Systems Thinking and Organizational Learning: Acting Locally and Thinking Globally in the Organization of the Future*

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The "New Work" of Managers

Eroding competitiveness, declining productivity growth, explosive technological, political, and environmental change, and dissolution of market and national boundaries form the familiar litany of problems which threaten traditional organizational structures and management practices. In the turbulence at the close of the century it is widely argued that organizations must change more rapidly than ever before.

Organizations stressed by these pressures have worked to clarify their missions, visions, and values. Many seek to reorganize into leaner, more locally controlled and market-responsive structures. Yet, all too often the core operating (as opposed to espoused) policies guiding organizational behavior remain unchanged. One reason core policies remain unchanged is that the thinking underlying such policies remains unchanged. Sincere efforts to instill new management practices often lead to frustration and cynicism rather than fundamental and lasting improvements. Efforts to improve strategic management often founder because new strategies and structures threaten traditional habits, norms, and assumptions. The problem lies, in part, with failing to recognize the importance of prevailing mental models. New strategies are the outgrowth of new world views. The more profound the change in strategy, the deeper must be the change in thinking. Indeed, many argue that improving the mental models of managers is the fundamental task of strategic management:

> Strategies are the product of a worldview... the basis for success or failure is the microcosm of the decision makers: their inner model of reality, their set of assumptions that structure their understanding of the unfolding business environment and the factors critical to success... When the world changes, managers need to share some common view of the new world. Otherwise, decentralized strategic decisions will lead to management anarchy (Wack 1985, 89, 150).

In response, managers and academics alike have identified organizational learning, the process whereby shared understandings and strategies change, as a key to flexibility and competitive advantage in the 1990s. While no one knows precisely what learning organizations will look like or how they will be built, all agree that they will require profound, much-needed shifts in the nature of managerial work. In the words of William O'Brien, CEO of Hanover Insurance Companies , "The dogma of the traditional hierarchical organization was planning, managing and controlling. The 'dogma' of the learning organization of the future will be vision, values, and mental models" (Senge 1990a). In a recent study of the beleaguered manufacturing industries, Hays, Wheelwright and Clark (1988) conclude "There is one common denominator in high-performance plants: an ability to learn – to achieve sustained improvement in performance over a long period of time. When assessing a manufacturing organization, learning is the bottom line." "I would argue that the rate at which individuals and organizations learn," wrote Analog Devices' CEO Ray Stata in the *Sloan Management Review*, "may become the only sustainable competitive advantage" (Stata 1989). Definitions of organizational learning vary, but there are common themes. Former chief of planning at Royal-Dutch Shell, Arie de Geus (1988) observes that an organization's ability to survive over an extended period

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depends on "institutional learning, which is the process whereby management teams change their shared mental models of their company, their markets, and their competitors. For this reason, we think of planning as learning, and of corporate planning as institutional learning." Similarly, Don Schön (1983a) defines organizational learning as change in the "norms, strategies, and assumptions that govern (an organization's) regular patterns of task performance." The "quality of organizational learning," in Schön's view, is determined by the quality of the "organizational inquiry that mediates the restructuring of organizational theory-in-use."

Many agree that organizational learning processes are most effective when they help managers develop a more systemic and dynamic perspective. Organization development professionals have long advocated a systems perspective for effective change (e.g. Beckhard and Harris 1987, Katz and Kahn 1978, Schein 1985, Weick 1979). A recent strategic management text begins by citing the views of Bruce Henderson, a "senior statesman" of the strategy field, who criticized...

> the essentially static nature of ... earlier work ... [which neglected] time, second order effects and feedback loops ... the ingredients for the insightful analysis that was needed to move the field of strategy its next step forward" (Lorange, Scott Morton, and Ghoshal 1986, xviii)

The challenge is how to move from generalizations about accelerating learning and systems thinking to tools and processes that help managers reconceptualize complex managerial situations, design new operating policies and guide organization-wide learning. How do organizations learn? What values, structures, tools and processes are supportive of a learning organization? How do we get there from here?

One new approach involves developing 'learning laboratories' or 'microworlds'– microcosms of real business settings where managers play roles in a simulated organization. As an aircraft flight simulator allows pilots to experience a wide range of conditions and try alternate strategies without risk, so too a learning laboratory provides a flight simulator for managers and management teams. A simulated microworld compresses time and space, allowing managers to experience the long-term, system-wide consequences of decisions (Sterman 1988; Graham, Morecroft, Senge, Sterman 1989). But, an effective learning laboratory is much more than just computer simulation. It trains managers and teams in the full learning cycle, as originally conceived by John Dewey: Discover – Invent – Produce – Reflect. Specifically, it develops skills in articulating hypotheses and reflecting on the outcomes of actions to confirm or disconfirm hypotheses, tasks in which most people are notably undisciplined (Hogarth 1987). The result is greater awareness of the assumptions underlying policies and strategies, better systems thinking skills, shared understanding of complex issues, and enhanced individual and group learning skills. No longer mere pilots flying the firm, managers become designers who continually analyze and improve the enterprise.

Systems Thinking: New Insights, New Perspectives

The research draws on the system dynamics methodology developed originally at MIT (Forrester 1961, Roberts 1978, Richardson and Pugh 1981, Meadows 1982). For systems theorists, the source of poor performance, organizational failure, and inability to adapt is often to be found in the limited cognitive skills and capabilities of individuals compared to the complexity of the systems they are called upon to manage (Simon 1979, 1982; Perrow 1984, Forrester 1961). A vast body of experimental work demonstrates that individuals make significant, systematic errors in diverse problems of judgment and choice (Kahneman, Slovic, and Tversky 1982, Hogarth 1987). Training and repeated experience often do not help (Brehmer 1980, Einhorn and Hogarth 1978). Market mechanisms and financial incentives do not eliminate the errors (Camerer 1987, Slovic and Lichtenstein 1983, Smith, Suchanek, and Williams 1988).

Dynamic decision making is particularly difficult, especially when decisions have indirect, delayed, nonlinear, and multiple effects (Sterman 1989a, 1989b, Kleinmuntz 1985, Dörner 1989, Kluwe, Misiak, and Haider 1989). Yet these are precisely the situations in which managers must act. The turbulence of the late 20th century is in large measure due to increasing complexity of feedbacks among institutions and our inability to understand the dynamics they generate. Managers can no longer ignore the feedbacks between their decisions and the environment which condition the choices they will face tomorrow, next quarter, and for years to come.

Misperceptions of feedback have been documented in a wide range of systems:

- Managers in a simple production-distribution system generate costly cycles of excess inventory and stockouts, even when consumer demand is constant (Sterman 1989b, MacNeil/Lehrer 1989);
- Managers of simulated consumer product markets generate the boom and bust, price war, shake-out, and bankruptcy characteristic of industries from video games to chain saws (Paich and Sterman 1990);
- In a simulation of People Express Airlines, students and corporate executives alike frequently bankrupt the company, just as the real management did (Sterman 1988);
- In a publishing industry simulation, people often bankrupt their magazines even as circulation reaches all time highs, just as did a number of real publications (Hall 1976, 1989);
- In a forest fire simulation, many people allow their headquarters to burn down despite their best efforts to put out the fire (Brehmer 1989);
- In a medical setting, subjects playing the role of doctors order more tests while the (simulated) patients sicken and die (Kleinmuntz 1985).

