# Designing the Future

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**at**
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**December 15, 1998**

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Today I will discuss systems in technology and society. Everyone speaks of systems: computer systems, air traffic control systems, economic systems, and social systems. However, few people realize that systems exist everywhere. Systems influence everything we do. Systems create the puzzling difficulties that confront us every day.

Understanding physical systems is far more advanced than the understanding of social, corporate, governmental, and economic systems. The field of system dynamics is leading to the new profession of enterprise designer. Methods now exist for designing the structure and policies of human systems so that the systems will better serve the people within them.

## Physical Systems and Social Systems

People are reluctant to believe physical systems and human systems are of the same kind. Although social systems are more complex than physical systems, they belong to the same class of high-order, nonlinear, feedback systems as do physical systems.

The idea of a social system implies that relationships between its parts strongly influence human behavior. A social system strongly confines behavior of individual people. In other words, the concept of a system contradicts the belief that people are entirely free agents. Instead, people are substantially responsive to their changing surroundings.

To put the matter more bluntly, a social system implies that people act partly as cogs in a social and economic machine. People play their roles while driven by pressures from the whole system. Accepting the dominance of social systems over individuals is contrary to our cherished illusion that people freely make their own decisions,

The troubles created by systems are apparent in real life. Throughout the world, banks are failing, exchange rates are shifting, and governments are threatened. None of the participants planned nor wanted such consequences. The turbulence has arisen from unfortunate designs of social and financial systems. People try to cope with the failures of systems, but seldom attempt to redesign systems to reduce failure.

We do not live in a unidirectional world in which a problem leads to an action that leads to a solution. Instead, we live in an on-going circular environment. Each action is based on current conditions, such actions affect future conditions, and changed conditions become the basis for later action. There is no beginning or end to the process. Feedback loops interconnect people. Each person reacts to the echo of his past actions, as well as to the past actions of others.

## System Dynamics

For the last 30 years, I have been developing a field known as system dynamics. System dynamics combines theory, methods, and philosophy for analyzing the behavior of systems. System dynamics arose from seeking a better understanding of management. Applications have now expanded to environmental change, politics, economic behavior, medicine, engineering, and other fields. System dynamics shows how things change through time.

A system dynamics project starts from a problem to be solved or an undesirable behavior that is to be corrected or avoided. The first step taps the wealth of information that people possess in their heads. The mental databases are a rich source of information about a system. People know the structure of a system, and the policies that guide decisions. In the past, management research and the social sciences have unduly restricted themselves to measured data. They have neglected the far richer body of information existing in the experience of people in the working world.

System dynamics uses concepts from the field of feedback control to organize information into a computer simulation model. A computer acts out the roles of people in the real system. The resulting simulation reveals behavioral implications of the system represented by the model.

System dynamics shows how the feedback structure of an organization dominates human decision-making. By a feedback structure, I mean those circular processes where decisions cause changes that influence later decisions. All actions take place in such circular structures.

The system dynamics field now extends worldwide. Centers of university research exist in many countries. Here in Spain, the University of Sevilla is an important leader in system dynamics.

In early work, we discovered we were able to identify reasons for crises in a troubled company. The symptoms might appear as falling market share, fluctuating production, or declining profitability. Such serious difficulties are widely known to employees, the community, and the business press.

In examining a company, we use our background about how structure and policies determine behavior. We interview people about how they make decisions. Statements describing reasons for decisions are the policies governing action. A system dynamics model is a structure of interacting policies. Policies determine day-by-day decisions. As I use the term "policy," it represents all the reasons for action, not just formal written policy.

Such interviews are extensive and penetrating. There might be several sessions with each of many individuals. Discussions range widely from normal operations, to actions that would result from various kinds of crises. We examine the self-interest of individuals, and locations of influential power centers. Interviews ask what a person is doing to help solve the serious problems facing the company.

Talking to a manager can reveal clear rules controlling decisions. When we talk to a second manager about the first manager, the same policy picture emerges. People see their own decision-making behavior very much as others see them. People are consistent in describing operating policies throughout an organization. Furthermore, people justify their policies as helping to correct the difficulties that the company is experiencing.

During the interview process, the study follows the case-study approach. That is, a comprehensive examination establishes the context for the corporate problem. However, if left at the interview stage, the weakness of the case-study method prevents a reliable solution. Interviews lead to a descriptive model that is too complex for the human mind to solve reliably. For those of you who have studied mathematics through differential equations, such a descriptive model is equivalent to a high-order, nonlinear, differential equation. No scientist or mathematician can solve such a system mentally. Just as with the operation of a chemical plant, only computer simulation methods can reveal the behavior implicit in actions of the many interconnected decision-making individuals.

