

## Systems, Messes and Interactive Planning<sup>1</sup>

### *The Machine Age*

Machine Age thinking was *analytical* and based on the doctrines of *reductionism* and *mechanism*.

*Reductionism* is a doctrine that maintains that all objects and events, their properties and our experience and knowledge of them, are made up of ultimate elements, indivisible parts. For example, the physical sciences, which ruled the scientific roost during the Machine Age, maintained that everything was ultimately made up of indivisible particles of matter called *atoms*. Although the concept of the atom is generally believed to have been first suggested by the ancient Greek philosopher Democritus in about 420 B.C., it languished for almost two thousand years. It was revived in the Renaissance by such important thinkers as Giordano Bruno, Francis Bacon, René Descartes and Isaac Newton; but as a philosophical rather than a scientific idea. It did not emerge as an important scientific concept until the latter part of the eighteenth century. Since then, the concept of the atom, which no one has ever observed directly, has undergone progressive development; for example, it was later taken to be made up of particles of energy. But it remained the ultimate particle of matter. Today some believe the atom itself has parts called “quarks” or “partons,” but they do not deny the existence of some kind of ultimate particle of matter.

Atoms were taken to possess energy and energy was conceived as the power of doing work. Work, in turn, was defined as the production of an effect on matter; for example, moving or transforming it.

Chemists reduced the different kinds of matter to different kinds of elementary substances. Biologists accepted the cell as the ultimate element of life. Gottfried Wilhelm von Leibniz (1646–1716), a major German philosopher and mathematician, postulated the existence of psychic elements—*monads*. John Locke (1632–1704), an equally distinguished British philosopher and prepsychologist, argued for the existence of ultimately simple elements of experience and knowledge—“simple ideas.” Much later Sigmund Freud, the founder of psychoanalysis, reduced personality to the interaction between three ultimate elements: the *id*, *ego* and *superego*. In addition, he and most psychol-

<sup>1</sup>Portions of Chapters 1 and 2 of *Redesigning the Future*. New York/London: Wiley, 1974.

ogists postulated the existence of such indivisible elements of psychic energy as instincts, drives, motives and needs.

Every science sought ultimate elements. But these elements were ranked in order of complexity. Because it was believed that what we experience directly are physical things and their properties, ultimate reality was taken to be physical. Therefore, physics was considered to be the basic experiential science. Even the basic concepts used in other sciences were taken to be derivable from those used in physics. Chemistry was taken to be based on physics, biology on chemistry, psychology on biology and the social sciences on psychology. These dependencies were believed to be one-directional. Nature was believed to be organized hierarchically, as science was.

*Analytical thinking* is a natural complement to the doctrine of reductionism. It is the mental process by which anything to be explained, hence understood, is broken down into its parts. Explanations of the behavior and properties of wholes were extracted from explanations of the behavior and properties of their parts. The temperature of a body, for example, was explained as a function of the velocity of the particles of matter of which it was composed. An automobile's behavior was explained by identifying its parts and explaining the behavior of each and the relationship between them.

Analysis was also central to problem solving. Problems to be solved were first cut down to size; that is, reduced by analysis to a set of simpler problems. The simpler problems were then solved and their solutions were assembled into a solution of the whole. If the problem to be solved could be reduced to a set of independent subproblems, then the solution to the whole was nothing more than the sum of the solutions to its parts. For example, the problem of running a city was broken down into running transportation, housing, health, education, police and so on. It was believed that if each of these functions was managed properly, even if independently of one another, then the city as a whole could be run properly.

When the whole to be explained could not be disassembled into independent parts, the relationship between them had to be understood in order to understand the whole. Consistent with reductionism, it was believed that all interactions between objects, events and their properties could be reduced by analysis to one fundamental relationship—*cause-effect*. One thing was said to be the cause of another—its effect—if the first was both *necessary* and *sufficient* for the other. An effect could not have occurred unless its cause had, and it had to occur if its cause had. For example, if striking a bell is considered necessary and sufficient for it to make a sound, then the strike is taken to be the cause and the sound to be its effect.