Throughout these studies runs a common theme: as the time delays grow longer and the feedbacks more powerful, performance deteriorates markedly (Diehl 1989). Experience and training do not eliminate the misperceptions of feedback: professional economists generate periodic depressions in simple economic models (Sterman 1989a); in simulations of real estate and shipping, a majority of managers tested typically go bankrupt at least once before learning how to survive, despite experience in these industries (Bakken 1990); government officials playing an economic development game often impoverish their simulated economies through foreign debt, poison their environments, and starve the population (Meadows 1989).

These findings have significant implications for educators and consultants. The chief limitation in past applications of tools like system dynamics is that the models were constructed by expert consultants, who then explained their operation to policy makers. The "traditional consulting" approach has produced many notable successes and use of system dynamics by firms in a variety of industries is growing (Morecroft 1988, Weil 1980, Cooper 1980, Roberts 1978). Nevertheless, the role of the outside expert as developer and interpreter of a model, while it may change what managers think about a particular strategic issue, rarely changes the way managers think about future issues. By contrast, the traditional consulting approach often results in enduring insight for the model builder. Why? Model development creates a laboratory microworld in which hypotheses can be tested, evaluated, and revised. Model builders not only learn about the substantive issues but develop skills in scientific method and critical thought. Passive consumption of model results does not transfer systems thinking ability into an organization, nor does it develop the discipline of scientific experimentation necessary to learn effectively from experience.

Learning Laboratories

Our research attempts to develop explicit learning processes aimed not only at improving managers' shared mental models of particular issues but altering the character of those models so that they become more systemic and more dynamic. In our view, this can only be achieved if managers themselves become the modelers to a far greater extent than in most prior work. Researchers in system dynamics and other systems traditions have experimented with many alternative processes to stimulate explicit model building and catalyze systems thinking in management teams. While effective learning processes are iterative and flexible, for purposes of exposition they can be divided into three stages:

- *Mapping mental models* – explicating and structuring assumptions via systems models;
- *Challenging mental models* – revealing internal inconsistencies in assumptions;
- *Improving mental models* – continually extending and testing mental models.

Mapping mental models involves the explication and sharing of the managers' assumptions.

These mental models are typically quite poor maps of the terrain. They ignore feedback and multiple causal pathways, underestimate time delays, and disregard nonlinearities. Axelrod's (1976) study of the cognitive maps of elites painted a...

> ...picture of the decision maker...[as] one who has more beliefs than he can handle, who employs a simplified image of the policy environment that is structurally easy to operate with, and who then acts rationally within the context of his simplified image.

But, flaws in mental models cannot be corrected until mental models become more explicit. Forrester (1971) argues:

> The mental model is fuzzy. It is incomplete. It is imprecisely stated. Furthermore, within one individual, a mental model changes with time and even during the flow of a single conversation. The human mind assembles a few relationships to fit the context of a discussion. As the subject shifts so does the model.... [E]ach participant in a conversation employs a different mental model to interpret the subject. Fundamental assumptions differ but are never brought into the open. Goals are different and are left unstated.

Many cognitive mapping tools have been developed to elicit and portray the mental models of individuals and groups (Morecroft 1988, Richardson and Pugh 1981, Eden, Jones, and Sims 1983, Checkland 1981, Hall 1984, 1989). The more effective mapping tools help people capture the time delays, long-term effects, and multiple impacts of decisions – the characteristics of complex systems which cause the most serious misjudgments in dynamic decision making. The more effective tools, increasingly computer-based, also facilitate group input and rapid revision (Richmond 1987, Morecroft 1988, 1982). In the mapping stage there is no attempt to converge upon a single, integrative model. Rather, different mapping tools may often be used, each illustrating a particularly important aspect of a problem, and also preventing inappropriate early attempts at convergence. Regardless of the tools employed, the most important result of the mapping stage is to uncover critical assumptions and set the stage for challenging them.

Challenging mental models is testing for internal and external validity. Once team members have gone public with their mental models they can begin to discover internal inconsistencies and contradictions with data and others' knowledge. Experienced managers often have accurate perceptions of causal structure and decision-making process. Nonetheless, they often draw erroneous conclusions about what happens when different parts of a system, each of which they may understand in isolation, interact. Challenging models thus requires an inference engine to deduce the consequences of interactions among the elements of the map. Simulation provides that engine. For simulation to be effective in challenging the managers' mental map, the team members must have a high level of ownership of the simulation models. Managers should be able to construct the models themselves in a short period of time. Such high involvement requires modeling software people can understand easily, without computer expertise or technical training. While a number of systems are available, we have used the simulation software STELLA which allows graphical construction of dynamic simulation models on microcomputers (Richmond, Peterson, and Vescuso 1987). STELLA is widely used in modeling physical, biological, and other systems. Applications in management and economics are growing rapidly (e.g. Milling and Zahn 1989, Nyhart and Samarasan 1989, Nyhart 1988, *HealthCare Forum* 1990, Solomon 1989). STELLA is designed to be used first as a mapping technology. The simulation model is then built directly from the cognitive map. Managers frequently can learn the mechanics of STELLA in an hour, allowing meeting time to be spent on substantive matters rather than simulation methods or computer languages. Typical questions posed to challenge mental models include "Are our strategic objectives internally consistent?" and "Can we get there from here?". The "reality check" models developed at this stage are designed to uncover inconsistencies or overlooked dynamics which bear on the success of the team's strategy. A good reality check model is simple. It should be a straightforward translation of the team's strategy map, and will typically be built up from pieces which are well understood and agreed upon in the mapping stage.

Challenging mental models is delicate. For the first time in the learning process the managers' beliefs are called into question. Inconsistencies between assumptions about the structure of the system and likely behavior are revealed. If trust and openness in the group are not well established, individuals may be threatened and react defensively. It has often proven useful to work with the team members on developing inquiry skills and recognizing defensive routines. A number of approaches to team development have been used successfully in conjunction with mapping technology, including Ed Schein's process consulting (Schein 1969, 1987) and the action science approach of Chris Argyris (Argyris & Schön 1978, Argyris, Putnam and Smith 1986) among others (Dyer 1987, Schön 1983b).

Improving mental models is the ongoing, open-ended process of explicating, testing, and revising managerial assumptions. Here the team members are creating new constructs and world views, and assessing the consistency of their own policies and behavior in the light of new understandings and experience. Now the team expands the simple reality check models to include potentially important feedback dynamics. Assumptions about exogenous environmental factors are questioned. Factors excluded from the initial maps are brought inside the boundary of the model. Linkages with other functions in the organization, and with other organizations in the environment, are considered. The time horizon may lengthen to insure the long-term effects of decisions are captured. Insight arises from formulating and testing hypotheses about the source of problem dynamics. Such dynamic hypotheses explain problematic patterns of behavior in terms of specific feedback interactions. These hypotheses are then tested, first in the simulation models, then through collection and analysis of relevant data, and later by actual changes in the organization's structure and policies.

