creating a reinforcing process (R4) between improvement results and commitment that sustained the improvement effort.

The behavioral and motivational dynamics discussed above played a critical role in stimulating participation in the APEX process. But no matter how enthusiastic team members are, improvement activity cannot occur if team members are under excessive pressure to meet throughput goals. The following section describes how emphasizing cycle time early in an initiative can help employees remain committed to improvement.

Emphasizing Cycle Time Reduction

At AT&T, the APEX teams sprang out of the Interval Reduction Initiative headed by Bill McCurdy and were conceived out of a need to lower TSBU's time-to-market. Not unexpectedly, Hofmann, the APEX leader, adopted a heavy emphasis upon interval measurement and cycle time reduction techniques. The APEX leaders saw numerous benefits to the cycle time reduction activities, which have also been documented in the product development literature (Cordero, 1991; Crawford, 1992; Gold, 1987; Mabert, Muth, & Schmenner, 1992; Millson, Raj, & Wilemon, 1992; Nayak, 1990; Rosenthal & Tatikonda, 1993; Smith & Reinertsen, 1991). These benefits include products becoming obsolete less quickly; earlier introduction of products increasing market share and can locking a customer into a product due to high switching costs. Firms with faster development capabilities may be able to enjoy higher profit margins and be more responsive to environmental changes. Time-to-market is a powerful and understandable metric to motivate people and is a good proxy for the effectiveness of the product development process. In addition, a focus upon interval reduction can make other quality issues become more apparent as buffers and time delays are eliminated.

Hofmann and the cycle time literature both failed to recognize another important attribute of an emphasis on cycle time reduction: the improvement initiative is more likely to be successful. The initial *Operational Changes* bring about a reduction in the *Cycle Time* within the product development organization. Since the product development process is functioning more swiftly, *Improvement Results* emerge more quickly. The product designers can then rework their designs or correct other defects sooner, meaning that quality problems do not persist as long. The reductions in product development interval (PDI) strengthens the commitment pulls identified in the previous sections (Loops R1, R2, and R4) by reducing the time it takes to generate results and perceive them.

APEX's Strategic Choices

Although the dynamics of self-improvement, commitment, and improvement of cycle time are common to all interval reduction initiatives, the success achieved by APEX seems to be the exception in product development improvement initiatives (Jones & Repenning, 1997; Repenning 1996; Sterman et al., 1997). This section describes two characteristics unique to the APEX initiative that were important determinants of its success.

The Divide and Conquer Approach to Process Improvement

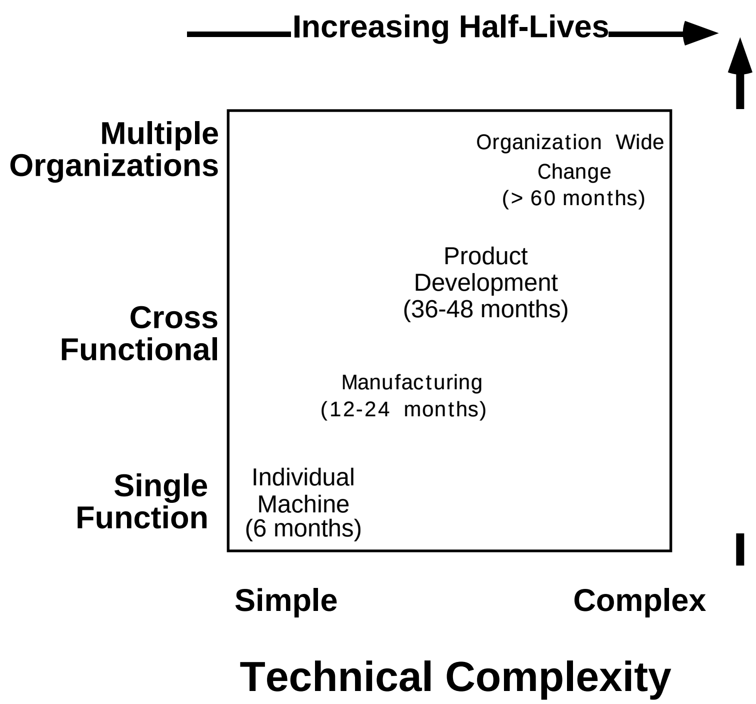
The APEX initiative offered an innovative methodology for process improvement that allowed the program to generate improvement results rapidly. Unlike many product development initiatives with a pilot project focus, APEX created a structure of cross-project teams composed of subject matter experts concentrating on a particular sub-process or module as depicted in Figure 1.