Because a cause was taken to be sufficient for its effect, nothing was required to explain the effect other than the cause. Consequently, the quest for causes was *environment-free*. It employed what is now called closed-system

thinking. Laws—like that of *freely* falling bodies—were formulated so as to exclude environmental effects. (The vacuum in which free falling can occur is a *nonenvironment*.) Specifically designed nonenvironments—*laboratories*—were used to exclude environmental effects on phenomena under study.

Environment-free causal laws permit no exceptions. Effects are completely determined by causes. Hence the prevailing view of the world was *deterministic*: everything that occurred in it was believed to be completely determined by something that preceded it. And since it was believed that everything and every event could be reduced to particles of matter and their motion, every phenomenon was believed to be explainable in principle by the laws that governed matter and motion. This belief applied to animate things as well as inanimate. Animate bodies were thus viewed as machines differing in no essential way from inanimate bodies. Hence the physical sciences were believed to be all that is required to explain life. Such a view was called *mechanism*.

Those who held the mechanistic view found no need for teleological concepts—functions, goals, purposes, choice and free will—in explaining natural phenomena. Such concepts were considered to be either meaningless, illusory or unnecessary in science. Philosophers were left to deal with the dilemmas their exclusion produced.

Carried to its limit, reductionistic causal thinking yielded a conception of the *universe as a machine*. It was believed to be like a hermetically sealed clock, an environment-free self-contained mechanism whose behavior was completely determined by its own structure and the causal laws that applied to it. The major question raised by this conception was: Is the universe a self-winding clock or does it require a winder—God? The prevailing belief was that God was required. The world was thus conceived as a machine created by God to serve His purposes, a machine for doing His work. Additionally, man was believed to have been created in the image of God. Hence it was quite natural for men to attempt to develop machines that would serve their purposes, that would do their work.

### *The Industrial Revolution*

Machines, not surprisingly, were thought to be reducible to three basic mechanical elements: the wheel and axle, the lever and the inclined plane. Work was similarly analyzed and reduced to ultimately simple work elements. The process of doing so came to be known as “work study.” Machines were developed to perform as many of these basic tasks as was technologically feasible. Men performed those that could not be mechanized. Men and machines were organized into processing networks the apotheosis of which is mass production and the assembly line.

Mechanization—the replacement of man by machine as a source of physical work—affected the nature of the tasks left for man to perform. Men no longer did all the things required to make a product; rather they repeatedly performed simple operations that were a small part of the production process. Consequently, the more machines were used as substitutes for men, the more men were made to behave like machines. Mechanization led to the dehumanization of man's work. This was the irony of the Industrial Revolution. It is not surprising that a society that thought of the world as a machine came to think of man as one also.

### *The Systems Age*

Although eras do not have precise beginnings or ends, the 1940s can be said to have contained the beginning of the Systems Age. The new age is attached to an intellectual framework that is built over and around the one it replaces. The old framework has not been destroyed or discarded; it has been adapted and extended. The new age is a remodeled version of the old. What was “all” in the past has become a “part” of the present. The doctrines of reductionism and mechanism and the analytical mode of thought are being supplemented and partially replaced by the doctrines of *expansionism* and *teleology* and a new *synthetic* (or systems) mode of thought.

Expansionism is a doctrine that maintains that all objects, events and experiences of them are parts of larger wholes. It does not deny that they have parts but it focuses on the wholes of which they are part. Expansionism is another way of viewing things; a way that is different from, but compatible with, reductionism. It turns attention from ultimate elements to wholes with inter-related parts—to *systems*. Preoccupation with systems emerged during the 1940s. A few of the highlights of this process are worth noting.

In 1942 the American philosopher Suzanne Langer (1948) argued that over the preceding two decades philosophy had shifted its attention from elementary particles, events and their properties to a different kind of element—the *symbol*. A symbol is an element that produces a response to something other than itself. Its physical properties are of no essential importance. Charles W. Morris (1946/1955), another American philosopher, built on Langer's work a framework for the scientific study of symbols and the *wholes* of which they were part—*languages*. The works of Langer and Morris were accompanied by the growing importance given to semiotics, the science of signs and symbols, and to linguistics, the science of language. It was natural for many to maintain that what we know about reality is reflected in the signs with which we represent its content and in the language of which these signs are part. But some went farther and claimed that what we know of reality is conditioned by what lan-

guage we use; hence the nature of reality is to be found in the analysis of language.