The important feature of the process is the discipline imposed by the modelling tools. Hypotheses and ideas for improvement must be translated into specific changes in policy and structure, and the effects must be tested and understood. There is no guarantee the models constructed by the team will predict what would occur if a new initiative were implemented. But the assumptions behind a new strategy or policy initiative will be explicit and well thought out, subject to continued testing and improvement. The managers become experimentalists practicing scientific method: formulating hypotheses, designing tests, and conducting the experiments which may invalidate their beliefs and lead to improved understanding of the structure and dynamics of their organization.

The full benefits of an effective learning process may accrue over a considerable period of time, in some cases several years. New conceptual perspectives are assimilated gradually, stimulated by ongoing processes of dialogue and debate among managers (Levitt and March 1988). Eventually, new perspectives lead to new perceptions. As illustrated below, one consequence may be difficulty in tracing the evolution of new ideas and new policies which might have germinated in a learning laboratory. The formal process is best thought of as catalyzing a larger, more diverse organizational learning process, gently nudging managers toward a more systemic and dynamic view of their world.

A Case Study: the insurance crisis

A number of learning laboratories and management microworlds have been developed. One of the more interesting examples has been developed for a leading property and liability insurance company in the U.S. The Hanover Insurance Claims Learning Laboratory (CLL) addresses the runaway costs that threaten the entire liability insurance industry in the U.S. Premiums on auto insurance doubled from 1983 to 1988. Rates on medical malpractice insurance have increased even faster. The tort system in the United States consumes more than 2.5% of GNP, the highest in the world (it is about 0.5% in Canada and Great Britain, less in Japan). Between 1979 and 1985, the number of product liability cases increased 150%. The average size of jury verdicts increased five-fold from 1973 to 1985. "[F]rom 1985-1987, some municipalities' premiums went up 100 to 200 percent, toy manufacturers' liability policies shot up 50 to 1000 percent, and chemical companies saw premiums rise 200 to 400 percent" (Richardson and Senge 1989). In New York state, rate caps imposed by the insurance commissioner in recent years have left all five providers of medical malpractice coverage technically bankrupt (Richardson and Senge 1989). Outraged Californians recently passed ballot referenda rolling back automobile insurance premiums. Other states are likely to follow suit.

Commonly cited causes of the liability crisis include the high number of lawyers per capita in the United States, the increasing litigiousness of society, the tendency for juries to side with victims rather than impersonal, uncaring big business, and the growing technological complexity of society (Huber 1987). The list goes on. Notably absent from such accounts are explanations relating to the management practices of insurers themselves. Why are there so many tort lawyers and lawsuits? Why are insurers perceived to be uncaring? Some of the top managers at Hanover Insurance, of

Worcester, Massachusetts, were asking the same questions. While a minority within the company, these managers intuitively felt that their own management practices had contributed significantly to the problem. They distrusted easy explanations which fix the blame on outside agents. Blaming greedy lawyers, juries, and policyholders is psychologically safe, absolving insurers from responsibility. While not denying the role of these factors, they also saw that blaming the problem on external forces prevented the company from contributing to constructive solutions.

Hanover Insurance is a medium sized firm specializing in property and casualty. 1989 premium income was $1.5 billion, and assets were $3 billion (table 1). Founded in 1852, Hanover went through a dramatic transition in the last twenty years. In the mid-1960s the company was at the bottom of the industry. In 1969 State Mutual purchased a 50% interest in Hanover, injecting much-needed reserves, and installing a new president, Jack Adam. With his marketing vice president and eventual successor, Bill O'Brien, Adam began to reorient the company around a new set of guiding principles designed to address deeply rooted problems in Hanover's traditional authoritarian management style:

Purpose – an antidote to a weak sense of common direction

Merit – an antidote to rampant politics and bureaucracy

Openness – an antidote to wide-spread game playing through hoarding information or operating from private agendas

Localness – an antidote to institutional blocks to strong morale and decision making authority in front line units

Vision – an antidote to low self-image and difficulties in communicating the scale of the firm's aspirations.

Table 1. Hanover Insurance Financial Highlights, 1989*
(Source: 1989 Annual Report)

Revenues:	Net premiums earned	1421
	Net investment income	154
	Other income	48
	Total revenues	**1622**
Expenses:	Losses and loss expenses	1,076
	Other expenses	463
	Total expenses	**1539**
Net Income:	**Net income**	**83**
Other:	Total assets	2,955
	Shareholders' equity	741
	Combined ratio	105.9%
	(Industry average	110.7%)

* Totals may not add due to rounding.

The new culture did not quickly take root. Personnel and structural changes accompanied the gradual internalization of the new philosophical foundation. Many of Hanover's original managers were unprepared for the organization Adam and O'Brien envisioned. During the early 1970s management turnover was high. A level of regional management was eliminated to encourage local autonomy and authority. By the mid 1980s Hanover emerged as a leader in the property and liability industry. Hanover's combined ratio, the ratio of operating expenses, including dividends, to premium income, a measure of the profitability of the insurance side of the business, has bettered the industry average for the past eleven years. During the same period Hanover grew 50% faster than the industry as a whole. There is a wide-spread belief in the organization that the company's business success is linked to its guiding principles (Bergin and Prusko 1990).

One logical starting point for Hanover to apply the systems approach was claims management. First, the problem is highly dynamic: the growth of Hanover's underwriting volume placed ever greater demands on the claims operation. There were more complex claims and increasing numbers of claims requiring litigation or subrogation (recovering costs from other insurers). The problem cut across all levels of management, corporate functions, and regions. Most importantly, Hanover's non-authoritarian culture and emphasis on local decision-making meant that the systems approach could not be successful if top management were the only participants in the process.

The project has proceeded in three stages: First, a team of top managers worked with MIT researchers to develop shared models of the problem. Next, a simulation model developed in phase one was converted into an interactive "Management Flight Simulator." The Hanover team designed a three-day workshop for claims managers throughout the firm, the Claims Learning Laboratory, using the flight simulator. Over one-hundred managers have now participated in the CLL. In the third stage, now underway, a second workshop is under development to help in managing change, systems thinking tools are being introduced throughout the firm, and the effectiveness of the systems thinking approach is being evaluated through longitudinal studies.[1]

The first stage involved a claims management team consisting of the senior vice-president for claims, Wim den Draak, and two of his direct reporters. The team met every two weeks for about a year with the MIT researchers. The group appeared to have a high level of openness and mutual trust, reflecting several years of working together in Hanover's culture. At the first meeting the team developed an initial statement of objectives, strategies, and perceived barriers facing the organization. The team's vision statement expressed their intent to be preeminent among claims organizations in the insurance industry, to provide "fair, fast, and friendly" service. They discussed at length their image of the ideal claims adjuster: a person capable of conducting thorough professional investigations, possessing excellent communication and negotiation skills, keeping accurate and complete records, and able to educate claimants regarding the fair value of their claims, while spotting those with the slightest fraudulent inclinations. They joked a little about the claims adjuster who "walks on water," but it was clear that the group held very high expectations for the people they sought to attract and develop.