Not only were the APEX teams an example of modular design, but they also served as a blueprint for transforming a tightly coupled design process into a loosely coupled one. Through the sharing of local best practices and APEX project reviews, the APEX teams introduced standards across development projects. The APEX teams worked to integrate their efforts with other activities, such as ISO-9000, so that subprocesses were similarly defined and documented by all groups. Finally, the standardization efforts led to designs intended for use in multiple development projects. The re-use and multi-use of design work enabled TSBU to make a critical step from an interconnected design process to a modular one based on common product platforms or shells that could be outfitted with a variety of standardized design components.

Three theories provide insight into the favorable improvement results from the modular, process improvement strategy. First, from a project management perspective, the decomposition approach appears promising. By optimizing each process particularly along the critical path, the design process can be shortened. Since Bell Labs engineers were accustomed to AT&T's previous monopoly position, the design processes were not entirely efficient, and slack could be readily eliminated without triggering harmful side effects.

Second, to avoid side effects due to tight coupling, Baldwin and Clark (1996) suggest that product design organizations may benefit by shifting from interconnected (tightly-coupled) to modular (loosely coupled) design processes (Eppinger, Whitney, Smith, & Gebala 1994; Krishnan, Eppinger, & Whitney, 1997; Simon, 1969). Firms with high rates of technological innovation, in particular, have profited by working to compartmentalize highly interconnected processes, so that tasks within a single module remain interconnected but have only limited connections with other modules. Baldwin and Clark suggest that modularization enhances experimentation by allowing many parallel experiments, speeding the chances of finding a better design and lowering the cost of each experiment. Modularity also permits decentralized decision-making, while maintaining some form of co-ordination, system-level testing, and integration. The APEX teams did benefit from a higher rate of experimentation. Viewing each project as an experiment, the members gathered data from the development projects, documented local best practices and distributed their findings back to the development projects both informally and through APEX project reviews.

<u>Figure 7.</u> Problem complexity matrix, adapted from Schneiderman (1992)



The Problem Complexity Matrix (Schneiderman, 1992) shown in Figure 7 provides a third perspective for understanding the success of the APEX modular approach. Schneiderman (1988 and 1992) suggests that the rate at which problems are removed by an improvement initiative for a particular type of process follows a half-life pattern, that is, the time required to reduce the number of problems in half is constant. Schneiderman further argues that the *improvement half-life* of a process is related to the number of organizational units that are enacting the process (organizational complexity) and the sophistication of the technology required to perform the process (technological complexity). Processes with low organizational and technical complexity, for example a machine-operator system, are improved relatively quickly because of their brief cycle time and the speed at which experimentation can be done in them. Processes situated further toward the upper right-hand corner of Schneiderman’s matrix – for example product development processes that require multifunctional groups with sophisticated technology – are associated with a higher improvement half-life due to the difficulties of coordinating experimentation and the delays in measuring results.

