# THE SYSTEMS PERSPECTIVE: METHODS AND MODELS FOR THE FUTURE

by

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## **CONTENTS**

## **ACKNOWLEDGMENTS**

## I INTRODUCTION

A Brief History The Field Today

## II FOCUSING ON THE SYSTEM AS A PURPOSEFUL WHOLE

Time and Motion

Probability

Complexity and Variety

## III DESIGNING AND BUILDING MODELS

Establishing a Purpose Defining The System

Data Gathering and Illustration

Testing and Revision

# IV STRENGTHS AND WEAKNESSES OF THE SYSTEMS APPROACH

A Situational Example

A Reductionist Model

Outlook for the Systems Approach

Some Specific Models

**Interactive Planning** 

How To Do It

When to Use Interactive

Planning

Comparison/Combination with

Other Models

Outlook for the Future

Living Systems Theory

How To Do It

When To Use It

Comparison/Combination with

Other Models

Outlook for the Future

**Operations Research** 

How To Do It

When To Use It

Comparison/Combination With

Other Models

Outlook for the Future

Socio-Technical Systems

How To Do It

When To Use It

Comparison/Combination with

Other Models

Outlook for the Future

Soft Systems Methodology

How To Do It

When To Use It

Comparison/Combination with

Other Models

Outlook for the Future

System Dynamics

How To Do It

When To Use It

Comparison/Combination with

Other Models

Outlook for the Future

**Total Quality Management** 

How To Do It

When To Use It

Comparison/Combination with

Other Models

Outlook for the Future

The Viable Systems Model

How To Do It

When To Use It

Comparison/Combination with

Other Models

Outlook for the Future

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#### I INTRODUCTION

This paper introduces a general perspective based on "systems" and specific tools and models that may be applied to messy problems in management, decision making, and resource allocation. Situations characterized by rapid change, multiple interests, limited resources, and high complexity are good candidates for a "systems approach"; indeed, that approach may be the only one with a chance of long-term success. Adapting a systems approach means putting the emphasis on "the big picture" or the whole and considering the functions of a system's parts based on their relations with one another and within the system's larger context. This approach has gone by different names at different times and places: systems thinking, general systems research, cybernetics, management science, operational research, decision science, and praxiology, to name a few. All share the concept of a multi-disciplinary approach to defining and solving complex, high-variety, dynamic, continuous, and interactive problems.

The systems approach is properly linked with the future, because it does not dominate either present practice or specialist education. The dominant problem-solving methodology has been the reductionist method. That method considers first the elements in isolation and then in combination one by one. Reductionism has been used to obtain many of the advances in science and technology currently enjoyed. It is an effective tool where problem definitions are shared and goals are clear. Today, fewer and fewer of our stubborn problems meet these criteria. Common sense suggests that evidence of an intractable or recurring problem is an indication that a completely new perspective on the situation is needed.

Comparison between the Reductionist and Systems Methods:

| Reductionist Approach       | Systems Approach                                |
|-----------------------------|---|
| Focuses on parts            | Focuses on wholes                               |
| Linear causality A causes B | Circular causality A causes B causes C causes A |
| Observer status objective   | Observer status subjective                      |
| Context not very relevant   | Context highly relevant                         |
| One 'truth' or best answer  | Multiple truths and answers                     |
| Externalities not important | Externalities important                         |
| Problems solved             | Problems dissolved                              |

The Systems Perspective

The systems approach is a different way of dealing with the planning and direction of action that emphasizes process. The systems approach is both very old and very new. Pre-industrial societies did not have technology to dominate nature nor the infrastructure to define a situation mechanically and organize human effort to manipulate it. They had to use their understanding of how nature and society worked as an applied methodology to survive and prosper. Indeed, Norbert Wiener's word for this new approach was cybernetics, which is taken from the Greek word for the steersman who guides a boat to its chosen destination without needing either complete understanding of the movements of wind and current or the force to be able to override them. This knowledge of systems, based on craft and experience, worked well and still works well in many settings. Such knowledge is conveyed through mythology, storytelling, and apprenticeship, although not usually codified.

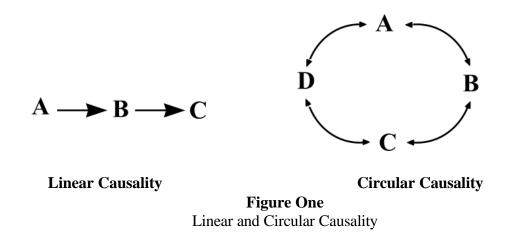
## **A Brief History**

About 200 years ago, people began applying their understanding of how dynamic systems work to regulate machines. For example, design instructions for the Jacquard Loom were translated for the weaving machine using punched cards. James Watt's steam governor regulated the speed of engine combustion by varying its supply of oxygen. As the engine speeded up (threatening to go out of control), centrifugal force propelled four whirling balls up into the tubes that carried air to the engine. This diversion reduced the oxygen available for combustion and brought the speed back under control.

Around the same time, Claude Bernard, a French physician, began drawing the attention of medical practitioners to the role of steady states in the body's fluid matrix-the milieu interior-which enables the body to adjust rapidly to changes in external conditions, like temperature or exertion. Finally, students of logic and mathematics began to turn their attention to undecidable propositions where certainty could not be established. Thus, the development of probability and statistics has had a profound effect on modern society from agriculture to physics.

The systems field began in earnest during the World War II. Britain and the United States brought interdisciplinary teams of scientists together to apply new discoveries in science and mathematics to defense. These cybernetic groups of scientists from diverse backgrounds found that they all had ways of discussing the dynamics of regulation. Feedback, the behavior of self-organization and chains of circular causality (e.g., A causes B causes C causes D causes A causes B...), appeared again and again in the basic processes they described. After the war, many of these researchers began to communicate with colleagues following parallel tracks in biology and psychology. Their communication and collaboration was facilitated by a series of conferences sponsored by the Josiah Macy Jr. Foundation. Gradually, books were published, conferences and

journals were organized, and associations were formed in both North America and Europe to explore the potential of these new insights and tools.



## The Field Today

Current work in systems draws from many roots in traditional disciplines. From work in mathematics comes techniques for application to problems of uncertainty and complexity. From biology comes descriptions of the processes leading to survival, adaptation, and growth. From neurophysiology comes an understanding of how the brain processes perceptions and creates patterns. From physics comes further understanding of uncertainty, relativity, and complementarity. From communication theory comes a deeper understanding of communications channels and the difference between information and noise. Psychology and the social sciences contribute understanding about how people behave in families, organizations, and societies. Together, these disciplines provide models that are well understood and may be generalized and applied to vastly different situations as long as their common dynamics can be identified and tested. Related developments in the computer field provide computational capability far beyond that which could be performed by hand and make extensive use of quantifiable models feasible. In a different area, systems insights have also been applied to creative arts.

A systemic view of the world is growing in popular understanding as a result of the interconnections and the speed of communications. Awareness of environmental threats has also increased substantially over the past 30 years. Many examples of consequences that affect the planet as a whole, like the shrinking of the ozone layer or the effects of pollution, have become manifest far from their

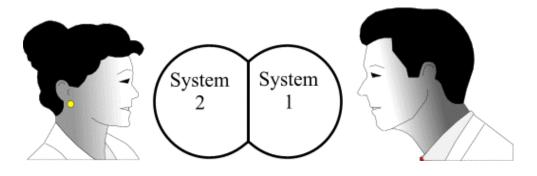
point of origin. In social and economic spheres, the effects of progress in national development, structural change in employment patterns, and implications of the global marketplace extend far beyond the ability of any one country to manage its economy in isolation.

Although the systems field has retained its interdisciplinary focus and flavor, the range of methods and tools has proliferated; consequently, current researchers and practitioners often specialize in classes of problems or areas of concern. This paper discusses primarily those theories and tools that apply to the management of human affairs, although several also explore harmony with the natural environment.

## II FOCUSING ON THE SYSTEM AS A PURPOSEFUL WHOLE

The first step in a systems approach is often backward. "Forgetting" a great deal of what you "know" is necessary in order to take a fresh look. The identification of a system begins with its designation by an observer. While a system may be defined as "an entity made up of interacting parts operating in an environment," that definition is just a beginning. A system does not exist until it has been specified by an observer who defines this system and establishes its boundaries according to some purpose or set of criteria. Another observer, needless to say, would have different specifications and might make different choices based on other purposes. In some situations, such as politics, factions may look at the "same" situation according to disparate loyalties, values, and ideological models and come up with opposing pictures or barely overlapping. Management and workers, farmers and herders, armies and citizens, and buyers and sellers are among the groups that may see a different picture from the one their counterparts see. Even within a business organization, the sales, production, accounting, and human resources departments will have different views based on their part of the whole system. People may not even see eye to eye on what counts as outside and inside the organization. Where they perceive this boundary depends on functions they perform and the extent of contact they have within their environment of constituents, customers, suppliers, and services.

**Figure Two**Two Observers of Differing Systems

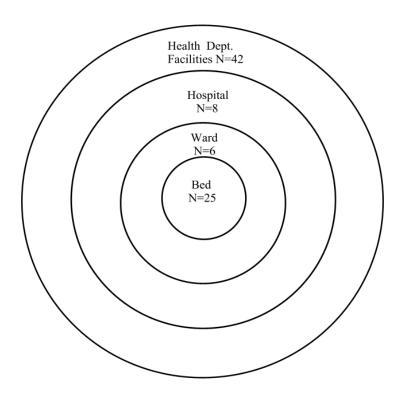


The Systems Perspective

The systems approach regards everything as ultimately connected to everything else. Nevertheless, boundaries of concern are possible to establish and to designate for the most relevant relationships. Specifically, most systems tend to be nested within larger systems and to contain smaller systems within them, like a set of Russian dolls. This hierarchy is not necessarily one of authority, but may be one of logic or completeness. This phenomenon is known as recursion, because many of the functions and relationships recur at each level.

Figure Three

Recursion in a Nested Hierarchy
...which replicates identity, professional standards, record-keeping protocols, *etc.*, throughout the system



The conclusions drawn at one level may be quite different from those drawn at the next; they may both be right within the parameters of the measures selected. The systems approach is characterized by the recognition that the most favorable outcome for the whole system is not achieved by each subsystem selecting its best option-but by coordinating their activities.

One of the most helpful insights provided by the systems approach is an appreciation of the differences introduced by a change of scale in time or space. Sometimes small or incremental changes

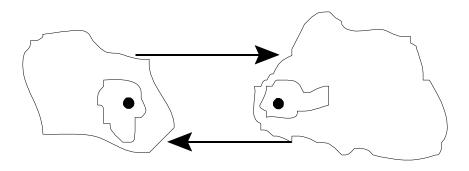
The Systems Perspective

may be indistinguishable from chance variations until they are seen from a broader perspective or a cross a threshold. In other situations, a delay or time lag may occur between the action and its consequence. In the spacial realm, phenomena that are either very large or very small are likely to escape notice. The impact of a change that is barely noticed in a city may hit a village like an earthquake. Sometimes, it is necessary to distinguish whether a condition applies to an individual only as an individual or whether it applies to every member of a set: "Southland" may have a 65 percent literacy rate, but each citizen is either literate or not. When a system has multiple purposes or when its purpose is not commonly understood, conscious efforts may be needed to identify issues of scale.

Let's say we have agreed on a purpose and identified our system. We have cast our net widely to make sure that the full range of relevant elements and stakeholders are included and all the important dynamics are considered. What can we expect to see?