The initial statement of strategic objectives identified ten different measures of performance, including productivity measures such as the production ratio (claims settled relative to new incoming claims), the pending ratio (the size of the backlog of pending claims relative to the settlement rate, a measure of the average time required to settle a claim) as well as subtle objectives like quality investigation and "vigorous oversight of litigation." They then elaborated twelve different strategies to accomplish these objectives. When asked to discuss the problems they perceived with their strategy, den Draak talked about having too many "balls in the air," the challenge of simultaneously keeping many performance standards on target, like a juggler. Whenever the organization worked to improve performance on a particular objective, such as controlling settlement costs, there was backsliding on other objectives, such as prompt settlement of claims. They also felt investigations needed to be more thorough, adjusters were too concerned with looking good, adjuster turnover was too high, customer service was inconsistent, and the status of adjusters within Hanover and the entire industry was too low. They felt their attorneys were not taking enough litigated cases to trial and that responsibility for litigation management was too diffuse. Typically, the team's vision statement expressed high aspirations but was unconnected to the current situation or how to get there from here. The team's initial conception formed a laundry list of disjoint problems and solutions. Interconnections among the elements were expressed through evocative but operationally vague metaphors such as the juggler with too many balls in the air.

The process of mapping, challenging, and improving mental models began in the first meeting. STELLA was used to map assumptions of the current strategy and simple reality check models

[1] The team initially consisted of P. Senge and consultant N. Forrester, and later D. Kim. J. Sterman was responsible for analysis of the results of the learning laboratory and design of ongoing systems thinking efforts.

quickly showed a mismatch between the anticipated growth in underwriting volume and the resources allocated for claims settlement. The team was soon engaged in the development and testing of their own models (Senge 1990b provides a detailed description). While the final model was comparatively simple, it was quite a bit more complex than the original map. It had been thoroughly tested. Most important, it was the team's model. They had built it, they knew what it assumed and why. The initial laundry list of causes had been transformed into a sophisticated theory of the problem dynamics. Moreover, the team's model carried potentially significant implications for long-standing management practices. Rising settlement costs are largely caused by systematic, long-term underinvestment in claims adjusting capacity. The firm simply has too few adjusters, with inadequate skills, experience, motivation, and incentives, to settle the volume of claims in a timely manner while still providing the quality of investigation and personal attention to the customer required to be fair, fast, and friendly.

Figure 1. Feedback processes causing self-reinforcing erosion of quality and increasing settlement costs.

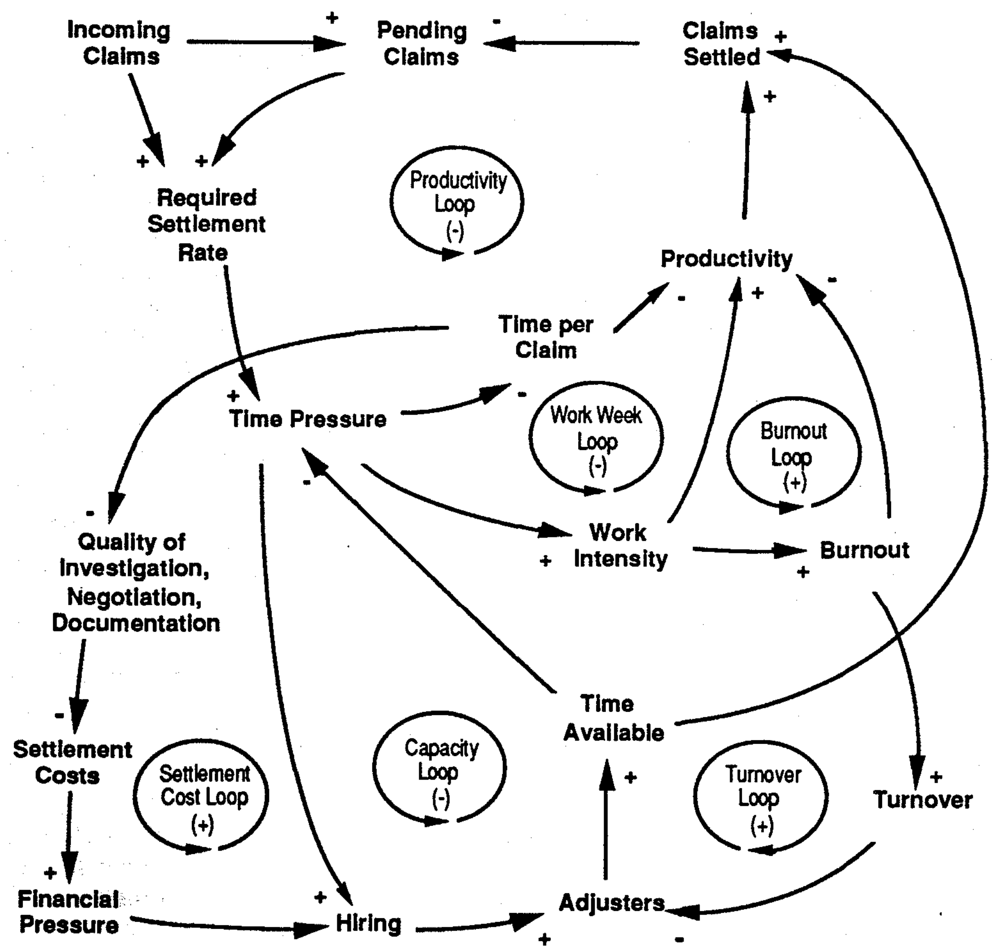

Figure 1 shows the feedback structure which underlies the drift to low performance Hanover, and the industry, has experienced. The structure is relevant to individual claims offices and to geographic regions comprising many offices. A claims organization, and each individual adjuster, constantly adjust the pace of work to control the backlog of pending claims. Hanover carefully monitors the pending pool, regularly reporting work flow measures including the production ratio and pending ratio. A high pending ratio means more dissatisfied customers as claimants find themselves waiting longer. An increase in incoming claims causes the pending pool to rise, intensifying the time pressure on each adjuster. Time pressure is the ratio of the time required to settle the claims in the pending pool relative to the time available. Time pressure measures the adequacy of the adjuster staff and skills available to accomplish the current level of work. There are only three ways in which high time pressure can be relieved: (1) devote less time to each claim; (2) increase work intensity; (3) add adjuster capacity.