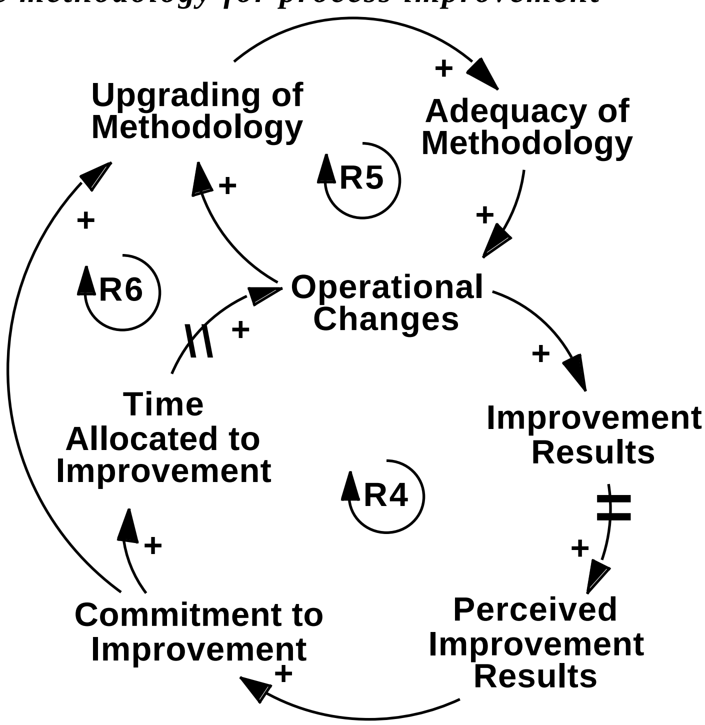
Unlike pilot projects which address an entire project, the APEX teams divided the interval reduction problem into manageable subprocesses and applied their techniques to the less complex units. This *divide and conquer* strategy, by enabling results to be achieved more quickly than would have been possible under the holistic approach, increased the strength of the reinforcing mechanisms (Loops R1 through R4) that sustain the improvement effort. In addition, the divide and conquer strategy permitted cycle time reductions to be achieved faster, strengthening the cycle time reduction dynamic.

Adaptive Methodology for Process Improvement

The APEX leadership selected a second strategy that differed from common improvement practices. Specifically, they readily adapted techniques from a variety of improvement methodologies. While most proponents of process improvement argue for a constancy of theme, focus and methods, APEX's flexible and adaptive methodology emphasized a poorly recognized feedback that reinforced the commitment of team members and perpetuated the improvement effort. The understated promotion approach and skunk works positioning of the APEX initiative allowed the leadership to be experimental in its approach and avoid rigid adherence to a single methodology. Accordingly, the APEX leaders were able to adapt the methodology as the improvement issues became more complicated. Essentially, the APEX leaders drew upon their experience from their *Time Allocated to Improvement* to *Upgrade the Methodology*, thereby increasing the *Adequacy of the Methodology* to the organizational and technological complexity being addressed. For example, APEX relied on PQMI for initial technique development, such as APEX project reviews. Similarly, when APEX leaders perceived the need to address integration issues, several new teams, objectives and practices were adopted. The associated self-reinforcing cycle of *upgrading through experience* loop (R5) shown in Figure 8 permitted the APEX teams to expand their ability to tackle more complicated problems.

A related feedback process (Loop R6) contributed to the ongoing revisions to the APEX methodology. As the APEX members became more committed to the program, they turned away from their *not invented here* mentality and searched actively for better product development practices and improvement techniques. For example, rather than abandon the APEX teams during the QI initiative, the APEX leaders and QUEST consultants selectively adopted good practices from QI, communicated their efforts to others through the QI story format, and ensured their longer term existence by fitting APEX into the Policy Deployment Matrix. The greater *Commitment to Improvement* enabled to the APEX members to welcome changes, including *Upgrading the Methodology;* the more sophisticated methodology then facilitated ongoing *Improvement Results* and team motivation.