In 1949 Claude Shannon (Shannon and Weaver, 1949), a mathematician at Bell Laboratories, turned attention to a larger process of which language was a part—*communication*. He provided a theory that formed the basis for what came to be known as the communication sciences. Almost simultaneously another mathematician, Norbert Wiener (1948) of the Massachusetts Institute of Technology, placed communication into a still larger conceptual context—*control*. In so doing he founded *cybernetics*, the science of control through communication.

Note that this progression from symbol through language, communication and control was one from elements to larger wholes. It was expansionistic, not reductionistic. This expansion did not end with Wiener's work. One more step was taken. In the early 1950s, science went through an "aha" experience and came to realize what it had been up to in the preceding decade: it was becoming preoccupied with systems. Attention was drawn to this concept by the work of biologist Ludwig von Bertalanffy (1968) who predicted that it would become a fulcrum in modern scientific thought. He saw this concept as a wedge which could open science's reductionist and mechanistic view of the world so that it could deal more effectively with problems of living nature—with biological, behavioral and social phenomena—for which he believed application of physical science was not sufficient and, in some cases, not even possible. The concept of "system" has since played an increasingly large role in organizing both our lay and our scientific view of the world. The concept is not new but its organizing role is. Its assumption of this role is a major factor in our "change of age."

A system is a set of two or more interrelated elements of any kind; for example, concepts (as in the number system), objects (as in a telephone system or a human body) or people (as in a social system). Therefore, it is *not* an ultimate indivisible element but a whole that can be divided into parts. The elements of the set and the set of elements that form a system have the following three properties:

- The properties, or behavior, of each element of the set have an effect on the properties or behavior of the set taken as a whole. For example, every organ in an animal's body affects its overall performance.
- The properties and behavior of each element, and the way they affect the whole, depend on the properties and behavior of at least one other element in the set. Therefore, no part has an independent effect on the whole, and each is affected by at least one other part. For example, the behavior of the heart and the effect it has on the body depend on the behavior of the lungs.
- Every possible subgroup of elements in the set has the first two proper-

ties; each has a nonindependent effect on the whole. Therefore, the whole cannot be decomposed into independent subsets. A system cannot be subdivided into independent subsystems. For example, all the subsystems in an animal's body—such as the nervous, respiratory, digestive and motor subsystems—interact and each affects the performance of the whole.

Because of these three properties, a set of elements that forms a system always has some characteristics, or can display some behavior, that none of its parts or subgroups can. *A system is more than the sum of its parts.* A human being, for example, can write or run, but none of its parts can. Furthermore, membership in the system either increases or decreases the capabilities of each element; it does not leave them unaffected. For example, a brain that is not part of a living body or some substitute cannot function. An individual who is part of a nation or a corporation is thereby precluded from doing some things he could otherwise do and he is enabled to do others he could not otherwise do.

Viewed structurally, a system is a divisible whole; but viewed functionally, it is an *indivisible whole* in the sense that some of its essential properties are lost when it is taken apart. The parts of a system may themselves be systems and every system may itself be a part of a larger system. For example, a state contains cities and is part of a nation; all are systems.

In the Systems Age, we tend to look at things as part of larger wholes rather than as wholes to be taken apart. This is the doctrine of *expansionism*. Expansionism brings with it the *synthetic mode of thought*, much as reductionism brought with it the analytic mode. In analysis an explanation of the whole is derived from explanations of its parts. In synthetic thinking something to be explained is viewed as part of a larger system and is explained in terms of its role in that larger system. For example, universities are explained by their role in the educational system of which they are part rather than by the behavior of their parts—colleges and departments.

The Systems Age is more interested in putting things together than in taking them apart. Neither way of thinking negates the value of the other, but by synthetic thinking we can gain understanding of individual and collective human behavior that cannot be obtained by analysis alone.

The synthetic mode of thought, when applied to systems problems, is called the *systems approach*. In this approach, a problem is not solved by taking it apart but by viewing it as a part of a larger problem. This approach is based on the observation that when each part of a system performs as well as possible relative to the criteria applied to it, the system as a whole seldom performs as well as possible relative to the criteria applied to it. This follows from the fact that the sum of the criteria applied to performance of the parts is seldom equal to the criteria applied to that of the whole. The following illustration makes this clear.