Each option forms a balancing feedback process which seeks to restore time pressure to its normal value. Spending less time on each claim means spending less time investigating and negotiating, which increases the number of claims settled, reducing the pending pool and relieving time pressure (the Productivity loop in figure 1). Increasing work intensity means longer workweeks, fewer breaks, and less time spent in 'non-productive' activities such as talking with colleagues or training new people, thus increasing the time spent settling claims and bringing the pending pool down (the Work Week loop). Finally, adding adjuster capacity means hiring additional adjusters, increasing the skills of the existing adjusters through training, and reducing turnover among existing adjusters, increasing time available and settlements, reducing the pending pool, and relieving time pressure (the Capacity loop). However, the three channels for controlling the paper flow have very different time delays, costs, and side effects.[2]

- Building adjuster capacity involves significant time delays. New adjusters must be found, hired, and trained. Adjusting is a highly skilled profession, and the ability to handle complex claims effectively requires several years of experience. Building capacity is also expensive and requires top-management authorization. Adding adjuster capacity was therefore the last resort in the organization.
- Working harder (increasing work intensity) involves only short delays and is easily accomplished with little apparent cost. It is frequently used to control the pending pool. However, sustained high work intensity produces stress, low morale, and burnout, lowering productivity and increasing turnover. These delayed side-effects form reinforcing feedbacks, vicious cycles, which can actually worsen time pressure (the Burnout and Turnover loops).
- By far the easiest and quickest way to control time pressure is to settle each claim faster. Individual adjusters have a high degree of control over the time they spend on a claim. They decide how aggressively to pursue investigation, whether to visit the claimant or handle the claim by 'telephone adjusting', how long to negotiate with the claimant, how much time to spend keeping thorough records. When time pressure rises, adjusters cut back on all of these activities, quickly cutting the pending pool and easing time pressure.

However, spending less time on each claim inevitably erodes the quality of the settlements.

– Inadequate attention to record keeping and documentation means the firm is less successful in litigation and subrogation, increasing settlement costs. Effort is also wasted trying to locate and reconstruct evidence improperly recorded at the time of the loss, increasing the time required to settle and further intensifying time pressure in a vicious cycle.

– Less investigation and negotiation means settlements are likely to be inflated. Settlement costs increase as adjusters under time pressure tend to agree to a claimant's initial request, up to the amount they are authorized to pay without a supervisor's approval: "Hello, Mr. Smith? Your basement was flooded? How much was your loss? Fine. The check will be in the mail tomorrow."

– Telephone adjusting and limited contact with claimants greatly increases customer dissatisfaction. Experienced adjusters report that customer satisfaction arises more from the process of listening to a customer, empathizing with them over their loss, and carefully negotiating a settlement value that the customer understands than the dollar amount of the settlement. After hanging up the phone, Mr. Smith's first reaction is likely to be "they gave me what I asked for - it must have been worth more!" Thus in contrast to the tradeoff between price and quality most businesses face, spending less time on each claim creates the paradoxical situation of high costs *and* low quality. Worse still, the unhappy policyholders, having had little opportunity to develop personal relationships

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[2] For clarity, additional feedbacks causing quality erosion and rising costs portrayed in the model are omitted from the diagram. ¶ The more time passes before investigation commences the more time is required to conduct quality investigation and negotiate with annoyed claimants. ¶ Poor investigation and documentation means additional time in litigation to reconstruct evidence. ¶ Rising turnover means more hiring and training, reducing the time experienced adjusters have to settle claims. ¶ Rising turnover dilutes average skill levels, increasing time pressure.

with the company, are more likely to litigate or attempt fraud, further increasing the burden on the adjusters and legal staff. These feedbacks result in a growing number of disputes and suits, one of the major trends of the liability crisis. Thus in the short run, spending less time on each claim controls the pending pool, but the long-term side-effects are higher average settlements and increased financial pressure to control costs, making it even harder to increase adjuster capacity – another vicious cycle (the Settlement Cost loop).

These feedbacks describe a system in which quality tends to erode and there is gradual escalation of settlement costs. Incoming claims are highly variable, as they depend on hurricanes, fires, and other unpredictable events. When the pending pool increases, management exerts strong pressure to increase the rate of settlements. Given cost pressures and delays in building adjuster capacity, adjusters are pressured to increase the number of claims they process per week. To the individual adjuster, lowering standards is the easiest way to relieve the time pressure. In the short run, spending less time on claims appears to increase productivity. But in the long run, customer dissatisfaction, inadequate investigation and poor documentation cause settlement costs to rise. The financial pressure created by higher losses creates organization-wide pressure for cost reductions and further reductions in capacity, intensifying time pressure still further and forcing quality standards even lower.

Counterpressures to the erosion of quality are weak. Management focuses on the tangible, salient, measurable aspects of performance: getting claims settled, controlling the pending pool, and controlling expenses – primarily adjuster salaries and overhead. Quality, in contrast, is hard to assess. It is multidimensional. Customers feedback about quality is delayed, diffuse, and often distorted by customers' desires to influence their settlements – and by management's suspicions about customer motives. Often customer feedback is altogether unavailable. Den Draak calls these intangible aspects of quality "the fuzzies" saying "in this business there are lots of ways to look good without being good." Quality can fall for years before any significant feedback becomes available to indicate the problem. Feedback from poor quality is not only delayed, it manifests in other areas such as increased litigation, market share erosion, and pressure for government regulation. By the time low quality is apparent, rising settlement costs, increasing turnover, low morale, and high stress may prevent the organization from increasing quality. Periodic campaigns to increase quality are likely to fail because they increase time pressure, causing stress, turnover, and powerful compensating pressures to settle claims more rapidly.

The culture of the claims organization changes as quality erodes. Adjusters who reduce quality to handle a backlog crisis quickly learn that lower standards for documentation, investigation, and service are not only acceptable but even rewarded since they allow the adjuster to perform well on the salient measures of production. Because adjuster turnover is high, new adjusters are socialized in an environment which places a premium on speed, and never experience the old, higher standards for quality. They enter a culture which increasingly focuses on processing claims swiftly, and are neither trained in nor asked to perform to the old standards. High turnover reduces the average skill level of the adjusters, further intensifying time pressure and quality erosion. Worse, the firm's response to high turnover is to routinize the adjuster's job to reduce training costs and minimize the skill level and salary requirements of recruits. Bob Bergin, senior manager for property claims at Hanover, notes:

> In my thirty years in the business, I have seen a steady decline in the pay and status of insurance adjusting. Once it was a respected profession. Today, most adjusters are young college graduates with no aspirations to a career in adjusting. Our management practices both react to and reinforce this attitude.

The insidious aspect of these dynamics is the gradual shift in the burden of controlling the workload from capacity expansion to quality erosion. The erosion in quality standards becomes self-reinforcing: *Once time pressure is relieved, so are the signals that more capacity is needed.* In the short run, slipping quality standards works. Pending claims drop. Time pressure is relieved. Management will not authorize an increase in adjuster head count since there is no apparent problem. In fact, management attention shifts to other problems, for example, what appears to be an inadequate legal staff to handle a growing volume of litigation – litigation brought on, in many cases, by inadequate adjuster capacity.

There are several implications of the feedback processes revealed by the model. First, the adequacy of claims adjusting capacity cannot be assessed through comparisons to other firms. Wim den Draak said that he had begun to wonder if perhaps "We may have half the adjusting capacity that we actually need for our current caseload, from the standpoint of high service quality and low total costs." One of us (Senge) responded that it seemed quite possible. He said, "You don't understand what a crazy thing I am saying. We *already* have a lower caseload per adjuster than almost all of our competitors." In the absence of the model, managers have little choice but to anchor on the competition to evaluate the adequacy of quality. But when all competitors suffer similar quality erosion, none serve as role models to demonstrate the potential leverage from increased adjuster capacity. Entire industries can thus experience eroding quality standards and underinvestment, as exemplified by many US industries in the 1960s and 70s.