Figure 8. ***Adaptive methodology for process improvement***



Failure Modes of Improvement Programs

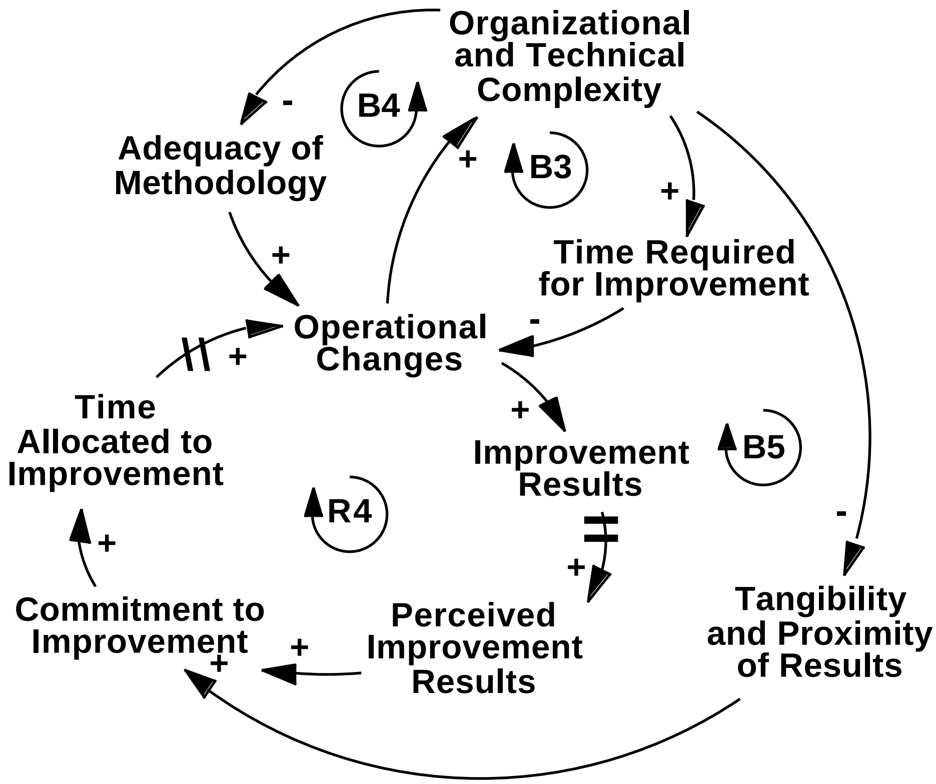
There are many environmental reasons why improvement programs fail or wane, for example, reorganization, technological obsolescence, and market changes (Oliva & Rockart, 1997). In contrast, we identified several structural factors that endogenously make sustaining improvement programs difficult. The self-improvement dilemma highlights a failure mode; if employees do not have adequate slack or motivation to engage in improvement efforts, the program does not live beyond inception. In some cases, a process improvement program is successfully launched through managerial push but does not yield improvement results due to the long time delays associated with introducing operational changes and translating them into productivity gains. These programs do not survive through the *worse before better* dynamic. Other programs, such as APEX, succeed in generating substantial productivity gains yet later falter. In this section, we will use the feedback structure to examine two late-emerging failure modes that are endogenous to self-improvement programs and explore their part in the end of APEX.

Complexity Slows the Improvement Process

The first late-emerging failure mode arises from the complexity of the problems being addressed. For example, once the APEX teams had generated substantial operational changes by focusing on the *fat rabbits*, they moved their problem domain outward in Schneiderman's matrix (Figure 7) to an area with higher organizational and technical complexity. In 1994, APEX shifted its unit of analysis from the subprocesses to the development process as a whole. Redirecting of the entire product development focus toward common platforms and re-use and multi-use of products also resulted in a shift outward in both the technical and organizational dimensions of the Problem Complexity Matrix.

The more sophisticated problem domain activated three related improvement counterforces: First, the new problem domain had associated with it a longer improvement half-life, which expanded the *Time Required For Improvement* to produce the same level of *Improvement Results*. One APEX leader describe this phenomenon as "the feeling that we were not getting anywhere." By accepting more complex challenges, the APEX effort had weakened several self-sustaining improvement processes through the *Time Required for Improvement* or *half-life* B3 loop in Figure 9. Since APEX participants were still expecting the same rate of improvement, they became frustrated and less committed to the APEX teams when improvement results were not forthcoming.