Suppose we collect one each of every available type of automobile and then

ask some expert automotive engineers to determine which of these cars has the best carburetor. When they have done so, we note the result. Then we ask them to do the same for transmissions, fuel pumps, distributors and so on through every part required to make an automobile. When this is completed we ask them to remove the parts noted and assemble them into an automobile each of the parts of which would be the best available. They would not be able to do so because the parts would not *fit together*. Even if the parts could be assembled, in all likelihood they would not *work together well*.

An all-star football team is seldom as good as the best team in the set from which the players are drawn. But, you might say, if the all-stars were to play together for a while they might become the best team. Yes, but when they do, some, if not most, of them would no longer be selected as all-stars.

System performance depends critically on how well the parts fit and work together, not merely on how well each performs when considered independently.

Furthermore, a system's performance depends on how it relates to its environment—the larger system of which it is a part—and to the other systems in that environment. For example, an automobile's performance depends on the roads over which it is driven and on the presence and driving of other automobiles on those roads. Therefore, in systems thinking, an attempt is made to evaluate performance of a system as a part of the larger system that contains it. A corporation, for example, is not evaluated by how well it performs relative to its own objectives but rather relative to the objectives of the society of which it is part.

One important consequence of this type of thinking is that science itself has come to be reconceptualized as a system whose parts—the disciplines—are interdependent. This contradicts the hierarchical notion of science in which there is only a one-directional dependence among disciplines and in which physics is taken to be independent of all other empirical disciplines. Scientific disciplines are no longer thought of as dealing with different aspects of nature, nor is nature believed to be organized in the same way science is. The disciplines are increasingly thought of as *points of view*, most of which are applicable to the study of most phenomena and problems. For example, no discipline is irrelevant in efforts to solve ecological problems. Therefore, the environmental sciences include all the sciences.

In the Systems Age, science is developing by assembling its parts into an expanding variety of increasingly comprehensive wholes. The new developments—such as cybernetics; operations research; the behavioral, communication, management and policy sciences and systems engineering—are *interdisciplinary*, not disciplinary. Even the interdisciplines are seen as parts of a still larger whole—the systems sciences—which forms a system of sciences.

In the past, a complex problem was usually decomposed into simpler prob-

lems suitable for different disciplines. Then each discipline would solve its part of the problem, and these solutions would be assembled into a solution of the whole. But contemporary interdisciplines do not work this way; a variety of disciplines work together on the problem as a whole. For example, experts in health, housing, transportation, education and other aspects of urban life work together on a city's problem taken as a whole rather than dividing it into parts suitable for each to work on separately.

Unlike traditional scientific disciplines which seek to distinguish themselves from each other and to spin off new disciplines when new areas of interest develop within them, the new interdisciplines seek to extend themselves and merge with each other, to increase the number of disciplines they incorporate and to enlarge the class of phenomena with which they are concerned. They strive for more comprehensive syntheses of knowledge and therefore thrive on interaction with each other. Systems Age scientists are not bound by loyalty to any one discipline or interdiscipline but move easily from one to another.

It will be recalled that in the Machine Age cause-effect was the central relationship in terms of which all actions and interactions were explained. At the turn of this century the distinguished American philosopher of science E.A. Singer, Jr. (1959) noted that cause-effect was used in two different senses. First, it was used in the sense already discussed: a cause is a necessary and sufficient condition for its effect. Second, it was also used when one thing was taken to be necessary but *not* sufficient for the other. To use Singer's example, an acorn is necessary but not sufficient for an oak; various soil and weather conditions are also necessary. Similarly, a parent is necessary but not sufficient for his or her child. Singer referred to this second type of cause-effect as *producer-product*. It has also been referred to since as probabilistic or nondeterministic cause-effect.

Because a producer is not sufficient for its product, other producers (co-producers) are also necessary. Taken collectively, these constitute the producer's environment. Hence, the producer-product relationship yields environment-full (open-system), not environment-free (closed-system), thinking.

Singer went on to show why studies that use the producer-product relationship were compatible with, but richer than, studies that used only deterministic cause-effect. Furthermore, he showed that a theory of explanation based on producer-product permitted objective study of functional, goal-seeking and purposeful behavior. The concepts *free will* and *choice* were no longer incompatible with mechanism; hence they need no longer be exiled from science.