A second implication is that simply increasing the adjuster head count will not solve the problem. Low quality standards have been institutionalized in the culture. Adjuster skill levels are constantly depleted by high turnover. Ambitious and talented people avoid claims and seek careers in underwriting, finance, or marketing. Increasing head count will not necessarily increase adjuster capacity. Increases in resources will be effective only in concert with changes in the prevailing mental models throughout the organization.

On the other hand, the potential impact of increased investment in adjuster capacity is substantial. The model, consistent with the judgment of the project team, suggests reductions in average settlement costs of 5 to 20 percent may be realized by increasing investigation and negotiation quality (Moissis 1989). Since settlements comprise about two thirds of all expenses (table 1), a reduction of ten percent would more than double net income.

The Claims Learning Laboratory

After working for a year with the claims managers, the MIT team felt that the model captured the causes of important dynamics. The managers had been intimately involved in conceptualizing and analyzing the model and placed a high level of confidence in it. They were able to articulate the policy implications of the model with conviction and clarity. The problem now facing the team was how to develop shared understanding throughout the organization. The managers who went through the intense learning process could not expect those who had not to agree with its 'counterintuitive' implications. At Hanover, and increasingly in other firms, decision-making responsibility is widely distributed throughout the organization. There are hundreds of individuals who implement new policies and may easily thwart new initiatives. For significantly new policies to come into practice, each person must go through their own personal learning process. There is no substitute.

The team decided to develop a workshop for claims managers to stimulate rethinking of established policies and practices. The workshop had to compress into a few days the process of mapping, challenging, and improving mental models the team itself went through in the previous year. The resulting Claims Learning Laboratory (CLL) is a three-day workshop attended by groups of ten to fifteen managers. It was impractical in a workshop format to have each group of managers build their own model from scratch. Instead of STELLA, the CLL employs a computer simulation game or Management Flight Simulator based on the model developed in the first phase. The game uses intuitive, easily learned software to simulate a claims processing center together with the decisions, data, pressures, and constraints characteristic of the real organization. Significantly, the CLL was developed and is delivered by the Hanover team without extensive assistance from the MIT modelers (Bergin and Prusko 1990, Moissis 1989, Kim 1989).

The CLL has now been in operation for about two years. Almost all claims managers, and a surprising number of managers from other functional areas, have attended. Bob Bergin and Gerry Prusko, two of the managers who deliver the workshop, report:

> The results of the learning laboratory have been positive. It has been credited with:
> 1. Shortening the learning curve for new managers
> 2. Improving communication skills
> 3. Creating an atmosphere for organizational learning
> 4. Clarifying and testing assumptions
> 5. Making mental models explicit

6. Integrating qualitative with quantitative measures of performance
7. Providing a shared experience for decision-making and problem analysis.

When claim managers integrate the systems thinking approach into their own decision-making, they accelerate the changes that need to occur in the organization" (Bergin and Prusko 1990, 35).

Many managers report the CLL to be their most meaningful training experience. Even more importantly, the workshop seems to be developing the rudiments of new, shared mental models. Managers are beginning to develop a language for discussing interactions between workload management, quality, and costs. Experiments with new policies and strategies are beginning. Although it is too early to judge the long-term effects on the core issues of runaway costs, a shift in the assumption that these problems are generated externally seems to be occurring. One recent participant reports:

> When I came back from the learning laboratory, I had a much better understanding of what the important issues were. Before the lab, I would have said that lack of quality was the only important factor. After the lab, it was obvious to me that productivity was also a key issue. So I restructured some units to enhance their ability to settle claims. After I saw dramatic increases in productivity [in the real organization], I applied pressure to improve quality – and I have seen a difference. (Bergin and Prusko 1990, 35).

Lessons: Elements of Effective Learning Laboratory Design

Experiences at Hanover and elsewhere point to three lessons for design of effective learning laboratories: (1) focus on conceptualization; (2) design opportunities for reflection; (3) beware the computer.

Conceptualization. In the Claims Learning Laboratory, most of the first day and one-half is spent in a series of conceptualizing exercises. Participants discuss basic questions such as "What are the determinants of adjuster productivity?" and "What influences quality of investigation?" to help them identify basic interdependencies. They gradually build up a causal map of the major feedback processes included in the model. The mapping accomplishes several goals. First, the participants *participate* – they discuss the issues of concern to them rather than receiving wisdom transmitted from the workshop leaders.[3] Second, cognitive mapping tools are introduced as a language for systems thinking. The participants learn causal loop diagramming in the process of mapping the mental models they discuss. Follow-up study (Kim 1989) shows that some managers continue to use the mapping tools after returning to their organizations. Causal diagrams are becoming commonplace inside Hanover. In addition, the process of mapping brings to light many of the key relationships in the simulation model. When the computer model is introduced, it is no longer a black box – the participants have already discussed the importance of the relationships in the model.

Reflection. In early tests of the claims management simulation we found that the manager-players were thoroughly engaged within fifteen minutes. They were, literally, on the edges of their seats. They argued with one another about the next decision. They bragged about cost reductions they achieved. But when asked what they had learned at the end of the session, none could articulate a significant new insight about claims management. They had played to win, to beat the machine, without pausing to reflect or to formulate and test theories about the causes of the problem. Worse, they showed little concern for the applicability of the game to the real organization.

These managers had fallen victim to the "video game" syndrome. To enable managers to experience the long-term side effects of current decisions, simulations compress space and time. Good simulations also enable rapid trials with different strategies. But these very capabilities enable people to play without careful experimentation and without reflecting on the causes of the outcome. The managers try a strategy; if it doesn't seem to be producing the desired outcome in a few months, they improvise. Rather than a series of controlled experiments, managers tend to vary multiple factors simultaneously. Instead of playing a game all the way through to see the long-term consequences of a strategy, people quit a game which is going badly and start another (Moissis 1989). They behave the

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[3] Of course, the importance of participation and the perception of control over process and content have long been recognized in education, organization development, and psychology. We wish to stress that introduction of systems thinking and computer simulation does not require taking control away from participants. Indeed, well-designed flight simulators may enhance participants' control over the learning process.

same way they do in real life. Trial and error produces little insight, whether performance is good or bad. Treated as a game, simulations can reinforce the misperceptions of feedback and cognitive errors in dynamic decision making: research on causal inference shows people are poor experimenters and often fail to learn from experience (Brehmer 1980, Hogarth 1987, Dörner 1989).

To compensate for the tendency for managers to undermine their own learning, simple learning scenarios are used to introduce the simulation game. The learning scenarios serve to develop disciplined strategic analysis and scientific method. The players, working in teams of two or three to encourage articulation of their reasoning, are presented with a problem such as an unanticipated increase in the volume of incoming claims. Though there are several possible standards to focus on, they are first directed to focus only on the work flow and rebalance the pending pool. Each method of controlling workflow (hiring more adjusters, increasing workweeks, or allowing quality standards to drop) is tried separately to isolate the different feedback processes and side effects associated with each. Before playing, the managers must state their strategy and what they expect to happen to the crucial variables. After playing, they must compare the actual results to their expectations and explain any discrepancies using their map of the causal interrelationships. They then present their analysis to the group for discussion. The process of reflecting on discrepancies between expectations and outcomes establishes a discipline the managers then carry forward to subsequent experiments with new strategies. Without such discipline, simulation all too quickly becomes mere game playing.