Our system will have a number of relationships exchanging matter, energy, or information within its environment. These exchanges enable the system to continue existing-and, in terms of systems with components that are alive-to remain viable. In order to survive, the system must have the means to keep all its essential variables within their physiological limits. Most systems have numerous processes to do this, which maintain their variables at a steady state or within an acceptable range. The name for these processes is homeostasis. Individuals maintain constant levels of body temperature (thermostasis, hence thermostat), blood sugar, alkali reserve, and so on. Communities and organizations seek population growth to maintain numbers, positive cash flow to maintain purchasing power, and trade to exchange their goods for those they cannot or do not wish to make. If one of these variables goes out of its safe range and does not return, the health and probably the survival of the system is at risk.

Figure Four Homeostas



The two points balance one other, so that both remain inside the smaller field, which satisfies its essential variables.

#### **Time and Motion**

Systems, even abstract systems, exist in time. Over a period of time, all systems change; their environments change; and the relations between them change. Some of these changes are predictable within statistics and probability, if one can gain enough information about the pattern of the cycle and its time scale. An animal will be born, grow to maturity, perhaps reproduce, decline, and die. Its time scale may range from a few weeks to a hundred years. A colony of animals is subject to the same sort of cycle, except that it may renew itself through new births or through innovation and reinvention. The cycle affecting a factory that produces fashionable clothing is measured in seasons; a factory producing tractors, in years; and of a professional school at a university, in decades. Probabilistic models must perceive and integrate different time scales present in the larger systems they address.

Other changes are less predictable. Stress on an individual or a collective may increase incrementally over time, until the last increment takes it over the edge to collapse. Hypothermia and losing one's temper are examples of this phenomenon at the individual level. At the collective level, examples may be seen in a sudden disappearance of fish stocks after a prolonged period of overfishing

or the breakdown of civil order after a number of instances of conflict in a community. "The straw that broke the camel's back" is a colloquial expression of this phenomenon. Bifurcation, chaos theory, and catastrophe theory are technical terms that describe the behavior of systems operating far from their points of equilibrium that may undergo a sudden and (usually) irreversible change of state. Not every change of state, of course, is unwelcome. Another increment of speed for an aircraft allows it to take off; while another person in a group may give it the critical mass to be more effective.

Nevertheless, organizational systems that are subjected to unanticipated change, multiple simultaneous changes, or accelerated rates of change may be far more vulnerable than if changes were anticipated or they occurred one at a time. For an individual, even a little bit of notice of an oncoming change may mean the difference between being overwhelmed or having an exhilarating but controlled ride. Organizations and cultures exhibit similar patterns. They handle change more effectively when it is anticipated; e.g., the babies born today will need schooling in five years and jobs, housing, and health services in turn. They are usually less effective in dealing with simultaneous change or with sudden impacts of change that reverberate throughout the society.

#### **Probability**

Many of us gain our first experience with probability by flipping a coin. Although we expect that it will come up heads half the time and tails half the time, no toss is influenced by the one before it; the probability of heads at each toss is fifty-fifty. As we consider more complex situations, some probabilities are influenced by previous events or by expectations. These predictions range from near certainty (the sun will come up tomorrow) to far from certain (our shop will be busiest on Thursday). Even if we know something about the pattern (20 percent of our customers return within six months or we expect 140 days of rain each year), we have no advance knowledge of which particular pattern will appear. Such patterns characterize probabilistic systems. In contrast, mechanical systems perform with near certain predictability, at least over the short term. They are considered deterministic. Most of the complex systems we are concerned about can never be fully predictable. They are subject to many, sometimes quite small, chance variations that may significantly alter the conditions affecting their essential variables. Over longer time periods, even the performance of machines becomes unpredictable; some will break down, while others will run without problems throughout their expected life.

A number of quantitative techniques have been developed to describe and infer patterns in observed behavior, to predict resource requirements under different conditions, or to signal a changing trend expressed as a change of state or slope in a time series. Control techniques in statistical process are used to improve the quality of manufactured goods by improving inspection techniques and indicating where redesign of a process might eliminate defects. In larger systems, which must be integrated to achieve optimum performance, operations research teams use techniques, such as queuing theory and linear programming, to build mathematical models that show where

improvements could be made. Statistical inference and dynamic models may also be constructed to test alternative scenarios of the future. What if energy conservation increases by so much? Given current trends and relationships, will ten, five, or no new hydroelectric plants be needed?

## **Complexity and Variety**

Complexity is a given when multiple factors, multiple actors, and multiple perspectives on a situation exist. Their relationships are not possible to compute exactly, so what is possible? Cybernetician Ross Ashby used the term "variety" to indicate the number of distinguishable elements in a set. He made a powerful suggestion: "Only variety," he said, "can absorb variety." Systems tend to organize themselves and to make more rather than fewer distinctions as they adapt to their environments. Successful systems deploy requisite variety to match the complexity their environments generate.

In any given system, the measure of variety has to do with the number of constraints or degrees of freedom, which, in turn, depend on the purpose of the system and the perspective of the observer. Is the observer a pollster in the run-up to an election, for instance? Then the variety might be the breakdown of preferences between several announced candidates and the undecided voters. Or, it might be the variety of preferences linked with demographics, the tendency to vote, or special issues. Decisionmakers often have to choose before they have sufficient opportunity to consider options carefully. If they deliberately shrink or attenuate the variety taken into account, they will be less likely to have their choices constrained by ignorance or overwhelmed by data.

A simple formula for determining the variety of the states of a system is to take all possible states of a system, n, and multiply them by n-1. [n(n-1)] Even a quite simple system, like an electric light, will have a high variety. It may be on or off (v=2); but, if it is off, it may be off for a number of reasons (v=6). It may be more or less bright (v=7), one of a number of different styles (v=50), colors (v=18), etc. For any given purpose, of course, not all the states or relationships are significant. By being selective about the information evaluated or by considering only practical alternatives in a given time period, decisionmakers can usually reduce the variety of their choices to a manageable number.

#### III DESIGNING AND BUILDING MODELS

Although people are not always conscious of doing so, they have been building mental models since they were babies. They learn what behavior will lead to being fed, played with, or comforted from the feedback or response they receive. As they grow up, they learn the interaction patterns of their families, their schools, and their communities. They construct a version of reality based on their own experiences and experiment with extending it. Generalizing from these experiences is not a big jump

to the conscious design of tools to investigate and test what results might be achieved from different investments of time, skill, or money or from trying out different perspectives on a situation.

The variety or complexity of a system does not necessarily have to be handled all at once. The selection of a purpose goes a long way to eliminating many factors from consideration. The use of modeling is itself a selection process that chooses only some aspects of a situation to examine closely. It enables the observers of a system to test out potential desirable or undesirable futures at considerably less time and expense than making direct experiments.

Models explicitly select certain features of a situation (but not others) and replicate them for evaluation. This selection happens informally when people use language to describe their experiences and fit them into patterns, but they can also be rigorous. Systems models often begin quite informally with a "what if" question, a sketch on the back of an envelope, or a metaphor. If that is helpful, the modeling can become more specific and information gathered for more accuracy. Models may be physical, like cardboard renditions of a stage set; they may be drawings or blueprints, abstractions, pure logic, or mathematics. The important factor is that the model makers select the features that are important, replicate them, and see how well they work.

## **Establishing a Purpose**

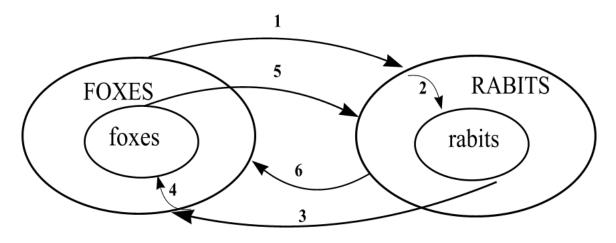
Deciding on the purpose may seem like the easiest part of building a model, but that is often not the case. Even if the modeler has no wishes but his or her own to consider (such as how shall I furnish my office), a number of questions will need to be answered, beginning with "will my needs be the same for as long as I work here?" If the answer is yes, the planning may still require some hard thinking and trade-offs, because usually only this much space or that much money is available. If the answer is maybe or no, a broad enough definition or a minimum range of flexibility must be established before the purpose can be explicit. Whether the purpose is being determined by an individual or a group, values are implicit and the consideration of options may lead to questioning the assumptions.

Most models of situations, though, have many people's wishes to take into account. Commitment and cooperation in an organization is easy to lose if everyone doesn't feel ownership in decisions. At best, huge opportunity costs are easy to incur if participation is limited. At worst, people offer resistance or simply abandon the situation. Ideally, the people affected should be offered the opportunity to participate in determining the purpose(s) of the system. If this is not possible, representatives of all major interests should have the opportunity to make their views heard. Several of the models briefly described in the second section of the paper explicitly address the question of purpose and the importance of participation.

#### **Defining the System**

Once the purpose is established, the observer may define the system and its boundaries. If the system under consideration is in nature or not able to be modeled, an influence or causal loop diagram may be the best way to begin. The major factors are written on a sheet of paper and arrows drawn to indicate the major processes and patterns of influence. Sometimes, this stage may reveal fluctuations around an equilibrium point or thresholds where the situation changes significantly.

The predator/prey models are of this type. The predator eats the prey and its population increases. Increased numbers of predators eat most of the prey, deplete their food supply, and subsequently their numbers. Fewer predators allow the prey to flourish and increase; whereupon, there would be more to eat for the remaining predators and their ascendancy would begin again.



**Figure Five**Predator/Prey Loop

No natural system is this simple; the food supply of the prey varies, predators eat more than one kind of prey, humans may intervene, and so on. Nevertheless, the basic dyadic relationship (such as predators and prey, or customers and producers) is often a helpful beginning until a limit of difficulty or relevance is reached.

Is the system under consideration one that the modelers may influence or even construct? In which case, the model will be selected to show structure, communications patterns, relationships, and flow of resources. At this stage, complete agreement about the definition of the system and its boundaries is not necessary; it is only necessary to have enough shared understanding to begin outlining the situation and the choices to be made. Several other models, described later, speak to this condition.

## **Data Gathering and Illustration**

Once the model of the system is built, it must be tested to see if it usefully predicts the behavior of the system or tests its alternative scenarios. At this stage, quantification is probably introduced. Even if exact numbers are unobtainable, models that show relative size, relative movement, and relative direction may still be helpful. In the absence of full quantification, threshold values or proxy measures that trigger responses may also be established. Examples are the water level of a river, changes in the rate of absenteeism, or an increase in the use of a facility. Tell-tale, indirect, or seemingly remote effects, which are strongly correlated with the events being modeled, may also be noted and monitored.

In large scale models, a focus on parts of the model will probably be necessary to elucidate in greater detail. Games and simulations may be useful here as well as surveys, operations research techniques, and experiments designed to answer specific questions.

## **Testing and Revision**

No model can be designed to run once and for all. It should be revised and redesigned on the basis of what is proven by the tests to be effective. The model should be adjusted to take into account whatever changes are occurring in its environments, whether natural, political, or economic. Parts of the larger model may work very well and others not work at all when tested. Suspicion of both is a good idea. A model that works well may be working too well and confirming its own prejudices or picking up obvious but spurious data. One that is quiet or looks like so much noise may be masking important variables that are canceling each other out.

Building redundancy into the model is always a good idea, such as having several independent tests or probes touching on some of the same features. If results are inconsistent, it's time to look again and review the tests.

Although systems thinking and building models are, to some extent, innate abilities, they require practice to develop skill. The better one has learned to work within a reductionist model of the world, however, the more difficult seeing the whole may be rather than its parts. In logic, one proceeds from the part to the whole by induction or analysis. Shifting to deduction and synthesis may seem as unfamiliar as throwing a ball with one's unaccustomed hand.

