DOCUMENT RESUME

ED 206 686 TM 810 584

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TITLE Some Contributions of General Systems Theory, Cybernetics Theory and Management Control Theory to Evaluation Theory and Practice. Research on Evaluation Program Paper and Report Series. Interim Draft.
INSTITUTION Northwest Regional Educational Lab., Portland, Oreg.
SPONS AGENCY National Inst. of Education (ED), Washington, D.C.
REPORT NO NWREL-REP-37
PUB DATE Jun 80
CONTRACT 400-80-0105
NOTE 69p.

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Cybernetics; Decision Making; *Evaluation; *Evaluation Methods; Information Utilization; *Models
IDENTIFIERS *General Systems Theory; *Management Control Theory

ABSTRACT

This document, one of a series of reports examining the possible contribution of other disciplines to evaluation methodology, describes the major elements of general systems theory (GST), cybernetics theory (CT) and management control theory (MCT). The author suggests that MCT encapsulates major concerns of evaluation since it reveals that provision of information to a decision-maker is a key process, and that the management function of controlling involves the utilization of information in the making of decisions regarding goals, and allocation and effective use of resources to accomplish these. Since GST and CT are closely related to MCT they are also discussed. The basic GST conceptual model, categories of systems and their properties, and the role of GST are outlined. Special emphasis is laid upon the three related categories of artificial, temporary, and living systems because evaluation occurs within systems possessing structure, process and function: man made organizational settings; settings of an ephemeral nature; as well as within ongoing, but dynamic, "living" systems. CT is identified as the science of control and communication which enables systems to maintain activities towards prescribed goals; feedback constituting the mechanism for displacement of the system due to external factors. (Author/AEF)

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No. 37 SOME CONTRIBUTIONS OF GENERAL SYSTEMS THEORY, CYBERNETICS THEORY AND MANAGEMENT CONTROL THEORY TO EVALUATION THEORY AND PRACTICE

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June 1980

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Published by the Northwest Regional Educational Laboratory, a private nonprofit corporation. The work upon which this publication is based was performed pursuant to Contract No. 400-80-0105 of the National Institute of Education. It does not, however, necessarily reflect the views of that agency.

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PREFACE

The Research on Evaluation Program is a Northwest Regional Educational Laboratory project of research, development, testing, and training designed to create new evaluation methodologies for use in education. This document is one of a series of papers and reports produced by program staff, visiting scholars, adjunct scholars, and project collaborators--all members of a cooperative network of colleagues working on the development of new methodologies.

What is the nature of general systems theory, cybernetics theory, and management control theory and what contributions might they make to educational evaluation? It was originally intended that this monograph would include three sections as a response to this question: (1) a description of the major elements of these three approaches, (2) an integration of these approaches and a discussion of their application in program evaluation, and (3) a collection of examples illustrating the utility of these approaches to evaluation theory and practice. Due to a prolonged and serious illness, however, Dr. Cook has been able to complete only the first section of the intended report. We have nevertheless decided to include this section in our paper and report series, since it does provide an excellent introduction to systems theory, cybernetics theory, and management control theory, areas with which program evaluators should have at least a passing familiarity. Perhaps including this report in our series will encourage others to look to these areas as sources of new methods of evaluation and to build upon Dr. Cook's first steps.

Nick L. Smith, Editor
Paper and Report Series

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SOME CONTRIBUTIONS OF GENERAL SYSTEMS THEORY, CYBERNETICS THEORY AND MANAGEMENT CONTROL THEORY TO EVALUATION THEORY AND PRACTICE

INTRODUCTION

The goal of this monograph is to explore and elaborate upon the potential contribution that three commonly viewed as separate indentifiable topics but in actuality possessing substantial overlap between and among them can make to the concept of evaluation in education. The specific topics are General Systems Theory, Cybernetics theory, and Management Control Theory.

Aninitial effort was made toward this end in a paper the author developed earlier (Cook, 1970). The basic focus presented was that much of the effort at that time devoted to the development of new evaluation models and methodologies was not necessary since the basic nature of management control theory provided a sufficient model for educational evaluation theory and practice. This view was taken because of the prevailing position was that educational evaluation should focus upon the utilization of information for decision-making and consequently necessary systems and procedures for providing such information.