The Computer. The participants in the Claims Learning Lab do not see the computer for the first day and one half. For many people, the computer is a predictive tool, a source of information, or a means of control (Orlikowski 1988, Weizenbaum 1976). It is not often seen as a tool for learning. In a successful learning laboratory, managers must perceive that the process is about their ways of thinking, their strategies, their problems – not about the computer. When the computer is introduced the problems of the claims organization are the focus of attention.

Learning laboratories such as the CLL represent what Donald Schön calls a "virtual world", "a constructed representation of the real world." In his study of ongoing learning among professionals, Schön (1983b) shows how virtual worlds play a critical role in learning. Constraints on experimentation are reduced. The pace of action can be varied. Actions that are irreversible in the real world become reversible. Changes in the environment can be eliminated. Complexity can be simplified. But, Schön cautions that "the representational reliability of the virtual world has its limits" and that learning always involves experimentation and reflection in the virtual world *and* the real world.

Herein lies a next major challenge for system dynamics in the domain of organizational learning. We must learn how to design and manage the process whereby managers move continually between the virtual world of the learning laboratory and the real world of management practice. In the virtual world, experiments can be run which are difficult or impossible in the real world. But there is no organizational learning if the experiments are confined to the virtual world. Experiments in the virtual world should lead to hypotheses which are conformed or disconfirmed through measurement and experimentation in the real world. Conversely, actions taken in the real world will continually provoke new questions and present new puzzles which can be illuminated in the virtual world.

Current research concerns the transferability of the lessons of early experiments with learning laboratories, such as at Hanover Insurance, to new organizational settings. The underlying feedback dynamics appear to have a significant generic component. For example, the claims game at Hanover Insurance is an example of a general theory of quality management in service businesses. The structural diagram in figure 1, though tailored for the insurance context, describes feedback processes which arise in any service delivery system. The process and modeling tools described here are now used successfully by organizations in diverse industries, including oil, petrochemicals, finance, health care, heavy manufacturing, consumer products, computers, and high tech. The library of microworlds embodying different general theories of business dynamics is gradually growing (see for example, Sterman 1988, Graham *et.al.* 1989). Experiments with learning laboratories in firms, universities, and other settings are leading to improved methods for team learning.

Managers and organization theorists often point to high-performing teams in sports or the performing arts as role models of flexibility, learning, and consistent quality. Yet most firms, unlike a basketball team or symphony orchestra, have no practice fields where managers' skills can be developed and team competencies enhanced. Organizations in the next decades will be challenged by problems of growing complexity, scope, and time scale. The mental models and learning skills of managers are ill-suited to effective management of these problems. Multiple confounding factors and the long time delays in gathering feedback make learning difficult. Opportunities to reflect, to experiment, to challenge and revise the mental models of the team may be even more important for learning in organizations than in sports or the arts. Learning laboratories are becoming an important tool of successful learning organizations to create meaningful practice fields for team learning. These laboratories increasingly utilize simulation to recreate the full range of interpersonal and substantive challenges which confront teams attempting to learn about complex, dynamic issues. By compressing space and time, simulation will become increasingly important as a tool to accelerate and deepen the learning process. But, simulation will aid learning and organizational change only if it is embedded in learning laboratories which engage managers in collaborative hypothesis testing and reflection.

References

Argyris, C. and D. Schön, 1978, *Organizational Learning: a Theory of Action Approach*, Reading, Mass: Addison-Wesley.

Argyris, C., B. Putnam, and D. Smith, 1986, *Action Science,*, San Francisco: Jossey-Bass.

Axelrod, R., 1976, *The Structure of Decision: the cognitive maps of political elites*. Princeton: Princeton University Press.

Bakken, B., 1990, Transfer and learning in simulated dynamic decision environments. Working paper D-4017, System Dynamics Group, Sloan School of Management, MIT.

Beckhard, R. and R. T. Harris, 1987, *Organizational Transitions, Managing Complex Change*, Reading, Ma: Addison-Wesley.

Bergin, R, and G. Prusko, 1990, The Learning Laboratory, *The HealthCare Forum Journal*, 33(2), March/April 1990, 32-36.

Brehmer, B., 1980, In one word: Not from Experience, *Acta Psychologica*. 45, 223-241.

Brehmer, B., 1989, Feedback Delays and Control in Complex Dynamic Systems, In Milling, P. and E. Zahn (eds), *Computer Based Management of Complex Systems*. Berlin: Springer Verlag, 189-196.

Camerer, C., 1987, Do biases in Probability Judgment Matter in Markets? Experimental Evidence, *American Economic Review*. 77, 5 (December), 981-997.

Checkland, P., 1981, *Systems Thinking, Systems Practice*. Wiley: Chichester.

Cooper, K. G., 1980, Naval Ship Production: A Claim Settled and A Framework Built, *Interfaces*, 10(6), December, 20-36.

de Geus, A.P., 1988, Planning as Learning, *Harvard Business Review*, March-April, 70-74.

Diehl, E., 1989, A Study on Human Control in Stock Adjustment Tasks, In Milling, P. and E. Zahn (eds), *Computer Based Management of Complex Systems*. Berlin: Springer Verlag, 205-212.

Dörner, D., 1989, Managing a simple ecological system, Working Paper, Lehrstuhl Psychologie II, University of Bamberg.

Dyer, W.G. Team Building: Issues and Alternatives, 2nd ed. (Reading, Mass: Wesley, 1987)

Eden, C., S. Jones, D. Sims, 1983, *Messing About in Problems*. Oxford: Pergamon Press.

Einhorn, H. and R. Hogarth, 1978, Confidence in judgment: Persistence of the illusion of validity, *Psychological Review*. 85, 395-476.

Forrester, J. W., 1961, *Industrial Dynamics*. Cambridge: MIT Press.

Forrester, J. W., 1971, Counterintuitive Behavior of Social Systems, *Technology Review*, 73, 3 (January), 52-68.

Graham, A., P. Senge, J. Sterman, and J. Morecroft, 1989. Computer-Based Case Studies in Management Education and Research. In Milling, P. and E. Zahn (eds), *Computer Based Management of Complex Systems*. Berlin: Springer Verlag, 317-326.

Hall, R. I., "A System Pathology of an Organization: The Rise and Fall of the Old Saturday Evening Post," *Administrative Science Quarterly*, 21 (1976), 185-211.

Hall, R. I., "The Natural Logic of Management Policy Making: Its Implications for the Survival of an Organization," *Management Science*, 30 (1984), 905-927.

Hall, R. I., 1989, A Training Game and Behavioral Decision Making research Tool: An alternative use of system dynamics simulation, in Milling, P. and E. Zahn (eds), *Computer Based Management of Complex Systems*. Berlin: Springer Verlag, 221-228.