## IV STRENGTHS AND WEAKNESSES OF THE SYSTEMS APPROACH

The systems approach is strong when the "big picture" or enough of the picture can be modeled as a viable whole. To be fully effective, enough data must be gathered over enough time to match the variety of the situation. Some models may show results sooner than others. System Dynamics especially, with its computer programs, can yield helpful results in a matter of weeks, although longer periods are recommended. Other models, such as the Viable System Model or Interactive Planning, may be helpful in providing a new viewpoint to a small group in a short period of time, but months are required to involve enough people adequately to gain the full benefit. Constraints that apply to a situation may proscribe the use of some models or suggest the use of others.

The strength or weakness of the systems approach, or any of the particular systems models described, depends on the fit between the model and the situation. Several caveats apply to where and how they are used.

The modeler must have a broad enough mandate to consider all relevant aspects. The results of an economic model may not be useful if only private industry is included, or those of a health model if threats to sanitation are omitted.

One risk with quantitative models is putting figures into a computer and getting answers that look better than they are. Equations or programs may yield unreliable results despite being precise and elegantly presented. This result occurs when the model is quantified too soon. More time is helpful with the qualitative models to take care and ask the right questions. Multiple models and independent tests that use different measures and different data also guard against elegant but spurious answers.

Not to see the forest for the trees or not to see the trees for the forest are both possible. In such cases, the scale of the model was wrong, the boundary conditions were wrong, or the parameters were insufficient.

Another type of error occurs sometimes when using models that cover more than one level of recursion. Assigning a process or a function to a level of recursion above or below its proper one, or not noticing that a single manager has roles at multiple levels that may sometimes be in conflict, are both especially easy errors to make when diagnosing large organizations.

Everyone agrees about simple situations. They need, at most, an operational research model to indicate an optimum strategy for achieving the desired results. Many situations, even complicated ones, are essentially deterministic. The mechanical, reductionist methods are the most effective for these situations and should be used. However, be wary of making this judgment too early. A whole

systems view of the broader picture may be necessary to ensure that the design of the part is properly aligned with the needs of whole.

Finally, using a systems approach is likely to involve a slower start and more detours, especially in a large group setting, than having an expert decides what is needed and goes about providing it. A system approach involves hammering out a common understanding in what may be a messy and emotional series of discussions. If an organization or community does not have much experience with participatory methods, a slower process may ensue. Such methods typically take longer to reach a decision. Once a decision has been reached, however, the implementation usually proceeds more smoothly and encounters less resistance.

## A Situational Example

Let's consider building a bridge using a systems approach. We would begin by asking some basic questions:

- What pattern of events could we expect to see if a bridge were built here?
- What pattern of events could we expect to see if the bridge were built somewhere else, or not built at all?

These general questions would be followed by more specific ones.

- Who needs the bridge now?
- What do they need it for?
- What services or facilities would a bridge replace?
- Would it completely replace them?
- How would it affect the current transportation network?
- Who would use the bridge in the future?
- How would they use it?
- What services and facilities would emerge with the bridge?
- What would be the impact of the bridge and its traffic on the natural environment?

- Who needs to be consulted about the type and location of the bridge?
- How much will it cost? Is this the best allocation of resources?
- What impact will it have on the local and regional economy?
- Are there security considerations?
- Special weather conditions?
- Is the bridge located on a national boundary?
- Would provision need to be made for customs?

If the preliminary discussions of these questions indicate taking the next steps, groups of stakeholders can be assembled to explore particulars of specifications, resources, politics, and so on. They may have recourse to models from a number of different areas. They might use physical models of the region and various types of bridges to determine the most appropriate design. Anthropological models could be used to predict changes in family and community interactions. They might use causal loop diagrams and quantified flow charts to examine the flow of people and goods. Attitude surveys might be commissioned to obtain preliminary ideas about patterns of usage. Mathematical models based on engineering criteria could help examine the technical needs of the bridge and its approach roads. Economic models might be developed to predict how other parts of the region's economy would be affected by the influx of resources to build the bridge and those generated by its availability under different political conditions in the country. Finally, management models could be sought to provide the organizational infrastructure and project management the effort would require.

#### **A Reductionist Model**

How would this process be different than if a reductionist model were followed? First, a larger number of views about the future of the area would be considered. These different views would explicitly address the value judgments implied by different alternatives. More local information would be gathered about the characteristics of the terrain and about what the best solution might be from different perspectives. These perspectives might be based on what would be most desirable from the standpoint of the tourist industry or an extracting industry or the time needed to transport perishable goods. Views of parents of small children and of people who use animals for transport might be relevant.

The impact on possible futures of the community from different choices about where to build the bridge and what kind of bridge to build would be explored. Threshold values might establish what additional measures would be required for each change in traffic patterns. Given a broader base of opinion and some trend analysis, a bridge of either greater or less capacity than first envisaged might be justifiable.

The discussions would lead to various models to test assumptions and implications from a variety of perspectives. Each particular set of models would contribute particular strengths. No "right" answer would probably be generated, but a series of "better" answers given different parameters of needs, resources, and political would emerge.

Finally, the main difference is that the bridge, its community, and the local economy would be considered as an inseparable whole.

#### **Outlook for the Systems Approach**

The outlook for the systems approach as a whole is promising. Although many in the systems field are frustrated by how long proven techniques have taken to enter the mainstream, it is happening and many of the new developments are assisted by software availability. A growing number of books and journals also cover the systems field.

The outlook for contributions that the systems approach could make to futures research is also promising. Both the participative and the data-oriented models are well suited to reach forward in time to explore possibilities and consequences of alternative choices.

## **Some Specific Models**

The systems approach uses many different kinds of models to learn about and influence situations. Sometimes these models are custom designed for a particular set of circumstances. At other times, the modeler does not have to start from the beginning but can use models already developed and generalized for use in different sorts of study.

- Interactive Planning
- Hiring System Theory
- Operations Research
- Socio-Technical
- Soft Systems Methodology
- System Dynamics
- Total Quality Management
- Viable Systems Model

These models have a theoretical background and a framework of rules or guidelines to use. Because the purposes of the model and its relevant parts are chosen by the modeler, each application of these models retains a flavor of custom design although following a pattern.

Some of the specific models in the systems field come from several sources of general systems and the management field and overlap in their functions and effects. These models have varying ranges of convenience, although usually more than one good option, or combination of options is provided for any given situation. Sometimes they come from different roots, although they cover similar ground. For example, Living Systems Theory is rooted in biology, while System Dynamics is rooted in control theory and industrial design; both are effective in modeling complex and varied relationships in dynamic systems. Interactive Planning and Soft Systems Methodology are both appropriate for fluid community or organizational situations, which need to make decisions about their basic missions and plans. The Viable System Model and Socio-Technical Systems approach are both most appropriate when a defined organization exists whose work and management will be aided by balance with their environments and the development of appropriate structure and information flows.

The models selected here are all general models that can be applied in many different contexts. They have all been tested and used for a number of years and in a number of different settings. All have print materials, and sometimes software, that offer step-by-step instructions on how to use them. Detailed references to the particular models described will be given at the end of each example.

In addition to these models, two other classes of models deserve mention. The first features widely applicable systems approaches that have not been formulated as tools or are of fairly recent origin and not yet fully explored. The work of Maturana and Varela on self-producing systems and on language is one example. Ulrich's work on Critical Systems Heuristics is another. The second class of models are situation specific models, often available only on software. Examples are the Second Generation Model (SGM), from Pacific Northwest Laboratories of Washington D.C., which models emissions and their effects on the global environment; and the `what If' decision support and large scale simulation package from Robbert Associates of Ottawa.

#### **Interactive Planning**

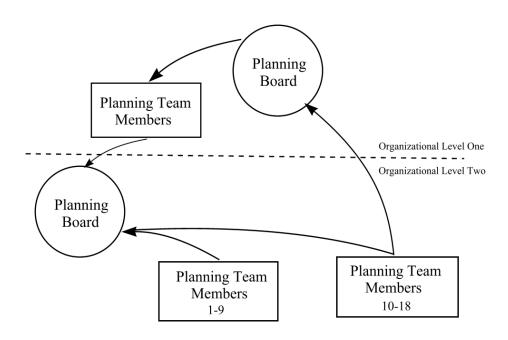
Interactive Planning is perhaps the best known of the models developed by Russell L. Ackoff and his team. Its roots are in the early interdisciplinary style of operations research and in planning where Ackoff, whose background includes architecture and philosophy, has made significant contributions. The team was based for many years in the Social Systems Science Department in Wharton School of the University of Pennsylvania (USA) but now operates independently under the name of Interact near Philadelphia.

Interactive Planning assumes that an organization's future depends on its own actions as well as events occurring in its environment. It stresses high levels of participation to achieve maximum input and commitment, calling upon a broad range of individuals in the organization to think creatively about its desired future and then take steps to make it happen. Ideally, the planning teams

include everyone in the organization who wants to take part, but the effort should involve a reasonable sample of the organization's members and stakeholders. This condition helps ensure that plans take account of everyone's circumstances and that the goals of the organization and those within it will be compatible.

The planning process is dispersed and highly autonomous. Units within the organization are free to carry out their plans as long as they have sufficient resources and do not affect other units. Plans that do have an impact on other levels and units are integrated both horizontally and vertically by planning boards so that the effort moves forward as a whole

**Figure Six** Organization of Planning Process



Ackoff distinguishes Interactive Planning from other sorts of planning. Reactive planning, which is usually bottom up and frequently focused on tactical steps, is based upon bringing the

situation back to a previous satisfactory state after a period of turbulence or drift. Preactive planning, which is usually top down, emphasizes the advantage of predicted future states, such as opportunities offered by new technology or expanding markets. According to Ackoff, these approaches try to "solve" or to "resolve" problems. Interactive Planning stresses creative thinking and the give-and-take both among internal players and between the organization and its external environment. In this way, they may "dissolve" problems rather than solving or resolving them.

Ackoff reminds planners that they must make their assumptions explicit, to themselves and to others, and test them continuously to ensure their validity.

## How To Do It

An Interactive Planning process requires five phases, which may take place in a different order or concurrently. When they are completed, the process of planning and adaptation continues, although the level of effort to maintain its momentum need not be as high. The five phases are:

- (1) Formulation of the Mess. Threats and opportunities faced by the organization are first described. Qualitative and quantitative data are gathered about its current state, internal and external obstacles to development, and a set of reference projections on its probable future without significant changes in the organization or its environment. Although the recommendation at this stage is to probe broadly rather than deeply, the picture must be robust enough to inspire confidence in the process. This phase culminates in the preparation of a reference scenario describing the likely results if the organization does not change.
- (2) Ends Planning. This phase calls upon participants to think creatively. Their deliberations should be subject to only two constraints: technical possibility and operational feasibility. Outlining a mission, nominating desired properties, formulating the idealized design, and identifying gaps that need to be closed can be an exhilarating process. The resulting idealized design should be an "adaptive learning system" that has the means to experimentally test its options and make adjustments. Two versions of the idealized design are recommended: one that accepts the constraints of the organization in which it is embedded, and another that does not. The comparison between these two versions and between the one selected and the reference scenario leads to the gap analysis and the identification of the new goals, objectives, and ideals.
- (3) Means Planning. This phase matches goals and objectives with the activities to accomplish them. An exercise in means planning should indicate the particular goals and means selected, the information on which the selection was based, the expected outcomes and their supporting assumptions, and a record of how the choices were made and who participated in making them. This documentation is extremely valuable as a base from which to adapt the plans as events unfold. Such documentation is crucial because memories fade and personnel change.