Later, the Oxford University biologist Gerd Sommerhoff (1950) independently came to the same conclusions as Singer. In the meantime, Arturo Rosenblueth, Norbert Wiener and J.H. Bigelow (1943; 1950), who collaboratively laid the foundations for cybernetics, showed the great value of conceptualizing

the new self-controlling machines developed during World War II as functioning, goal-seeking and purposeful entities. In effect, they showed that, whereas it had been fruitful in the past to study man as though he were a machine, it was becoming at least as fruitful to study self-controlling machines as if they were men. Thus, in the 1950s, *teleology*—the study of goal-seeking and purposeful behavior—was brought into science and began to dominate our conception of the world.

In mechanistic thinking, behavior is explained by identifying what caused it, never by its effect. In teleological thinking, behavior can be explained either by what produced it or by what it produces or is intended to produce. For example, a boy's going to the store can be explained either by his being sent there by his mother or by his wanting to buy ice cream. Study of the functions, goals and purposes of individuals and groups—not to mention some types of machine—has yielded a greater ability to evaluate and improve their performance than did the study of them as purposeless mechanisms.

### *The Postindustrial Revolution*

The doctrines of expansionism and teleology and the synthetic mode of thought are both the producers and the products of the Postindustrial Revolution. But this revolution is also based on three technologies the first two of which were developed during the First Industrial Revolution. One of these emerged with the invention of the telegraph in the first half of the nineteenth century. It was followed by Alexander Graham Bell's telephone in 1876 and Marconi's wireless in 1895. Radio and television followed in this century. Such devices mechanized *communication*, the *transmission of symbols*. Since symbols are not made of matter, their movement through space does not constitute physical work. The significance of this fact was not appreciated until recently.

The second technology emerged with the development of devices that can *observe* and *record* the properties of objects and events. Such machines *generate* and *remember symbols* that we call *data*. The thermometer, odometer, speedometer and voltmeter are familiar examples of observing machines, instruments. In 1937 there was a major advance in the technology of mechanized observation when it "went electronic" with the invention of radar and sonar in England.

Instruments can observe what humans cannot without mechanical aids. But observation, like communication, is not physical work.

The third and key technology appeared in the 1940s with the development of the electronic digital computer. This machine can *manipulate symbols logically*. It is able to process raw data in such a way as to convert them into usable form, into *information*, and to convert information into *instruction*. Thus it is

both a *data-processing* (information-producing) and a *decision-making* (instruction-producing) machine.

The technologies of symbol generation, storage, transmission and manipulation made it possible to mechanize *mental work*, to *automate*. Automation is what the Postindustrial Revolution is all about.

Development and utilization of automation technology requires an understanding of the mental processes that are involved in it. Since 1940 many interdisciplines have been developed to generate and apply understanding of these mental processes and their role in control. These interdisciplines include those previously mentioned: cybernetics; operations research; the behavioral, communication, management and policy sciences and systems engineering. Such interdisciplines provide the “software” of the Postindustrial Revolution just as industrial engineering provided much of it for the First.

Neither the hardware nor the software of the Postindustrial Revolution provides panaceas for our problems. They can be used either to create or to solve problems, and they can solve them either well or badly. The net effect of this revolution will depend on how well we use its technology and the ends for which we do so. The revolution can become retrogressive if we do not control it. It is controllable, but we may not control it or we may control it badly.

The future depends greatly on what problems we decide to work on and how well we use Systems Age technology to solve them.

### *The Organizing Problems of the Systems Age*

Because the Systems Age is teleologically oriented it is preoccupied with systems that are purposeful; that is, with systems that can display choice of both means and ends. Most of what interest remains in purely mechanical systems derives from their use as tools by purposeful systems. Furthermore, Systems Age man is most concerned with those purposeful systems whose parts are also purposeful—with *groups*; in particular, with those groups whose parts perform different functions—*organizations*.

All groups and organizations are parts of larger purposeful systems. Hence all of them are purposeful systems whose parts are purposeful systems and which themselves are part of a larger purposeful system. All the organizations and institutions that are part of society, and society itself, are part of such three-level hierarchical systems.

Therefore, there are three central problems that arise in the management and control of purposeful systems: how to increase the effectiveness with which they serve their own purposes, the purposes of their parts and the purposes of the systems of which they are part. These are, respectively, the *self-control*, the *humanization* and the *environmentalization* problems.