Hays, R. H., S. C. Wheelwright, and K. B. Clark, 1988, *Dynamic Manufacturing: Creating the Learning Organization.* London: Free Press.

HealthCare Forum 1990, *The HealthCare Forum Journal*, 33(2), March/April 1990.

Hogarth, R., 1987, *Judgement and Choice. 2nd Edition.* Chichester: John Wiley.

Huber, P., 1987, Injury Litigation and Liability Insurance Dynamics, *Science*, 238 (2 Oct.) 31-36.

Kahneman, D., P. Slovic, and A. Tversky, *Judgment Under Uncertainty: Heuristics and Biases*, Cambridge University Press, Cambridge, 1982.

Katz, D. and R.L.Kahn, 1978, *The Social Psychology of Organizations*, New York: John Wiley.

Kim, D., 1989, Learning Laboratories, Designing Reflective Learning Environments, in Milling, P. and E. Zahn (eds), *Computer Based Management of Complex Systems.* Berlin: Springer Verlag.

Kleinmuntz, D., 1985, Cognitive Heuristics and feedback in a dynamic decision environment, *Management Science*, 31(6), 680-702.

Kluwe, R. H., C. Misiak, and H. Haider, 1989, Modelling the Process of Complex System Control, in Milling, P. and E. Zahn (eds), *Computer Based Management of Complex Systems.* Berlin: Springer Verlag, 335-342.

Levitt, B. and J. March, 1988, Organizational Learning, *Annual Review of Sociology*, 14, 319-340.

Lorange, P., M. Scott Morton, S. Ghoshal, 1986, *Strategic Control Systems.* St. Paul, Mn: West Publishing Company.

MacNeil-Lehrer Report, 1989, *Risky Business - Business Cycles*, Video, Public Broadcasting System, aired 23 October 1989.

Meadows, D. H., Whole Earth Models and Systems, *Co-Evolution Quarterly*, Summer 1982.

Meadows, D. L., 1989, Gaming to Implement System Dynamics Models, in Milling, P. and E. Zahn (eds), *Computer Based Management of Complex Systems.* Berlin: Springer Verlag, 635-640.

Milling, P. and E. Zahn (eds), 1989, *Computer Based Management of Complex Systems.* Berlin: Springer Verlag.

Moissis, A., 1989, Decision Making in the Insurance Industry: A Dynamic Simulation Model and Experimental Results, Unpublished S.M. Thesis, Sloan School of Management, MIT, Cambridge, MA 02139.

Morecroft, J., 1988, System Dynamics and Microworlds for Policymakers, *European Journal of Operational Research*, 35, 301-320.

Morecroft, J., 1982, A Critical Review of Diagramming Tools for Conceptualizing Feedback models, *Dynamica*, 8(I), 20-29.

Nyhart, D., 1988, Computer Modeling in Dispute Resolution – An Overview, *Dispute Resolution Forum.* April, 3-15.

Nyhart, D. and D. Samarasan, 1989, The Elements of Negotiation Management: Using Computers to Help Resolve Conflict, *Negotiation Journal.* 5(1), 43-62.

Orlikowski, W., 1988, Computer Technology in Organisations: Some Critical Notes, in Knights, D., & H. Willmott, *New Technology and the Labour Process*, London: The MacMillan Press, 20-49.

Paich, M. and J. Sterman, 1990, Riding the Rollercoaster: Dynamic Decision Making in Corporate Strategy, presented at the conference on Behavioral Decision-making Research in Management, The Wharton School, June 1-2.

Perrow, C., 1984, *Normal Accidents: Living With High Risk Technologies.* New York: Basic Books.

Richardson, G. P. and A. Pugh , 1981, *Introduction to System Dynamics Modeling With DYNAMO.* Cambridge: The MIT Press.

Richardson, G. P. and P. Senge, 1989, Corporate and Statewide Perspectives on the Liability Insurance Crisis, in Milling, P. and E. Zahn (eds), *Computer Based Management of Complex Systems.* Berlin: Springer Verlag, 442-457.

Richmond, B., 1987, *The Strategic Forum: From Vision to Operating Policies and Back Again,* High Performance Systems, 13 Dartmouth College Highway, Lyme, NH 03768.

Richmond, B., S. Peterson, P. Vescuso, 1987, *An Academic User's Guide to STELLA.* High Performance Systems, 13 Dartmouth College Highway, Lyme, NH 03768.

Roberts, E. B., 1978, *Managerial Applications of System Dynamics.* Cambridge: MIT Press.

Schein, E., 1969, *Process Consultation: Its Role in Organization Development.* Reading, Mass: Addison-Wesley.

Schein, E., 1987, *Process Consultation,* Volume II, Reading, Mass: Addison-Wesley.

Schein, E., 1985, Organizational Culture and Leadership, Jossey-Bass.

Schön, D., 1983a, Organizational Learning, in Morgan, G. (ed.), *Beyond Method.* London: Sage.

Schön, D., 1983b, *The Reflective Practitioner,* New York: Basic Books.

Senge, P., 1990a, *The Fifth Discipline: Mastering the Five Practices of the Learning Organization.* New York: Doubleday.

Senge, P., 1990b, Catalyzing systems thinking in Organizations, in F. Masaryk, *Advances in Organization Development.* Norwood, N.J.: Ablex.

Simon, H. A., 1979, Rational Decision-making in Business Organizations, *American Economic Review,* 69, 493-513.

Simon, H. A., 1982, *Models of Bounded Rationality.* Cambridge: The MIT Press.

Slovic, P. and S. Lichtenstein, 1983, "Preference Reversals: A Broader Perspective," *American Economic Review,* 73, 596-605.

Smith, V., Suchanek, G., and A. Williams, 1988, Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets, *Econometrica,* 56(5), 1119-1152.

Solomon, J., 1989, Now, Simulators for Piloting Companies, *Wall Street Journal.* 31 July, B1.

Stata, R., 1989, Organizational Learning -- the Key to Management Innovation, *Sloan Management Review,* 30, 3 (Spring), 63-74.

Sterman, J., 1989a. Misperceptions of Feedback in Dynamic Decision Making. *Organizational Behavior and Human Decision Processes.* 43(3), 301-335.

Sterman, J., 1989b. Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment. *Management Science.* 35(3), 321-339.

Sterman, J. D., 1988, *People Express Management Flight Simulator.* Software and Briefing Book. Available from author, Sloan School of Management, MIT, Cambridge MA 02139.

Wack, P. "Scenarios: Uncharted Waters Ahead," and "Scenarios: Shooting the Rapids," (two-part article) Harvard Business Review, Sept-Oct, and Nov-Dec, 1985.

Weick, K.E., 1979, *The Social Psychology of Organizing,* Reading, Ma: Addison- Wesley.

Weil, H., 1980, The Evolution of an Approach for Achieving Implemented Results from System Dynamics Models, in J. Randers (ed.), *Elements of the System Dynamics Method.* Cambridge: MIT Press.

Weizenbaum, J., 1976, *Computer Power and Human Reason: From Judgment to Calculation.* San Francisco: W. H. Freeman.