After describing important policies, information flows, and interconnections in a company, the next step is to translate that description into a computer model. Such a model allows a computer to act out the roles of each decision point in the system. The computer feeds decisions at each point to other connected decision points to become the basis for the next round of decisions. In other words, a laboratory replica of the company exists in the computer. One can then observe the interacting behavior of the policies that were described in the interviews. Remember that the interviewees justified their decision-making behavior as helping to reduce the corporate difficulties.

To the surprise of those unfamiliar with the devious nature of complex dynamic systems, a computer model usually generates the very difficulties that a company has been experiencing. In short, the policies established to solve a problem are actually the cause. Such a situation can create a serious downward spiral. If the policies being followed are believed to alleviate a problem, but, in hidden ways, are causing the problem, then, as the problem gets worse, pressures increase to apply still more strongly the very policies that are causing the problem.

Early in the development of system dynamics, we discovered surprising things about corporations that apply to all social systems:

- first, most difficulties arise from internal causes, although people usually blame troubles on outside forces.
- second, actions that people take, usually in the belief that the actions are a solution to difficulties, are often the cause of the problems being experienced,
- third, the very nature of the dynamic feedback structure of a social system tends to mislead people into taking ineffective and even counterproductive action,
- fourth, people have enough information about a system to permit successful modeling.

## Policies versus Decisions

I have referred to policies as the rules that govern decisions. We should emphasize the difference between policies and decisions.

Decisions are made moment by moment as time progresses. Decisions control present action. One can act only at the present time. One can not act yesterday or tomorrow.

By contrast, policies are the rules that determine the making of decisions. If one knows the policy governing a point in a system, one then knows what decision will result from any combination of information inputs. Unlike decisions, policies are timeless and enduring. If a policy is sufficiently comprehensive, it can continue to apply over an extended interval of time. Depending on the objectives of a model, policies might remain unchanged and effective as long as years, decades, or even centuries.

My present research on national economic behavior uses a model that illustrates the use of policies that apply over a long time span. The model has no exogenous time series to drive behavior. All behaviors come from internal interactions within the model. The model exhibits the several important kinds of economic behavior that have occurred in real economies. Policies in the model remain fixed for 200 years, from 1800 to 2000. Even so, the fixed policies generate decisions that create behavior ranging from business cycles through stagnation, inflation, deflation, and the economic long wave, also known as the Kondratieff cycle.

System dynamics is most useful for understanding how policies affect behavior. Emphasis should be on designing policies that will yield systems with more favorable behavior. One builds a simulation model from policies that in turn make decisions. The model generates streams of decisions controlled by policies built into the model. The policies make all the decisions step-by-step in time as the simulation unfolds. Then, if the resulting behavior is undesirable, one searches for a better set of policies that yield improved results.

However, in the system dynamics field, many people are now using models in a less effective manner. Instead of using models for designing policies, models have often become business games in an effort to train people in decision-making rather than in policy design. In business-game usage, some feedback loops in a model are broken and people are inserted to replace a policy that would otherwise have existed in the model. People then use their own intuitive mental policies to make decisions as a simulation moves through time. In a business game, policies become obscure. A business game hides the reasons for system behavior. Even worse, people learn very little from business games that they can carry over to real life. In fact, playing a business game often does not improve performance even in following sessions of the same business game.

Many consulting companies are using business games. Games connect quickly with clients. Games achieve immediate emotional involvement. Games give the illusion of learning. But games fall far short of yielding the deep insights that are needed for the design of social systems.

## Designing Social Systems

People think very differently about engineering systems compared to social systems. We expect technicians to design engineering systems using advanced methods of dynamic analysis and computer modeling. In designing an engineering system, such as a chemical plant, engineers realize that dynamic behavior is complicated. Engineers would make extensive studies using computer models to simulate behavior before construction. If the chemical plant were of a new type, a small pilot plant would test the design before building the full-size plant.

Although social systems are far more complex than engineering systems, design of social systems has employed methods much weaker than the methods used for technical systems. Managers and politicians have limited themselves to intuition and debate in designing corporations and countries. Corporations and governments change designs without using powerful system-design methodologies that have evolved over the last 50 years.