The push toward new models and methodologies came about, in this writer's opinion, because the definition of the concept of evaluation in existence during the early 60's was changed. Early definitions of evaluation focused upon the judgemental nature and valuational character of the concept. Once that interpretation was rejected, and evaluation redefined along the line of information-providing, it became necessary to develop the new models and procedures. As noted above, the basic proposition presented in the earlier paper was that mangement control theory as developed over many years could serve as an adequate model. An understanding of control theory reveals that the provision of information to a decision-maker is a key process. Therefore, an adequate grasp of information-control-decision theory by an educational evaluator could provide techniques and tools to carry out temporary program and project evaluation as well as evaluation of the continuing functions and operations of a parent organization (i.e., school district organization).

The previous paper high lighted the principal topics of information and control systems. A restropective view of this paper reveals that a more fundamental area was omitted, General Systems Theory, Contemporary writings by Cleland Koontz Anthony Emery Head and others on Management Theory emphasize the necessity of looking at mangement from a "systems" perspective. Indeed, the focus is upon developing and operating systems for managing. Given that current emphasis on systems, it seems desirable that the prior paper be expanded to include a discussion of General Systems Theory.

Not only does omission call for such a discussion but commission does likewise. If the emphasis of the current Research on Evaluation project, that of looking at metaphors for evaluation from other disciplines, is to be fulfilled then it would seem that the field or discipline of GST, forming as it does a close relationship with cybernetics and the two combining to form the basis of management control theory, must be examined for its potential contribution to educational evaluation. It is intent of this monographed review three topics noted in the opening paragraph in such a manner they can be easily understood by the novice in evaluation and yet serve as a stimulator for the more advanced professionals involved in both theory and practice.

To accomplish the above goal, the monograph has been divided into four major sections or components. The first component provides an overview of the basic propositions of General Systems Theory, Cybernetic Theory, and Management Control Theory. Interrelations will be established where they seem appropriate and timely to do so. A second section deals with the application of the basic concepts presented to evaluation. The last section provides illustrative techniques from the three dominant areas designed to have utility for the practitioner. A final section presents case problems and how they can be handled from the basic perspectives presented.

It is perhaps worthwhile to state at this point that the focus of the monograph is upon the conceptual and substantive contributions that the three identified fields can make to educational theory and practice. The focus is not upon the applications of administration and/or management theory to the conduct of evaluative activities viewed largely as procedural matters (e.g. activity scheduling, personnel acquistion, conduct of staff meetings, evaluation report briefings, etc.). The view presented here is that evaluation is a management activity. As such, it falls under the general functions carried out by managers for whom evaluators work. The basic propositions presented is that the conceptual base for evaluation as a function can be adequately drawn from the knowledge bases already familiar to those fulfilling the managerial role provided that they have had some exposure to this knowledge base. The management of evaluative activities is important in and of itself and could justify a separate monograph outlining in detail the techniques and tools utilized by evaluation managers. The focus of the current monograph precludes any extended discussion of such techniques and tools.

GENERAL SYSTEMS THEORY - AN OVERVIEW

The purpose of this section is to present an overview of the basic concepts, models, and principles of a general theory of systems, or General Systems Theory (GST) as it is more commonly called. Within this context, a special emphasis will be placed upon the concept of "living systems" as defined by Miller (1978). Selected aspects of the "living systems" concept and its application to organizations have particular meaning for the field of educational evaluation.

The System Concept

The facilitation of an understanding of GST requires an initial definition of the phenomenon of which it is concerned - a system. To define a system is a hard task since there are perhaps as many definitions as there are writers about systems. Klir (1969) in his text, notes as many as 20 plus definitions running from verbal descriptions through mechanical to mathematical formulae. Ackoff (1971) recognized the dilemna of persons using the systems approach by noting that there was not yet a commonly accepted definition of the concept systems. To facilitate movement in the field, the following definition was presented.