Means planning involves identifying the relevant variables and distinguishing those that can be controlled or influenced from those that cannot. Ackoff warns against mistaking association for causality and strongly urges planners to experiment directly or, if not feasible, use iconic, analogue, and symbolic (including mathematical) models to test options as they are proposed. This experimentation and modeling is what keeps the idealized design grounded in actual practice. Reliable data is needed to proceed confidently and effectively as well as to maintain direction in the face of turbulence or changes in internal or external circumstances.

- (4) Resource Planning. This phase formulates an assessment and schedule of inputs, facilities and equipment, personnel, information, and resources needed to bring about the stated goals. Resource planning should take into account possible fluctuations in the cost or availability of needed resources and the development of alternative strategies. These decisions may also be supported by the use of simulation models that could explore the differences, say, between continuing with the same facilities or investing in more expensive energy-efficient equipment or between developing needed personnel internally or recruiting from outside. External scenarios should also be modeled. For example, information from financial models, which could simulate variations in costs as a factor of changes in interest rates or taxation, would help establish alternative scenarios and decision points.
- (5) Implementation and Control. In the final phase, plans are translated into a schedule and a set of assignments for each unit. The implementation phase should be supported by such tools as PERT charts, control forms, and other statistical process control and quality measures. These are particularly important in tracking deviations from the schedule, budgeted resources, or results obtained so that adaptation can occur.

Interactive Planning employs planning boards to provide the necessary organizational infrastructure. They consist of about ten people who perform different functions in the unit with a representative from the units above and below in scope of responsibility. These interlocking boards ensure that consistency and high levels of communication are maintained.

## When to Use Interactive Planning

Interactive Planning requires several conditions for success:

- (1) An organization, legally constituted or not, must remain intact over time. Without that, boundaries are insufficient to contain and develop the efforts.
- (2) The organization must have some maneuvering room and a realistic opportunity to put learning into practice. An invitation to think big is frustrating when only small changes in routine processes are possible. The authority for planning must come from a high enough level in the organization to underwrite the plans or, at least, to submit them directly for approval.

- (3) The organizational culture must be able to tolerate or better yet, support high levels of participation and free exchange of ideas. If the organizational style has been autocratic, trust issues need to be handled directly.
- (4) The full benefits of Interactive Planning are difficult to attain unless ample resources of time and information are available. In particular, the other phases cannot proceed effectively without solid information about the current state of affairs and the capacity to test options and measure or simulate outcomes.
- (5) An expectation of some continuity is needed to sustain the confidence and commitment to move forward.

## Comparison/Combination with Other Models

Interactive Planning shares many of the same assumptions as other systems models of organizational activities and overlaps or duplicates some aspects of others. Thus, Interactive Planning can be used simultaneously or in tandem with other systems models.

Prior to making a decision to engage in Interactive Planning, locating the organization in a causal loop diagram or System Dynamics model with respect to the major influences in its environment. Otherwise, this information is gathered in the "mess formulation" phase.

During the planning effort, Socio-Technical Systems analysis of key variances in processes and attributes of the quality of working life may help establish answers to important questions. Other answers may be provided by models and techniques from operations research.

In the implementation phase, tools from Total Quality Management may be used to monitor progress toward specific goals or the Viable Systems Model applied to managing communications links between the various management functions marshalled to fulfill the plans.

#### Outlook for the Future

In futures research, highly participative processes are in great demand to deal with complex situations where no one viewpoint will suffice. Interactive Planning is well equipped to meet these needs. It is broad enough to be useful in interdependent interorganizational settings with no functioning hierarchy and deep enough to provide real help.

## **Living Systems Theory**

Living Systems Theory (LST) was developed by James Grier Miller and his colleagues at the University of Chicago (Illinois, USA) and, later, at the University of Michigan (USA) in the late 1940s and the 1950s. When Miller took up the presidency at the University of Louisville, (Kentucky, USA) work continued in its Systems Science Institute. LST is rooted in the life sciences and is

primarily associated with the perspectives of General Systems Theory. Its central assumption is that every living system, at whatever level, must carry out the same 20 processes to survive.

Jim Miller was one of the group who began the Society for General Systems Research (now the International Society for Systems Science) in 1955. He published his definitive book <u>Living Systems</u> in 1978 and has continued to expand and elaborate on the basic structure, adding a new subsystem (the timer) and a new level (the community) in the 1990s. He currently serves as editor of <u>Behavioral Science</u>, which publishes many applications of LST.

LST looks at systems from the standpoint of their structure, their process, their subsystem processes, the relations between subsystems, and their systemwide processes. LST organizes concrete living systems into eight levels; each of which is included in the next, as in a nested hierarchy. They are: the cell, the organ, the organism, the group, the organization, the community, the society, and the supranational system.

Each living system exhibits 20 subsystems that carry out its functions. The first two subsystems process both matter-energy and information; the next eight subsystems process matter-energy; and the last ten subsystems process information. These 20 subsystems are:

- (1) <u>Reproducer</u> carries the system's basic blueprint or program from its genetic codes to its constitution, as well as the plan for mobilizing matter and energy to produce similar systems;
- (2) <u>Boundary</u> includes the subsystems at the perimeter of a system that distinguish it from its environment, maintain its identity against outside stresses, and filter matter, energy, and information;.
- (3) <u>Ingestor</u> takes in matter and energy from the environment;
- (4) <u>Distributor</u> carries inputs from the environment and outputs from other subsystems through the system;
- (5) <u>Convertor</u> digests inputs to the system and changes them into more useful forms;
- (6) <u>Producer</u> manages the conversion of matter-energy and information inputs into outputs and enables growth, maintenance, repair, movement, and other external and internal activities;
- (7) <u>Matter-Energy Storage</u> banks matter or energy for future use and retrieves these when needed:

- (8) Extruder puts products or wastes resulting from system functions into the environment;
- (9) <u>Motor</u> moves the system or its parts within its environment and may also move parts of the environment in relation to one another:
- (10) <u>Supporter</u> coordinates the location and spacial relationships of system parts to keep them from interfering with one another;
- (11) <u>Input Transducer</u> converts sensory input to internal signals and information on which other subsystems can act;
- (12) <u>Internal Transducer</u> receives information from internal components or subsystems and changes them to matter-energy forms for internal transmission;
- (13) <u>Channel and Net</u> provides the routes, in physical space, for the transmission of information within the system;
- (14) <u>Timer</u> monitors and transmits time-related information about the external environment or the system's internal states so that the `decider' can alter the phases or rates of the system's internal processes;
- (15) <u>Decoder</u> receives and changes information from the Input and Internal Transducers into a "private code" which can be used in the system's internal communications;
- (16) <u>Associator</u> recognizes patterns and makes associations, which is the first stage of the learning process;
- (17) Memory stores and retrieves information at different times and in different contexts which is the second stage of the learning process, and also serves as the repository of culture and values in larger systems;
- (18) <u>Decider</u> is the executive subsystem that receives, evaluates, and transmits information to control the system and maintain its operations and this is the only subsystem that cannot be provided from outside if the system is to retain its identity;
- (19) <u>Encoder</u> changes the "private code" used in internal communication to a "public code," which can be received and interpreted by other systems in the environment; and

(20) <u>Output Transducer</u> changes internal information markers to forms of matter-energy, which can be received and interpreted in its environment. Similarly, in organic systems, such as in a cell, organ, organism, group, organization community, society, or supranational, this can be applied.

#### How To Do It

LST applications start by identifying the relevant system, its purpose, major inputs, and outputs. Then applicable portions of the matrix of 160 blocks (8 levels and 20 subsystems for each) are selected and information added about where they are located and what their essential variables are.

Merker notes that seven steps employ LST for management. They are: (1) identifying the system under study, which is sometimes more complicated than it might appear; (2) discerning its purpose; (3) naming its critical inputs and outputs; (4) identifying its 20 subsystems; (5) describing the critical inputs and outputs of each; (6) quantifying the critical inputs and outputs; and (7) making management decisions based on the analysis of these data.

For example, a training organization will have a legal identity and a mission. It might generate a satellite center (reproducer). It would establish its physical perimeters, such as fences, walls, and rooms; its area of concentration, such as agriculture; and the qualifications of its teachers and students (boundary). It might have an admissions officer and purchasing agent to bring in students and supplies (ingestor). It would transport these within the system through corridors or on hand trucks (distributor). It would work on materials that came in to make lesson packages or lunches (converter). It would keep some supplies to be used later in the supply cabinet (matter-energy storage). It would graduate its students and send them on to jobs or further training (extruder). It might send its teachers out to conduct classes in remote areas (motor). It would schedule the use of classrooms and laboratories so that everyone would be able to use them (supporter). It would maintain subscriptions to technical journals to keep the teachers' lessons up-to-date (input transducer). It would develop a grading system to keep track of students' progress (internal transducer). And so on...

Obviously, the more complex the system is, the more variety in each of its 20 subsystems. A characteristic of LST is that comparable activities take place from the cell to the supranational organization. This characteristic is called "fray out," which invokes the picture of a ship's cable that is made of ropes, which are made of strands, which are made of threads... Fray out stands for recursive duplication in a nested hierarchy, although the duplicative process of, say, reproduction does not have the same features in an organism as in an organization. A similar analysis could be done at a different level of the system.

LST has been used to analyze a great variety of systems at all eight levels. Its use in management and social science is just beginning to move to a wider audience, although Miller has given many examples and articles have been appearing for some years in <u>Behavioral Science</u>.

Some work has been done with Living Systems Process Analysis (LSPA), which combines the theoretical structure with various quantitative models and techniques. This approach, while producing fruitful results, has not been widely applied, because of the difficulty in finding researchers who are strongly grounded in both LST and the requisite quantitative techniques and because a considerable amount of time and effort is needed to perform the experiments and assemble the data.

A more modest strategy called Qualitative Living Systems Analysis (QLSA) has been suggested by Taormina. This strategy follows lines similar to a medical check-up. It takes a case history, analyses the organization's subsystems, formulates a diagnostic summary of the problem, and offers a prescription. The QLSA focuses on the ten information processing subsystems and uses a standardized questionnaire. For each subsystem, it asks for a description of its recommended and existing structure and processes and a description of the pathologies to which the subsystem is prone. (A pathology in LST terminology is defined as a condition where an essential variable departs from its safe range frequently or over a long period of time, e.g., important incoming information is either frequently lacking or usually inaccurate.) The results of the subsystem analysis form the base for a diagnosis and prescription for the whole system.

#### When To Use It

LST provides an exhaustive model to describe the structure and processes of any living system and to study processes up and down and across levels. The picture LST provides can incorporate much detail and enables the consistency and adaptation of its processes and structures to be traced with considerable precision. Applying the model to the diagnosis or design of a system is an ambitious undertaking and requires either experience in using the process or a team that can take the time to master it. LST is not a "back of the envelope" methodology.

Although designed for living systems, LST has been used to analyze abstract systems, such as computer programs and other formal systems. Still, it is easiest to use in living contexts where concrete measurement of the activities of dynamic systems can be made directly. It is more difficult to use when no tangible measurement are possible or when subsystems do not share a common purpose.

With its 8 levels, 20 subsystems, and biological vocabulary, LST has a steep learning curve. Although the concepts themselves are straightforward, keeping 20 variables in mind pushes another of Miller's (George A.) recommended limits of complexity "seven plus or minus two", even when the subsystems are further divided into matter-energy and information groups.

#### Comparison/Combination with Other Models

LST has been recommended as a "shell" model within which to incorporate other systems models to elaborate particular functions. For example, within one of the subsystems of a level, the significant processes within each could be mapped using Systems Dynamics or Total Quality Management. Tools from operations research might also be useful.

Opportunities also exist to map the 20 subsystem processes onto aspects of other models. The matter-energy processes can be mapped onto the physical aspects of the technical analysis and work flow design in a Socio-Technical Systems (STS) study and the information processing subsystems overlap with the STS designations of support and management work.