People may dislike the idea of "designing" social systems. Designing social systems may seem mechanistic or authoritarian. However, all social systems have been designed. Corporate policies, computer systems, organization charts, and laws constitute partial designs of social systems. Governments pass laws after superficial debate. Laws redesign political and economic systems. Such redesigns are experiments using a country as a laboratory. The experiments include no dynamic modeling of the long-term effects. Changes in corporate policies receive even less analysis. For example, the recent wave of corporate mergers and the reduction of trade barriers constitute a major redesign of the world economy without adequate consideration for the results. People have designed the systems within which they live. The shortcomings of those systems result from defective design, just as the shortcomings of a power plant result from erroneous design.

When we were in Sevilla in 1986 for the international system dynamics conference, my wife and I toured the Alhambra, those great castles built 700 years ago by the Moors on the mountain above Grenada. At one point, our guide identified the room in which Moorish leaders met to discuss their difficulties with inflation and the unfavorable balance of trade. That sounds like today's business headlines. Seven hundred years have produced little advancement in controlling economic behavior.

Consider the contrast between advances during the last century in understanding technology, and the relative lack of progress in understanding social systems. What explains such a difference? Why has technology advanced so rapidly while social systems remain as puzzling as ever? The answer lies in failing to recognize that social institutions are indeed systems. People do not accept the idea that families, corporations, and governments belong to the same class of dynamic structures as do chemical refineries and autopilots for aircraft.

Organizations built by committee and intuition perform no better than would an airplane built by the same methods. Often venture capital groups finance new enterprises in which policies, products, and markets are chosen in such a way that they predetermine failure. As in a bad airplane design, which no pilot can fly successfully, such badly designed corporations lie beyond the ability of real-life managers.

I first glimpsed the possibilities of enterprise design in the 1960s when on the board of directors of a rapidly growing high-tech company. To guide my recommendations, I constructed a system dynamics model of how high-technology companies evolve. The model contained 250 variables. These included 60 stocks, or integrations, so the model was a 60th-order dynamic system. The variables included physical processes, managerial goals, leadership characteristics, and interactions among company, market, and competitors. The model exhibited the full range of typical new-company behaviors. Depending on assigned policies, the model showed either early failure, or limited growth followed by stagnation, or sustained growth with repeated major crises, or untroubled growth. The differences in corporate evolution shown by the model matched those in companies having the corresponding policies. From the model came policies that contributed to unusual success.

## A New Kind of Management Education

Several decades of progress in system dynamics point to a new kind of management education. Such a future education will train a new kind of manager for the future. I anticipate future management schools devoted to "enterprise design." Such business schools would train "enterprise designers."

A fundamental difference exists between an enterprise operator and an enterprise designer. To illustrate, consider the two most important people in successful operation of an airplane. One is the airplane designer and the other is the airplane pilot. The designer creates an airplane that ordinary pilots can fly successfully. Is not the usual manager more a pilot than a designer? A manager runs an organization, just as a pilot runs an airplane. Success of a pilot depends on an aircraft designer who created a successful airplane. On the other hand, who designed the corporation that a manager runs? Almost never has anyone intentionally and thoughtfully designed an organization to achieve planned growth and stability.

Education, in present management schools, trains operators of corporations. There is almost no attention to designing corporations. Corporate successes and failures seldom arise from functional specialties alone. Corporate performance grows out of the interactions among functional specialties. Present day management education fails to convey the importance of how parts of a business interact with one another and with the outside world. In the future, we must deal with the way policies determine the future of an organization.

Enterprise design will build on four major innovations that have occurred during the past century:

- first, beginning around 1910, the Harvard Business School pioneered the case-study method of management education,
- second, in the 1930s and 1940s, the Bell Telephone Laboratories and MIT developed theory and concepts related to dynamic behavior of feedback systems,
- third, after World War II, MIT, Carnegie and others focused on a more quantitative, mathematical, and research-based approach to management education,
- fourth, during the last forty years, system dynamics has demonstrated the way to combine both numerical and descriptive information into models that permit simulation of systems that are too complex for mathematical analysis.

The first innovation, the case method of management education, has achieved a wide following. Case studies address the problems of general management and the interactions among parts of the corporate-market-competitor system. Case studies draw strength from using descriptive information and managerial knowledge from the working world. However, the case method, has a major weakness. Description of a case captures policies and relationships within a system that is too complex for intuitive understanding. Case studies often draw the wrong dynamic conclusions. They fail to reveal why corporations in apparently similar situations can behave so differently.