***Figure 9.* Complexity slows the improvement process**



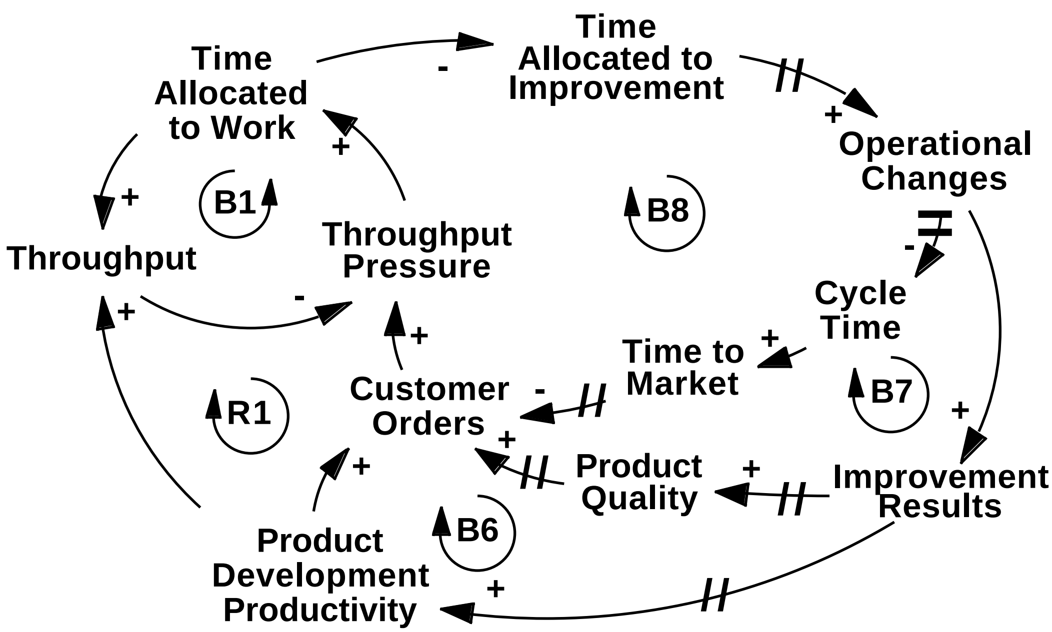
Second, the *Adequacy of the Methodology* declined as the existing techniques proved increasingly less effective with the challenging problems (Loop B4). For example, several product developers complained that the simplistic QI methodology could not tackle difficult product development problems. As the QI techniques were inflexible, the QI teams were unable to address effectively the relatively complex problems. This led to a substantial drop in the participation in QI teams within the product development area after two years.

Finally, due to the growing complexity, it became increasingly difficult for product developers to relate the benefits – both potential and realized – of their improvement efforts to their development work. With low *Tangibility and Proximity of Benefits* (expectancy and instrumentality), each member began to behave as a passenger or free rider, receiving recognition for the improvement results of the whole team without making the personal commitment to undertake the improvement effort. As a result, the process improvement teams were further weakened by the B5 *for the common good* self-correcting feedback process.

Better Product Development Products and Processes Boost Customer Demand

As previously described, the rewards from a successful improvement initiative include greater *Product Development Productivity*, higher *Product Quality*, and faster *Time-to-market.* These welcome improvements permit an organization to book additional *Customer Orders*, increasing profitability. The supplemental customer demand, however, generates *Throughput Pressure* that can undermine the continuation of the improvement initiative. In the case of AT&T/Lucent, three factors resulted in a substantial rise in throughput pressure.

***Figure 10.* Better product development products and processes boost customer demand**



First, the TSBU management modified their marketing plans once the APEX-generated product development productivity gains became apparent. For example, two senior managers reported that AT&T responded to the enhanced *Product Development Productivity* by increasing its willingness to accept *Customer Orders* and increase *Throughput* rather than ensuring additional productivity gains by explicit managerial measures to designed to sustain the improvement effort. While the managerial response to greater product development efficiency benefited TSBU financially through higher orders, it also produced a side effect – less *Time Allocated to Improvement* – that undermined the APEX initiative and lessened future productivity gains (Loop

B6 in Figure 10).