LST has been compared with the Viable Systems Model (VSM) in a transportation study. The researchers believed that LST offers the more exhaustive treatment. However, they recommended that VSM be used first for identifying where to start the more detailed analysis. The VSM might also be used to study relations between subsystems or to elaborate a single subsystem, such as channel and net.

Other approaches might be used prior to undertaking an LST analysis. Soft Systems Methodology could be helpful in the initial stages of identifying the system and its sub and supra systems.

#### Outlook for the Future

Futures research using LST is a possible choice for community and nations in designing processes. Given different assumptions and initial variables, alternative scenarios could be explored with considerable thoroughness.

The continuous stream of articles and presentations that appear in professional journals and conferences (especially of the International Society for Systems Science) indicate an interest in a broad and growing range of applications. So far, LST has been used in the diagnosis of many organizations; its use in the design and management of organizations may be possible as well.

#### **Operations Research**

Operations Research (OR, and called "operational research" in Britain) is an approach to problemsolving and decisionmaking in complex situations that uses various methods of quantitative analysis. It began in World War II when interdisciplinary teams of scientists in Britain and, later, in the United States gathered together to do research on wartime operations. Perhaps the best known of these teams was led by Patrick Blackett, known as Blackett's circus, who were renowned for their work on radar. Work was also done on: devising tactics, such as improving the success rate of dropping depth charges on submarines; technical problems, such as the design of warplanes to

withstand damage; and human factors, such as the optimum duration of training programs for different assignments.

Russell L. Ackoff, one of the American pioneers, defined OR as the application of scientific method by interdisciplinary teams to problems involving control of organized man/machine systems to provide solutions that best serve the purposes of the organization. During the post-war period, OR was applied to a wide range of problems at the executive level in industry and government. In later years and as one-off solutions to complex problems became generalized, the field narrowed to focus on a number of techniques rather than on the interdisciplinary problemsolving approach. They included: inventory control (establishing the right balance between the costs of holding stocks against the penalties of being caught short); queuing theory (determining the required capacity to process input, such as customers at ticket windows); allocation strategies (such as the assignment of students to classes); routing problems in networks (the traveling salesman problem); and replacement policies (obtaining the best balance between the cost of replacing a piece of equipment and the probability of breakdown verses its remaining unused capacity). The refinement and use of these techniques came to dominate OR practice and became the focus of university OR programs. Current applications of OR tend to be directed to well-defined problems with unambiguous goals and criteria for success.

#### How To Do It

An operations research project typically has five stages:

- (1) Formulate the problem, which includes establishing the goals and indicating any constraints on the solution (for example, the design of an optimum delivery schedule for a truck carrying food could have a goal of making the maximum number of deliveries in the shortest possible time, but that goal might be operating under any number of constraints, such as the perishability of different foodstuffs or limitations on the number of hours a driver can work before taking a break);
- (2) Construct a Model (or select an appropriate tool or combination of tools from the software);
- (3) Run the Model (and get its solution to the stated problem);
- (4) Test the Model and evaluate its solution (some models may be tested empirically; others arrive mathematically at a feasible solution and proceed to test other solutions against the criteria for satisfaction using statistical methods until an optimum solution is found);
- (5) Implement the Model, evaluate its effect, and establish a plan for maintaining the model in the face of predicted variations in circumstances (unpredicted variations may call for a new cycle beginning with a reformulation of the problem).

An OR project has access to a number of tools from the general to the specific. They include: critical path analysis, decision theory, dynamic programming, linear programming, network analysis, program evaluation and review technique, queuing theory, regression analysis, and simulation.

Descriptive detail about how to use any of these particular OR tools is not within the scope of this paper. These tools depend on algebra, statistics, probability theory, differential and integral calculus, and other tools of mathematics and logic. A number of software packages are available that are geared to specific applications, such as inventory control and project management. A number of books exist, at different levels of mathematical sophistication and covering different application areas. Several journals publish new developments, including the *Journal of the OR Society, Management Science, Interfaces, the European OR Journal and OR Letters*.

## When To Use It

OR is difficult to use if the problem situation does not lend itself easily to quantification. Modelers should be wary of giving preference to factors that can be measured accurately over others, which may be more important, that cannot. In some instances, eliminating options or reducing decision space may reduce uncertainty in data poor situations.

OR should not be used until a problem is well defined and its priorities and parameters established. It works best in clear-cut situations where everyone agrees about what counts as an optimum solution. In most situations, the use of OR tools should be postponed until questions about values and priorities have been settled to everyone's satisfaction. The techniques and tools of OR are generally computer-based and therefore, capable of giving answers that may look better than they are if insufficient attention was paid to formulating the problem correctly. In addition, OR models should be continually tested in light of changing conditions.

## Comparison/Combination with Other Models

OR is the narrowest and most quantitative of the systems models and tools described here. It is a valuable approach to use with other systems models when the time comes to take specific aspects of broader models and make them quantitative or to explore alternative scenarios. In this way, OR may be used with any of the other systems models, even Soft Systems Methodology. OR has been included in applications of the Viable Systems Model and Socio-Technical Systems. Some of the statistical techniques overlap with Total Quality Management, and one of its tools (simulation) overlaps with the more sharply focused applications of System Dynamics.

## Outlook for the Future

We may expect to see continuing development of OR technical tools and their accompanying software. Interesting developments also exist in the field of community OR, which is exploring applications in developing countries and in community management and decisionmaking. OR is well suited to providing quantitative projections in futures research projects.

#### **Socio-Technical Systems**

Socio-Technical Systems (STS) theory brings a philosophy and a set of tools to designing work that improves productivity by obtaining the `best fit' between social and technical considerations. STS began in the 1950s with the work of Trist, Bamforth, Emory and others on the introduction of automation to coal mining in Britain. STS found that not only did the new machine technology not improve productivity, it lowered it. Studies revealed that changes in work methods eliminated much of the social interaction, support, and coordination that had kept the mines functioning productively. Trist and others conducted additional research at the Tavistock Institute of Human Relations in England on work practices in Britain and in Scandinavia. They found that the highest productivity did not come from maximizing either the social or the technical aspects of the work but from finding the best mix.

More recent work under the heading "quality of working life" extends the social and technical fit to administrative and environmental considerations. This inclusion distinguishes between "core," "support," and "coordinating" work, and the management of self-managing teams. With its emphasis on task identity and variety, task significance and autonomy, STS runs counter to the mechanistic or Taylorist view of management, to autocratic management styles, and to the de-skilling of labor.

STS approaches engage self-managing teams of workers in problem solving, equipment maintenance, quality inspections, and scheduling. STS can take over many of the basic internal supervisory roles formerly handled by first-line managers. Management is available to facilitate the group and help solve problems but leaves the bulk of decisions about how to do the work to those doing it. This leaves managers free to concentrate on external matters: making sure that necessary supplies and resources are available, protecting the teams from interference, and monitoring customer needs and satisfaction.

STS has had numerous applications, most frequently in new industrial plants. The bulk of applications so far have been in industry, but office and information technology applications are growing. To date, much of the STS analysis has been on routine or semi-routine work.

#### How To Do It

An STS application begins by deciding to make the change and securing the necessary political, financial, and legitimizing support. Although the organization can expect to attain greater productivity and adaptability through STS, the decision represents a commitment to invest time and energy both in applying the analysis and in overcoming resistance to changes that threaten the privilege and status of present arrangements. Lower and middle managers, many of whom have come up through the ranks without any formal management credentials, need particular training and support

to assume their new roles. Workers also need time to become accustomed to the new ways and to grow into their increased responsibilities.

A crucial element in successful application is a high level of participation among workers, support staff, and management. A participatory structure is not possible to hand down by dictate. Information gathering and design need to be done in a participatory mode if gains in satisfaction and productivity are to be achieved.

Once the decision has been reached and endorsed, a five step process is followed.

(1) The Initial Scan looks at the organization and its environment; determines and documents the organization's major inputs, transformations, and outputs; and prepares a profile of its philosophy, culture, values, and mission. Interviews and reviews of the organization's history and paper records are usually part of this last step.

The environment is divided into two classes. The first class is the "transactional environment," which includes all external factors and stakeholders that the organization directly influences and is influenced by (customers and suppliers, also local labor markets, technical training facilities, and community leadership). The second class is the "contextual environment," which includes all environmental factors that have a primarily one-way influence with the organization, such as regulators, market trends, business cycles, and political occurrences.

- (2) The Technical Analysis establishes detailed technical information about each stage of the conversion process in each unit of the organization, covering both tasks associated with the physical conversion of materials and those relating to the informational conversion of orders and invoices. For each process, "key variances" are tagged to indicate the locations in the conversion process where trouble frequently occurs, such as when a boundary is crossed from one functional group to another. Efforts are made to track the variances to their source, which may precede their earliest visibility in the process by several steps. Sometimes redesign can eliminate variances. If it cannot, variances should be controlled where they arise, not sent on to another stage in the process. A number of specific notions and tools are available to assist in this portion of the work, such as templates, matrices, and diagrams.
- (3) The Social Analysis describes the social networks and relationships in the organization. The role of networks and interaction patterns among the various units and their members are articulated with particular attention to internal boundaries and how information crosses them. A work quality grid is prepared, showing the social ranking of tasks according to identity, significance, variety, autonomy, and discretion, and indicating their potential for learning and growth.

(4) In the Work Redesign phase, tasks and roles are restructured to create boundaries between units that allow for completing an identifiable product or stage of the process, control of variances within the unit, and a high degree of self management and decision-making. The flow of information to a work unit is designed so that the team has appropriate and timely feedback on its output. Some design changes can be implemented immediately. Others, such as doing the maintenance of machinery in the unit, may have to wait until the team member can acquire the necessary additional training.

Many STS applications seek to introduce "multi-skilling." That is, workers are encouraged to acquire ability for several jobs and are paid a premium for the additional skills they acquire. Multi-skilling makes their work more challenging, and management gains greater flexibility to respond to changes. Labor unions have been suspicious of multi-skilling, especially if introduced where rigid contract specifications narrowly define jobs.

(5) The Approval phase also includes, enhancement and implementation of the work redesign. The work redesign phase in STS is never over, because design must stay open to worker suggestions and adaptable to environmental changes.

The implementation of the STS approach cannot be done quickly. Organizations that have been successful report that it takes 18 months to 3 years before the new systems begin to operate smoothly.

#### When To Use It

STS design is appropriate for the design of work and the structure of work organizations. It is most useful when the organizations have a high degree of contact and identifiable products or services.

STS may not succeed, or may succeed more slowly, if introduced into an organization with a history of adversarial relationships. In such cases, managers attempting to introduce it must "walk the talk" of maximum participation and willingness to trust. If mixed messages are received, the whole effort will be viewed with suspicion.

STS tools are good on the design of core, support, and coordination work, but less agreement exists on the how to design management work in this model.

# Comparison/Combination with Other Models

STS has integrated Total Quality Management with its own efforts in organizational culture and practice to ensure that the social side of work is not neglected. Some STS techniques used in the task analysis phase correspond closely with TQM techniques.

STS and the Viable System Model have been taught together in workshops designed to help organizations manage change. The VSM supplies a structure for management support that is compatible with autonomous work groups and self management.

STS analysis and Interactive Planning appear to share a number of features at the reference scenario stage. Interactive Planning, however, is more oriented toward the future and to rethinking the organization's mission, while STS is more concerned with the improvement of current practice.

Systems Dynamics or Living Systems Theory could be used in the diagnostic scanning phase of STS and in portions of the task and social analysis to add detail to their descriptions.