The self-control problem consists of designing and managing systems so

that they can cope effectively with increasingly complex and rapidly emerging sets of interacting problems in an increasingly complex and dynamic environment. The humanization problem consists of finding ways to serve the purposes of the parts of a system more effectively and to do so in such a way as to better serve the purposes of the system itself. Finally, the environmentalization problem consists of finding ways of serving the purposes of environmental systems more effectively and doing so in such a way as to better serve the purposes of the system itself.

### *The Self-Control Problem*

When one purposeful system controls another of which it is part, the first *manages* the second. Management involves *decision making*, and decision making involves *problem solving* whenever the decision maker is in doubt about the choice to make. Therefore, problem solving has traditionally been taken to be an essential function of management. Through systems thinking, however, we have come to doubt the existence of problems and solutions to them. This doubt, and the sense in which "existence" is a part of it, requires explanation.

In the Machine Age, problems were thought of as "out there," as purely objective states of affairs. But John Dewey (1930), the great American philosopher, challenged this notion and argued that decision makers have to extract problems from the situations in which they find themselves. They do so, he said, by *analyzing* the situation. Hence problems are products of thought acting on environments; they are elements of problematic situations that are abstracted from these situations by analysis. What we experience, therefore, are problematic situations, not problems, which, like atoms and cells, are conceptual constructs.

We have also come to realize that no problem ever exists in complete isolation. Every problem interacts with other problems and is therefore part of a set of interrelated problems, a *system of problems*. For example, the race problem, the poverty problem, the urban problem and the crime problem, to mention but a few, are clearly interrelated. Furthermore, solutions to most problems produce other problems; for example, buying a car may solve a transportation problem but it may also create a need for a garage, a financial problem, a maintenance problem and conflict among family members for its use.

English does not contain a suitable word for "system of problems." Therefore, I have had to coin one. I choose to call such a system a *mess*. This concept is as central to this paper as is that of a "system." This paper is about messes. This section is about "mess management."

A mess is a system of external conditions that produces dissatisfaction. It can be conceptualized as a system of problems in the same sense in which a physical body can be conceptualized as a system of atoms. Therefore, problems

that can be decomposed to simpler problems are really messes. Ultimately simple problems, like any ultimate elements, are abstract subjective concepts. Such elements cannot be observed because we cannot conceive of anything that can be observed but not taken apart. For example, we cannot see geometric points; they are abstractions. What we see and call points are small areas. Therefore, even what appears to us as a simple problem is really a "minimess."

In the Machine Age, messy problematic situations were approached analytically. They were broken down into simpler discrete problems that were often believed to be capable of being solved independently of one another. We are learning that such a procedure not only usually fails to solve the individual problems that are involved, but often intensifies the mess. The solution to a mess can seldom be obtained by independently solving each of the problems of which it is composed. This appears to be the case, for example, in our current handling of the urban mess. Efforts to deal separately with such aspects of urban life as transportation, health, crime and education seem to aggravate the total situation.

The attempt to deal holistically with a system of problems is what *planning*, in contrast to problem solving, should be all about. In the Machine Age, a great deal of effort went into the development of effective methods of problem solving but little thought was given to planning. In the Systems Age, more attention is being given to development of effective methods of planning.

### *Planning*

For many years social and organizational planning was ignored and held in disrepute in the United States and other Western nations because of its association with communism. The communists believe in strongly centralized planning. Hence it was incorrectly assumed by many Americans that planning necessarily implies a strong central government or management. It was only after noncommunist France successfully planned its recovery from World War II, and did so without either centralized planning or concentration of power at the top, that we began to understand that planning can serve any political or organizational philosophy, just as problem solving can. It can increase the effectiveness of either a decentralized democracy or a centralized autocracy.

There are many managers and administrators who still do not believe in planning. Attitudes toward it vary a great deal but they can be grouped into four general types: *inactive*, *reactive*, *preactive* and *interactive*. These attitudes are mixed in varying proportions in each individual and organization and the mixture may change from time to time or from situation to situation. Furthermore, a wide variety of attitudes toward planning may be found in any one organization at any one time. Nevertheless, one of these attitudes usually domi-