The second innovation, the understanding of feedback systems, now reaches beyond engineering to become also an organizing concept for human systems. Feedback processes govern all growth, fluctuation, and decay and are the fundamental basis for all change. The feedback viewpoint reveals new insights into managerial and economic systems that have escaped past descriptive and statistical analysis.

The third innovation, the quantitative approach to management education, has brought a more disciplined analysis of corporations. However, the past quantitative approaches have failed to address the major challenges faced by top corporate management. Early quantitative methods were limited to linear mathematical analysis, and stressed optimum solutions rather than realistic practical answers. They dealt with separate functional specialties of business. They did not establish adequate linkages to the mental database used by practicing managers. Traditional quantitative methods have not incorporated the feedback structure surrounding decision-making. Nevertheless, the idea of a quantitative approach to management opened the door to more powerful methodologies that are now emerging.

The fourth innovation, system dynamics, now allows going beyond case studies and descriptive theories. System dynamics is not restricted to linear systems; it can make full use of nonlinear features of systems. Most real-life dynamic behavior depends on nonlinearities in systems. System dynamics models, combined with desktop computers, allow efficient simulation of complex systems. Such simulation is the only way to determine behavior in complicated nonlinear systems.

Bringing these four innovations together permits a major breakthrough in management education. The combination will go far beyond the case-study method of management education. System dynamics adds a rigorous dynamic framework for organizing the rich policy and structural knowledge possessed by managers.

The difference between present management schools and those in the future will be as great as the difference between a trade school that trains airplane pilots and a university engineering department that trains aircraft designers. Pilots will continue to be needed. So also, operating managers will be needed. However, just as successful aircraft are possible only through skilled designers, so in the future will successful corporations, countries and social systems be possible through enterprise designers.

Enterprise designers will be able to reduce the number of mistakes in the structure and policies of social institutions. Correct design can make a corporation less vulnerable. Design can distinguish between a corporation that is vulnerable to changes in the outside business environment and one having a high degree of independence from outside forces. Correct design can improve the stability of employment and production. Correct design, by balancing policies for pricing, capital plant acquisition, and sales force, can make the difference between growth burdened by debt and growth out of earnings. Correct design can avoid the adoption of policies offering short-term advantage at the expense of long-term failure. Correct design can prevent expenditure of managerial time in debating policies that have low leverage and are therefore unimportant. Correct design can help identify the very small number of high-leverage policies capable of yielding desirable change.

Future training in enterprise design will include study of a library of models of generic management situations. Generic models are those that apply in many different settings; they can be moved from one industry to another, and backward and forward in time. Each model would combine descriptive case studies with dynamic simulations applicable to a variety of businesses. I estimate that about 20 such general, transferable, computerized cases would cover 90 percent of the situations that managers ordinarily encounter.

Several powerful examples of generic models already exist:

- stability and fluctuation in distribution systems,
- pricing and capital investment as they determine growth,
- promotion chains showing evolution into a top-heavy distribution of management personnel when growth slows,
- Imbalances between design, production, marketing, and service as they influence market share.

Each such model manifests many modes of behavior ranging from troublesome to successful depending on the policies employed within it.

## The Profession of Social System Design

Social-system design will become a recognized profession. It will require the same kind of intensive education that is necessary in other professions. Only fragments of a system-designer education now exist. Teaching materials are available for no more than a two-year sequence in system dynamics. Many academic levels now teach system dynamics—in precollege schools, in undergraduate programs, and in graduate schools. However, the different educational levels all start with students as beginners. The programs are not cumulative. Education in the behavior of social systems is now at about the same point of development as was education in medicine and engineering a hundred years ago.

Social system design presents a major challenge to the educational establishment. Precollege schools from kindergarten through age seventeen are now pioneering the use of system dynamics as a foundation under most subjects. Teachers and students are building simulation models of environmental, family, city, and political systems. English teachers are experimenting with simulation of plots in literature. Students are fascinated with the insights gained by modeling psychological dynamics as in Shakespeare's "Hamlet."

After observing progress in learning about systems in kindergarten through high school, many of us believe that everything now known in the field of system dynamics can be learned by age 14. If all that we now know about systems can be learned before high school, we lack material for the four years of high school, and the four years of undergraduate education, and three years of graduate study. We must create at least eleven years more of educational materials before we can claim to have a curriculum for training social-system designers.

During the past century, the frontier of human advancement has been the exploration of science and technology. Science and technology are no longer frontiers, they have receded into the fabric of everyday activity. I believe that we are now embarking on the next great frontier, which will lead to a far better understanding of social and economic systems.