#### Outlook for the future

STS theory continues to be extended by applications in different fields. It is being extended by Pava to the design of non routine and perhaps interorganizational work. This application uses deliberations and discretionary coalitions as the units of analysis. The analysis of deliberations should be especially useful to futures research.

## **Soft Systems Methodology**

Soft Systems Methodology (SSM) is a process-oriented approach for channeling debate about situations characterized by messy ill-structured problems with multiple perspectives. SSM was developed by Peter Checkland of the Business School of Lancaster University in the 1970s and 1980s. His book, *Systems Thinking, Systems Practice*, is the primary reference on this model. Checkland had noticed that "hard" systems processes, which moved from defining objectives and measures to evaluating alternatives and making choices, were not effective when the problems could not be stated clearly. He began to perform action research in organizations with the explicit understanding that the researchers would become part of the process they were investigating and would not attempt to impose laboratory standards on the situation. Soft systems thinking developed a method of alternating between direct investigation of the situation and making formal statements about it using systems concepts.

Soft Systems thinking may be distinguished from "hard" in that SSM locates the use of systems concepts in the process of inquiry rather than "objective" observations of the real world. Checkland stresses that observations based on so-called hard data are also subjective, because each observer brings a slightly different idea of what data are relevant and how they should be interpreted.

SSM employs systems notions primarily to structure logical debate and increase common understanding among an inclusive group of participants about how their situation should be characterized and what should be done about it. It focuses on questions of culture and cultural feasibility rather than on structure and information flow, and it focuses on viewpoints of people rather

than on technical aspects of a problem. Technical aspects may be chosen and implemented as a result of agreements made during the SSM process, however, they should not drive the process.

#### How To Do It

Use of SSM begins with the decision that a problem situation exists that could benefit from a complete rethinking. Checkland defines a problem as a condition characterized by a state of mismatch that eludes precise definition and may be expressed simply as a state of unease. Participants are recruited to bring together as diverse a group of stakeholders as possible to consider the situation in a systemic way. SSM is done through a seven-stage process. The stages do not need to be taken in any particular order.

- (1) Looking at the Unstructured Problem. As much as possible is learned about the unstructured problem situation. This learning takes into account diverse perspectives on the situation through wide-ranging discussion among participants. This stage may also include information gleaned from direct observation, attitude surveys, and formal interviews, and study of relevant background materials.
- (2) Structuring a Problem Statement. The second stage comes to an agreement about how to express the problem, blending the insights of different participants and the results of their interactions and discussion. This stage should include investigation of the situation's structural or slow-to-change elements, its processes or continuously changing elements, and a view of the climate that is generated by the way they fit together. This material is summarized in a "rich picture" which usually includes graphics as well as words. This sequence completes the "finding out" phase. The difficulty in this stage is to avoid structuring the problem too quickly or too neatly.
- (3) Formulating Root Definitions. In this stage, the "primary tasks" are distilled and each task is described in a "root definition." The tasks should include both formally constituted activities and informal ones that are central to the system's identity. The root definition should provide an idealized view of what the system should be or should accomplish. Root definitions include a description of six factors, each composing the acronym CATWOE.
- Customers. Stakeholders or those on the receiving end of the actions, who are not necessarily only those whose usage the group wishes to facilitate; e.g., they could include people who might be tempted to ignore safety rules or commit criminal acts;
- Actors. Those who perform the actions;
- Transformations. Activities that transform inputs to outputs;

- Weltanschauung. The "worldview" that encompasses the group's culture, values and reason for existing, which forms the context for the activity and its root definition;
- Owners. Those who have the final say over whether or not the activity occurs; and
- Environment. The constraints in which the situation is embedded and form its physical and behavioral boundaries.

Each primary task should be described in a root definition that includes the CATWOE elements. Multiple root definitions, which stretch the imagination, may be used to explore the same part of the situation from different perspectives or at different levels of generality. One of the most stimulating sources of root definitions is the view held by the organization's most severe critics.

(4) Building Conceptual Models. The construction of a conceptual model is an exercise that indicates the organization's essential activities and the sequence in which they are performed. This portion of the SSM process is the most rigorous. The process calls for the activities to be described using the minimum number of verbs (usually not more than six) that would fully describe the activities. These verbs are then arranged to form a pattern of how the activity could take place. More than one such pattern can be explored for a root definition, but the pattern should not include any elements that were not covered in the root definition. If a conceptual model is too complicated or not relevant, the group returns to the root definition to break it into parts or to reconsider it altogether. The model should not simply be a description of an existing system, because the model serves as a standard to which the existing system is compared in order to explore changes.

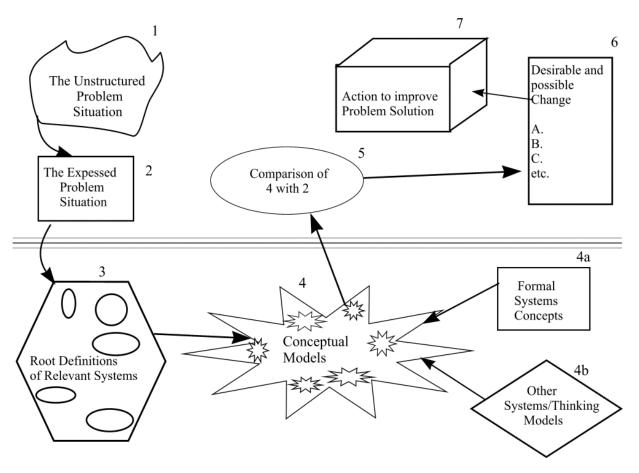
Stages Four A and Four B inform the conceptual model by testing it against formal systems concepts (A) and other systems thinking (B). Stage Four A describes the root definition in terms of nine characteristics of a formal system. They are: (1) its purpose or mission, (2) the measure(s) of its performance, (3) its decision-taking process (not the individuals), (4) its subsystems, (5) the interaction of its components, (6) the wider system with which it interacts, (7) the boundaries of its decision-taking process, (8) the resources at the disposal of the decision taker, and (9) the expression of its continuity. Stage Four B might explore all or part of the root definition and the conceptual model from the perspective of System Dynamics, Socio-technical Systems Theory, the Viable System Model, or any other systems model that seems relevant.

(5) Comparing Models and "Reality." The comparison between the conceptual models and reality forms the basis for ordered questioning. In this stage, different options for dealing with the problem situation are suggested and debated. Comparisons may be made with varying degrees of emphasis. Some might focus on issues or on culture and values (issue-based systems). Others might focus on the organization and its tasks (primary task system). Either focus would have recourse to information from the "real world" to help evaluate the usefulness of the model. These processes may result in a

variety of approaches to gap analysis, wherein the idealized picture is compared with the current picture to see what needs to be accomplished or understood for transition to an improved state of affairs.

- (6) Defining Changes. This stage evaluates the changes suggested by the comparisons between models and observed realities. Participants are expected to debate suggestions rigorously in order to ensure that recommended changes make sense in terms of both systemic logic and group culture.
- (7) Taking Action. In the final stage, those activities, which have been determined to be culturally desirable and feasible according to the needs of all relevant participants, are performed and recommended changes are implemented.

**Figure Seven**Soft Systems Methodology
(after Checkland 1975)



The process of inquiry characteristic of SSM moves between two modes of thought: the abstract systemic mode, as represented by stages three and four; and the real world mode of culture, problems, and actions, as represented by the other five stages. During the SSM process, users are urged to move back and forth between these models in a conscious manner.

SSM has been used in a great variety of contexts and with a great variety in styles of intervention. Although many applications have taken place inside organizations, no need exists for abounded organizational context to learn and to benefit from the exercise. Also, the seven stages do not need to be used separately, although their functions should all be performed. Experienced users of SSM may blend them in a more loosely structured way.

SSM is most useful when the subjectivity of the situation and its lack of structure make action premature. It is geared to answer "What should we do?" rather than "How do we do it?" nevertheless, the `how' question may be helpful in cases that reveal mismatches of culture and values.

### When To Use It

SSM was designed for situations where the problem is ill-structured and where considerable differences of perspective limit the applicability of any one view. SSM is not usually a good choice to use in situations when no uncertainty exists about the problem, even if some disagreement exists about strategy.

Organizations have used SSM successfully where implementation of a change met massive resistance and it was necessary to start over. The SSM process provided the opportunity for the fuller exploration of missing perspectives.

Effective use of SSM requires a situation where participants have sufficient time to share and learn from each other and a high enough level of trust to discuss their preferences and requirements openly.

SSM is popular with people who want to promote a systemic approach to airing and incorporating a multiplicity of viewpoints. Participants have less need to learn new vocabulary with SSM than with some other models. Without the systems vocabulary, however, their efforts may not be as easily defended or transported to other situations.

SSM does not give much prominence to either the collection or the use of quantitative information. Therefore, SSM is an appropriate option in a noncomputerized environment and when discussants are not mathematically inclined. Where quantitative information is valuable, SSM may involve outside technical expertise in a nondecision-making capacity as part of Stage Five.

# Combination/Comparison with Other Models

SSM occupies the "softest" and therefore, most subjective position of the models considered here. None of the models discounts the role of the observer in defining the system or rejects the subjective view, but none gives as much primacy to the observers as SSM.

In addition to Checkland and his colleagues, a number of researchers have combined SSM with other models. They have used it to define the problem situation prior to employing other models to focus on particular aspects, such as management structure, communications channels, etc. Flood and Jackson include SSM in their Total Systems Intervention strategy.

In Stage Four B of the SSM process, other models are explicitly brought in for comparison.

#### Outlook for the future

SSM is well suited for futures research. The exploration of different root definitions could be used to explore alternative scenarios. One possible comparison between the conceptual and real models focuses forward in time to realized expectations.

SSM is well equipped to help shift an organization's identity toward a "learning organization." Further work will combine SSM with other models and find ways to do SSM processes in a computer network environment.

## **System Dynamics**

System Dynamics is a modeling and simulation tool to investigate complex dynamic problems in terms of their stocks and flows and feedback loops. This model grew out of work with control systems and servomechanisms and was first applied to industrial processes where lags and multiple feedback loops made simple controls ineffective. Jay Forrester and his colleagues at MIT (Boston, USA) developed and extended these ideas and began to apply them under the name of Industrial Dynamics. The name was generalized to System Dynamics when the model was successfully applied to biological and social systems.

A System Dynamics application begins with the definition of a problem. It then draws in all major patterns of influence that together create the "system" that produces and perpetuates the problem. A successful model is able to replicate these patterns and "produce" system behavior. Different values for variables and different policy structures may then be introduced to simulate how the system would respond to different circumstances or initiatives.

System Dynamics searches for the causes of system behavior that lie within the system, with events "outside" serving as triggers rather than causes. The system boundaries in a System Dynamics model are typically broader than those of other systems models. For example, most of the "transactional environment" of a Socio-Technical System will be **inside** a System Dynamics model, which makes it suitable for modeling situations that do not have formal or official status and may even include competing or adversarial elements.

System Dynamics looks for dynamic patterns rather than discrete events and their actors. It describes these patterns in terms of structural relationships between its multiple positive and negative feedback loops and the levels (stocks) and rates (flows) of its primary variables.

Models using System Dynamics are nonlinear with multiple feedback loops, which allows its use in complex situations where one dominant factor may be replaced by another over time. Any variable is likely to be connected to several different feedback loops. Some of these will be positive or self-reinforcing. Others will be negative, tending to correct "error" to achieve or maintain a

desired goal or equilibrium state. The dynamic behavior of a system is a consequence of the dynamic tendencies of its positive and negative feedback loops and shifts in the dominance of these loops.