Second, due to the success of the APEX teams and improvement efforts in manufacturing (McPherson, 1995) and supplier quality (Krahmer, 1996 and 1997), TSBU products became more attractive with higher quality and shorter delivery time. The winning of the Malcolm Baldrige National Quality Award by TSBU helped attract substantial new orders from quality-conscious customers, thereby achieving the original aim of the TSBU improvement program. It, however, created unanticipated side effects that undermined the ability to sustain the improvement effort. Specifically, the higher *Product Quality* and lower *Time-to-market,* while producing the desired increase in *Customer Orders,* placed additional *Throughput Pressure* on the Bell Labs engineers' processes, creating two balancing forces (Loops B7 and B8) that dampened future improvement efforts. By producing satisfied customers, the improvement program attracted customer orders, thereby increasing throughput pressure and hampering the future progress of APEX.

Finally, customer orders also expanded during the five-year (1989-94) period of the APEX initiative due to increased demand for telecommunication equipment worldwide. The rapidly changing telecommunications market created an expanding market for broadband products to accommodate internet and video-conferencing in the US market, while demand for more basic telecommunications equipment from overseas markets grew.

Summary

The APEX teams provided a rich set of experiences from which to develop a dynamic theory of process improvement. The main elements of this emerging theory are summarized in this section. First, slack in product development resources allows process improvement programs to be started without immediately increasing throughput pressure. More importantly, sufficient slack is a necessary condition for activating the reinforcing commitment processes that sustain improvement programs beyond their managerial roll-out. Second, team commitment and improvement results can be initiated through managerial push. However, employee-based pull mechanisms are needed to perpetuate the improvement initiative over the long term. Third, emphasizing cycle time reduction before introducing other process improvement objectives permits improvement results to be perceived sooner and allows commitment to be garnered more quickly with employees.

The APEX initiative also revealed additional factors that can sustain process improvement teams in settings as complex as product development. By dividing complex processes into smaller modules, the improvement half-life can be reduced, thereby generating improvement results sooner. In addition, by adapting the improvement methodology to the complexity of problems addressed process improvement teams can continue to generate ongoing improvements. Finally, two endogenous late-failure modes for process improvement teams were identified. Methodological adaptation can be insufficient to overcome the increasing complexity of issues that are addressed once the simpler problems are removed. Without careful management of customer orders, the success of the improvement initiative might create a surge in customer demand that forces team participants to re-focus their energies on their conventional development work, limiting the time allocated to improvement and slowing the improvement progress.

Conclusions

The paper presents a dynamic theory for sustaining process improvement teams in product development. The theory suggests that generating team commitment is critical to activating and sustaining a successful process improvement initiative. The APEX team field research revealed several techniques for developing commitment that have been largely overlooked by process improvement gurus and academic theorists. The elements of the *worse before better* dynamics as well as the endogenous failure modes created by process improvement programs in product development are readily generalizable to other settings, such as manufacturing, supplier quality or marketing. The worse before better dynamics have emerged repeatedly in Total Quality Management as well as business process re-engineering (Hammer and Champy, 1993) programs and is observed in any work unit undertaking improvement activities. The model presented in the paper, therefore, can serve as the basis for understanding change management in a wide variety of processes.

The theory offers practitioners insight into issues to be considered when implementing a change initiative in product development. Rather than the heavily promoted roll-out by management of a pre-established program supported by numerous incentives, management may be better served by adopting a different strategy. A more understated approach, relying on up-front data collection, such as benchmarking, and an active role for employees in disseminating information about the improvement programs, can generate slower building but longer lasting commitment to an improvement initiative. By selectively nurturing commitment, the committed employees then become the key promoters of the program through their favorable word-of-mouth, peer recognition and their ingenuity in adapting the process improvement methodology. In addition, process improvement efforts can sustain commitment by reducing the time required to generate improvement results by decomposing the product development process into less complex sub-processes.

The theory also identifies several obstacles inhibiting the phase-in and suggests several organizational counterforces that may arise years after an improvement program has been launched. Practitioners, therefore, need to incorporate measures to overcome not only the self-improvement dilemma at start-up but also anticipate and mitigate the ill effects of its re-emergence in later years. The key to long term success is to understand the available policy levers and associated resistance and establish an ongoing balance between normal work and improvement activities.

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