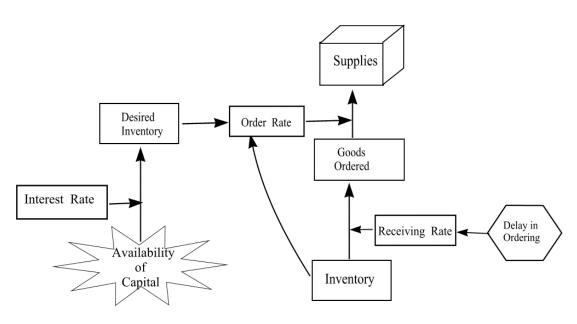
One of the most helpful features of System Dynamics is that it can indicate counter-intuitive behavior or shifts in loop dominance that reverse system trends. Its wide boundaries allow for inclusion of side effects, which are distantly linked to system variables. The process can be used at the macro as well as micro level. In fact, some of the best known System Dynamics applications have been models of worldwide population and resource interactions.

## How To Do It

The production of a System Dynamics model may involve three stages: (1) a set of paper and pencil flow and influence diagrams with their primary feedback loops; (2) a formal rendition of the influence diagram using Forrester's graphic icons for levels (rectangles), rates (valves), and auxiliary variables (circles); and (3) a computer-generated simulation beginning with quantified variables.

The design of a System Dynamics model begins with a problem and a time frame. The factors that contribute to the problem are listed and their structural relationships sketched with particular attention to characterizing them as levels (or stocks) and rates (or flows) that feed or drain them. Levels and rates must alternate in the model; no level can control another without an intervening rate, nor any rate influence another without an intervening level. They need not be physical: for example, a code of ethics that sets a standard for behavior may be taken as a level, or a change in public opinion before an election may be taken as a rate. Variables that contribute less directly are classed as auxiliary variables.

# Figure Eight



Iconic Loop Diagram

The next step is to quantify these factors and the assumptions behind them. Computer simulations can then be run to test the validity of the model. The model will begin from the initial quantified values for the variables and step through them at discrete time intervals (dt). The basic computer model employs a set of first-order, coupled, nonlinear differential (or integral) equations to reflect changes over time, with the chosen time interval small enough so that system behavior appears continuous. More advanced versions may use different mathematical tools. The most direct test is to see if the model simulation yields the current state of affairs from the past recorded values of its variables. Finally, alternative simulations are designed and run to increase the model's sensitivity and usefulness.

Several computer packages are available to run System Dynamics simulations. DYNAMO, for DYNAmic MOdels, has been available in different versions for different machines since 1959. It is currently available for PCs as well as mainframe environments. STELLA and iThink are available for the MacIntosh. They enable the modeler to draw the feedback diagrams on the computer, while the software writes the model equations. Other packages include DYSMAP2, S\*\*4, and Vensim.

Modelers who use System Dynamics recommend that great care be taken in the early stages of the process. The sophistication of the software can produce elegant models from unreliable data or flawed understanding. The software can guide the user in modeling principles (e.g., alternating rates and levels), but it cannot evaluate whether the modeler has defined the problem accurately, included the appropriate variables and their relationships, or quantified them accurately. The only way to accomplish all that is to test each model against system structure and behavior or, if that is not possible, against alternative models and simulations. System Dynamics' literature identifies more than 15 tests that can contribute to model evaluation and build confidence in its structure and behavior. A number of texts are available to help the user apply System Dynamics (see references). New work is presented in the journal, *System Dynamics Review*.

## When To Use it

System Dynamics Models are used to understand and anticipate change over time in puzzlingly complex systems. The information base for conceptualization and formulation of System Dynamics models is much broader than the numerical data base employed in operations research and statistical modeling. Consequently, the System Dynamics approach can be used with what are thought to be "data poor" problems. The approach is sometimes used to gain insight and understanding in a messy situation by sketching increasingly sophisticated causal loop diagrams. This qualitative usage helps policymakers ask better questions and may help anticipate patterns and sources of dysfunctions, even if simulation were not employed. However, the dynamics generated by information feedback and circular causality are difficult to discern without computer support. Serious System Dynamics analyses almost always require simulation to uncover or corroborate dynamic insights.

System Dynamics could be effective in monitoring change as long as modelers keep a close eye on the emergence of any variables not included in the original. The closure of the System Dynamics model, which is useful in understanding systems that remain relatively consistent over time, becomes a weakness when the system is subjected to new and unanticipated variables. A different version of a System Dynamics model could be designed on the basis of the system's perceived new states. Indeed, practitioners emphasize an iterative model-building **process**, not the correctness of a single model.

A System Dynamics model is only capable of running one version of a situation at a time, although it may capture a great deal of variety in the changing values of its variables. Other stakeholders or groups with different cultural or political agenda might bring different assumptions and thus see a quite different picture. Properly handled, however, these different perspectives should be incorporated in model structure and the model used to build consensus.

A System Dynamics diagram can become very complex when actual situations with lots of variables are modeled. In these cases, it is desirable to break up the model into sectors and present them one at a time to avoid having the information it conveys received as noise.

## Comparison/Combination with Other Models

System Dynamics can be used with most of the other models to increase understanding of system behavior or to simulate the future. It is explicitly included as one of the models that may be useful in building the conceptual model in Soft Systems Methodology. It may contribute to the simulation capability of the Socio-Technical Systems search conference. In the Viable System Model's future-oriented System Four, System Dynamics has been used to probe future options. It can assist in building the reference scenario and performing the means and resource planning stages of Interactive Planning. It can also focus on the dynamics within any cell of a Living Systems Matrix. In short, System Dynamics is effective in extending future probes and in filling gaps in other models.

Other models could contribute to a System Dynamics study as well. Soft Systems Methodology might be useful preliminaries to the problem definition phase of System Dynamics. At the testing phase, the tools from Total Quality Management could monitor system activities, while other participative models might be used to monitor buy-in or political acceptance of model recommendations.

Peter Senge and his team have developed a number of management games, which demonstrate the counter-intuitive consequences that can be modeled using System Dynamics.

## Outlook for the future

System Dynamics is an appropriate tool for forecasting trends based on different variables and their change patterns. It is useful in modeling effects on both natural and social systems over time.

System Dynamics will obviously enjoy widespread use as more people become familiar with the model and its supporting software. New and more sophisticated software, including sophisticated probabilistic simulations and groupware applications, are already being developed.

# **Total Quality Management**

Total Quality Management (TQM) is not properly a single model but several. All have in common, however, an emphasis on meeting and exceeding customer expectations and a commitment to continuous improvement. A TQM implementation will normally include monitoring the processes that produce the customer's goods and services with daily measurement, data collection, and statistical tools; providing the information and authority to employees who need to make decisions

about their own work processes and then send suggestions for wider improvements up the line; and developing long-term relationships with customers and suppliers.

The quality movement began in Japan when W. Edwards Deming, and later Joseph Juran, went to Japan to help rebuild their industry after World War II. The Japanese adopted the statistical process controls and philosophy of quality and extended it to include the social and cultural supports that make TQM a way of life in their top companies. Studies of TQM adaptation in medium to large organizations suggest that top quality performers have been working on TQM for up to 20 years. A year or two is needed to get a program underway and to realize the first improvements, then another five to seven years to complete the analyses, correct the identified problems and spread the attitudes that lead to a philosophy of continuous improvement.

What counts as "quality" depends on the specific needs and priorities of the customer. One customer's idea of quality may be characterized by the Stradivarius violin, the highest standard of excellence. Others may value durability and long life, as typified by the rotary dial telephone. Still others may require high levels of standardization so that parts are interchangeable, production is high volume, or delivery of the product wherever and whenever is ensured. Cost is often an important factor for both profit and nonprofit organizations. A producer who can reduce costs and lower prices will be more competitive, while a service provider who can reduce waste will be able to do more with the same amount of resources. Different tool sets are appropriate to different situations: linear approaches that emphasize statistical analysis are most appropriate to production; nonlinear methods are more appropriate to less determinable settings.

#### How To Do It

A group planning to initiate a quality effort might follow these steps:

- (1) Identify the Product. This step may seem obvious, but the thinking that follows "we make bottles" is not the same as the thinking that follows "we make containers for shipping liquids, which must be protected against spillage, breakage, and contamination." Several different definitions may be tried and their implications explored.
- (2) Identify Your Customers. Look at what product you are now offering your customers and your customers' customers as far as the end user and what you could offer them in the future. Look also at how you are supporting them now and how you might support them in the future. This investigation will help set the direction for continuous improvement and may lead to increased collaboration in design or in development of distribution systems.
- (3) Identify Your Key Suppliers. Look at what they are providing to you and what they might provide to you and at the support you are receiving and might be receiving from them. Are there ways in which your relationship might be expanded or improved?

- (4) Identify One or Two Goals. Discuss ways to drive your efforts toward continuous improvement with the people who are involved at every level of the organization to see how it translates in terms of their part of the process and to refine it in light of their comments. Seek opportunities to find out about how others (who are not your direct competitors) do it through a program of benchmarking successful ventures that operate under similar conditions.
- (5) Implement Changes and Evaluate Progress to establish measures. Evaluate the results from changes and share these so that all relevant actors can contribute to making the necessary refinements and adjustments.

The pursuit of quality requires both philosophy and techniques.

Here is the basis of Deming's philosophy, expressed in 14 Points. (See Reference.) Although expressed in the context of a production company, these points are equally applicable to services, whether provided by private business, government, or nonprofit organizations.

## Deming's 14 Points

- Create constancy of purpose toward improvement of product and service, with the aim to become competitive and stay in business, and to provide jobs.
- Adopt the new philosophy...management must awaken to the challenge...and take on leadership for change.
- Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.
- End the practice of awarding business on the basis of a price tag. Instead minimize total cost.
   Move toward a single supplier for any one item, on a long-term relationship of byaty and trust.
- Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs.
- Institute training on the job.
- Institute leadership. The aim of supervision should be to help people and machines and gadgets do a better job...
- Drive out fear, so that everyone may work effectively for the company.

- Break down barriers between departments. People in research, design, sales, and production must work as a team, to foresee problems of production and in use that may be encountered...
- Eliminate slogans, exhortations and targets for the workforce asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the workforce.
- Eliminate work standards (quotas) on the factory floor. Substitute leadership.
- Eliminate management by objective. Eliminate management by numbers, numerical goals. Substitute leadership.
- Remove barriers that rob hourly workers of their rights to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.
- Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, inter alia, the abolishment of the annual or merit rating.
- Institute a vigorous program of education and self-improvement.
- Put everybody in the company to work to accomplish the transformation. The transformation is everybody's job.

A number of techniques may be brought in to help accomplish the quality mission. They include: the PDCA, or Deming cycle, which stands for Plan, Do, Check, Act (to improve or correct errors through negative feedback loops); a number of aids to daily measurement, such as run charts, tree diagrams, and Pareto charts; and a number of planning and consultation methods, including quality circles, cross-functional teams, and Hoshin Planning. The aim of these techniques is to achieve consistency of purpose, implement vertical and horizontal alignment, and develop solid measures of success.

Although some of the tools are sophisticated, many are not. A common one is to use a simple L-shaped matrix to plot the occurrence of one variable against another or against time. A number of excellent works on the subject give step-by-step instructions on how to use the various tools.

Like other systems models, TQM stresses a high level of participation and information sharing, not just within the organization but also between the organization and its principal customers

and suppliers. Joint Application Design (JAD), Just-In-Time delivery, and long-term supplier contracts, and employee tenure are characteristic of a TQM environment.

## When To Use It

TQM is effective when a definable product or service has an internal or external customer or an established context for providing one. TQM is premature to use before the proceeding has been put in place.

TQM may be more difficult to implement when the product is not standard or completely known in advance, when external variables are likely to have considerable influence, or when final results will not be known for some years. In those cases, attaching measures to the processes followed internally or to the criteria set by the customer or client is more suitable. TQM applications have failed when organizations have attempted to bring them in piecemeal, or as a quick fix, or at too low a level, or without changing other inhibiting parameters. Nor is TQM likely to succeed unless team spirit rather than competition exists within and among units.

Management may not always realize that TQM requires a change of attitude from the top to the bottom. This attitude change cannot be expected to take place instantly; it is a gradual process that may continue over months or years and will require continuous investment in training, education, and customer research.

## Comparison/Combination with Other Models

TQM has been used both to integrate the use of other models and to extend the effectiveness of other models for improving their operation. TQM has considerable overlap with the technical side of Socio-Technical Systems and covers some of its social side as well. TQM has also been linked to VSM in articles and workshops. A quality checklist tracing improvements through the five management systems of VSM was developed by the Business School at Liverpool John Moores University (Britain).

## Outlook for the future

Improvements and new tools continue to be added to the TQM toolkit. Some risk exists, however. Because TQM has become a fad, it may be abandoned by many who attempt it because of the time and commitment required. A number of software tools are available to assist TQM applications in specific fields.

## The Viable Systems Model

The Viable Systems Model (VSM) is the best known of management cybernetics models developed by Stafford Beer. It originated in the course of his work applying operational research and cybernetics in the British steel industry in the 1950s. Its usefulness was confirmed during widespread

consultancy applications in the 1960s. VSM is a neurocybernetic model. That is, it draws upon research on the human nervous system, especially on the brain. Beer was profoundly influenced by Warren McCulloch and his experiments with neural nets and by Ross Ashby's discoveries relating to brain models and variety. In particular, he has emphasized Ashby's Law of Requisite Variety, which says that only variety can absorb variety. Regulation depends on matching complexity in the control with the complexity generated on the ground. Beer has applied VSM and related tools in settings from the factory floor to national government. His most ambitious project was modeling the social economy of Chile under President Salvador Allende.

VSM is used to diagnose or design organizational structure and communications. It distinguishes among five management functions and among a number of vertical and horizontal communications channels. Through the principle of recursion, VSM also provides a means to describe and compare these functions at different organizational levels: e.g., from the community to the nation or from the workshop to the international corporation. VSM is most useful when a shared agreement exists about what entity is being modeled (i.e., the boundaries of the system concerned) and what its basic goals are. Beer makes the assumption that viability is a common goal-either long term or, in the case of temporary organizations, long enough to accomplish its intended purposes.

### How To Do It

Groups wishing to use VSM would identify the basic "system in focus" that they wish to model and the context or environment in which it operates, then describe its activities in terms of the five management functions.

(1) System One activities produce something or provide a service for customers in the outside environment. These activities could, in principle, operate as independent units-as viable systems in their own right. An organization may distinguish among its System One activities according to a number of different criteria, such as geographical location, type of product or service produced, kind of raw materials required, type of clientele served, time frame in which performed, or any other criterion that makes sense. Some groups find it useful to sketch out several different models based on different distinguishing criteria. However, one should not mix up System One activities at different levels of recursion, such as looking at provincial and village services together or comparing small, single-product plants with multi-site, multi-product producers.

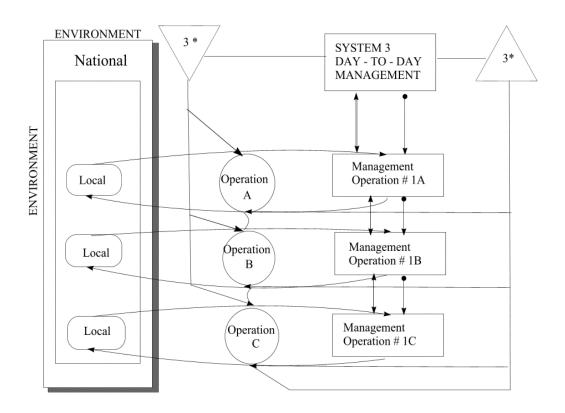
Each System One operation has its own links to their consumers in their local environment, which is embedded in the larger environment of the whole. Each system one also has its own management, which guides the distribution of its internal resources. People at this level, because they are richly connected, will know more about their own capacities and their market needs than anyone at a higher or more comprehensive level. Other management functions exist to support this basic unit level, make it viable, and more effective. They are needed to accommodate each unit within the

whole enterprise. If they intervene too much in the System One management, however, they run the risk of under-utilizing its expertise and stifling its initiative.

- (2) System Two exists to harmonize the activities of the different System One operations, especially with regard to the use of common resources and their administration according to consistent protocols and standards. In cybernetic terms, this function damps oscillation among the different operations.
- (3) System Three manages those activities of the System One units that impinge upon one another or that can be coordinated for greater effectiveness. System Three's attention is internal and present oriented. It looks for the best means of distributing resources to achieve greater synergy and balancing the needs and opportunities of the separate units.

System Three has a special audit function called **Three Star**, which allows it to probe deeply into System One operations in specific areas. Procedures-such as the financial audit, inventories of plant, staff, or distribution capacities, or safety and quality inspections-are examples of System Three Star. Three Star functions can be performed internally or by outside consultants.

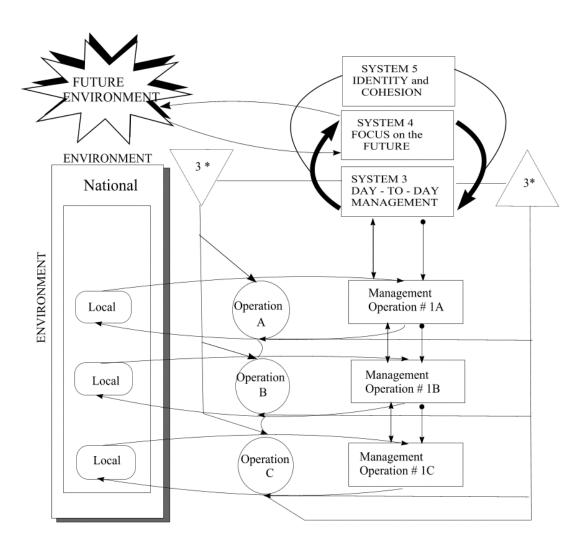
Figure Nine
The Viable System Model
System 1, 2, & 3



(4) System Four is the management function that looks at the future. Like the System One units, system four is directly connected to the environment; this environment, however, is thehypothesized environment of the near, mid, and long-term future. System four is concerned with the expected needs of the organizations' customers and the changes that may occur in its operating context. System Four includes all activities that are oriented toward providing for the future of the organization, including demographic and market research, new product development, recruitment, training, and strategic planning. It provides the principal engine to drive the organization's evolution and adaptation. System Four is closely connected with System Three in order to provide information and to check the feasibility of alternative directions. Depending on the volatility of the environment and the needs of the customers, System Four may be large or small in relation to System Three.

(5) System Five provides closure for the management at this level of recursion. This function maintains the organization on a course consistent with its purpose and identity and maintains the proper balance between concern for present operations and preparing for the expected future. System Five is in action whenever the organization's culture is being expressed. That is, ideally, every member of the organization is represented here.

**Figure Ten**The Viable System Model
Systems 1, 2, 3, 4, & 5



The management functions One to Five should not be confused with actual individuals or boxes on the organization chart. Most individuals will perform duties in more than one functional area at some level of recursion. If an organization has one solo practitioner, that person will perform all five functions.

Systems Five, Four, and Three together comprise the management of this organization's System One at the next higher level of recursion. This structure repeats itself as far as desired. This recursive feature makes using the model practical in extremely complex and diversified organizations.

The model's attention to communications channels incorporates the concepts from communication theory of channel capacity, filters, transduction, and noise in a general theory of organizational autonomy and cohesion. Four communications channels connect System Three with the System One units. A resource bargaining channel takes most of the weight of direct communication. Information, requests, and responses travel continuously in this active, two-way channel. A command channel also communicates directly between Systems One and Three. This channel communicates requirements and decisions that are not debatable and should be used sparingly, except for relaying legal and regulatory matters. The third channel connects System Three to System One via System Two and exists to damp oscillations. The fourth is the audit channel, an intermittent channel that goes through Three Star.

Other channels include the loop between Systems Three and Four, which is called the Three-Four homeostat, because the requirements of the present are balanced with those of the future. Channels connect the different System One managements to their operations. Another channel connects System One operations with one another. It may convey information but also frequently carries supplies and work-in-progress. Separate multi-link channels connect the System One operations and the System Four future probes to their respective environments. Another channel connects significant portions of the environment whose interactions impinge upon the system. Finally, one internal channel speaks instantly from the bottom to the top of the organization. It is called the algedonic signal and conveys messages of pleasure and pain. This channel is capable of overriding other messages, much as the touch of a hot stove does or the sight of your train coming in.

## When To Use It

The VSM can be used whenever an entity has survival as an issue. VSM has been applied in settings as diverse as a bee colony and a natural language, as well as more common organizational settings. It is not a useful model until a "system in focus" is identified.

The VSM was designed to deal with organizational structure and communication. It does not contain capabilities to address either the design of tasks or the behavioral and social means to support them, although it does not conflict with these.

The VSM has been used extensively in the diagnosis of organizations. In this mode, an experienced practitioner can develop and present a rich diagnosis in about a week without necessarily having recourse to systems language and vocabulary.

If VSM is intended to manage an organization, staff will need one to several days training to use it effectively. Some applications have been performed with blue collar and other nonprofessional workers. They did not have difficulty using it within a familiar organizational context.

The VSM has been criticized for being too "hard." Some of these critics object to the rigor of the diagrams that accompany the model **S** a rigor that merely reflects the mathematical basis of the model. Others do not see sufficient emphasis on the construction of realities through subjective interactions. Still others have criticized VSM for being too "soft" because it allows the modeler wide latitude in arranging activities and allocating of significance. In fact, VSM incorporates both hard and soft aspects, which makes it valuable for users who wish to blend them but less valuable for those who wish to concentrate on one or the other.

# Combination/Comparison with Other Models

VSM works well as a "shell" to contain and integrate other models. Beer himself has utilized Systems Dynamics to provide simulations in System Four, His employment of quantified flow charts and real-time information systems overlaps with some features of TQM.

Others have employed the VSM to design a management structure to support SocioTechnical Systems applications, as a broad-brush diagnosis before conducting a Living Systems Theory application, and as a follow-up to an Interactive Planning or Soft Systems Methodology project.

#### Outlook for the Future

Beer himself continues to develop and extend new models to combine with VSM. The most recent of these is Team Syntegrity, a process for involving 30 people in a nonhierarchical in-depth planning effort. Others have begun developing software to help individuals apply VSM. Inquires may be directed to Dr. Barry Clemson, 602 Massachusetts Avenue, Norfolk, VA 23508 (USA) concerning VSM software for MacIntosh.

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Behavioral Science James Grier Miller, Editor Editorial Office P.O. Box 8369 La Jolla, CA 92038-8369 USA

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The quarterly journal for the International Society for the Systems Sciences includes excellent coverage of developments in Living System Theory, although it is not limited to that approach.

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The journal is published bimonthly by Taylor & Francis, 4 John Street, London, U.K., for Hemisphere Publishing in cooperation with the Austrian Society for Cybernetic Studies.

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Systems Practice Robert L. Flood, Editor Department of Management Systems and Sciences University of Hull Hull HU6 7RX UK

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Systems Research Prof. Dr. Henk Koppelaar P.O.Box 356 2600 AJ Delft The Netherlands

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The journal is published quarterly and is the official journal of the International Federation for Systems Research.