> A system is a set of interrelated elements. Thus, a system is an entity which is composed of at least two elements and a relation that holds between each of its elements and at least one other element in the set. Each of a system's elements is connected to every other element, directly, or indirectly. Furthermore, no subset of elements is unrelated to any other subset. (p. 662)

The current concensus with regard to system definition or characterization is a focus upon the general proposition that it is an assemblage of parts, interacting and interdependent, making up a whole which is more than the simple summation of the parts. Thus, a school district is

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a whole greater than the simple summation of teachers, physical plant, books, and other parts independently put together. Von Bertalanffy stresses, in his seminal text General Systems Theory (1968), the use of the term constitutive in constrast to summative. By summative, he means that the parts in a complexity can be understood as the sum of the elements. Constitutive, on the other hand, is that characteristic emphasizing not only the elements but their relation to each other. As he notes, ". . . constitutive characteristics are not explainable from the characteristics of isolated parts." (p. 55)

Other writers elaborate upon the basic definition by noting that systems are organized hierarchies and serve some kind of function or purpose. In brief, a necessary definition of a system includes the idea of purpose or function. For the immediate purpose of providing a background for further reading fo this section, a system shall be defined or characterized as follows:

- A set or assemblage of parts or entities
- interrelated and interdependent yet identifiable that
- operate or interact together or in relationship
- to accomplish a stated function, objective, or function.

As the reader moves through succeeding sections, this basic definition will be expanded in terms of presenting a basic conceptual model of system as well as noting categories of systems, system properties, and the role of General Systems Theory.

In developing any basic definition of a system, two generalizations about systems need to be highlighted. First, any definition or delineation of a system is done so be the person defining the system. That is, the elements or parts constituting the system are established by the person interested in examining that system. Thus, no two persons would necessarily define the given system in the same way. Each person's definition would be further limited by the set of perspectives, knowledge, and experience brought to the system definition act. Persons with one set of life experiences could conceivably define a given system one way while a second person with different experiences would define it another way. Second, all systems are said to exist within a time-space dimension. As Miller points (1978) out, it is easy to conceive of a system (radio-TV-stereo) in a traditional three dimensional space. But what is equally important is the time dimension. Our radio-TV-stereo system, while we are looking at it, is undergoing a process of change with time. All systems are moving through time. When systems are viewed as dynamic, which is the position taken in this monograph, then while we are examining them, they are changing before our eyes. Perhaps, the best we can think of is that we can take an instant photo of our system but even while we wait 10 seconds for the picture to develop, it has undergone change in structure and maybe even in function.

The Nature and Aims of General Systems Theory

An orientation to General Systems Theory (hereafter referred to as GST) is appropriate here because of the basic propositions set forth in this monograph regarding the nature of evaluation. Restructuring the words, GST is concerned with developing a general theory about systems. Von Bertalanffy (1968) reviews the history and antecedents of contemporary systems theory in his basic works, General Systems Theory. In this work, he traces the gradual emergence of concern about the mechanistic nature of the traditional science disciplines with their emphasis on analysis toward a movement concerned with synthesis and the need to move toward a unity of science. In discussing the nature of different fields of science with respect to the role of mathematical expressions and models, Von Bertalanffy notes that such models were applicable to other fields and hence giving root to GST.

> The structural similarity of such models and their isomorphism in different fields became apparent; and just those problems of order, organization, wholeness, teleology, etc., appeared central which were programmatically excluded in mechanistic science. This, then, was the idea of "General System Theory." (p. 13)

He goes on to note that in the past, science has tried to explain observable phenomena by reductionism while more contemporary science has become concerned with what is "...vaguely termed wholeness." (p. 37) Relating this to GST, Von Bertalanffy notes that it is a science of "wholeness" which previously had been a vague, hazy, and metaphysical concept. The significance of GST, for those sciences concerned with organized wholes, would be comparable to that of probability theory for those sciences concerned with chance events.

Given the brief introduction to the idea of GST, the aims of GST have been enunciated by Von Bertalanffy:

- Recognition of a tendency toward integration in the natural and social sciences.

- The center of this integration is in a general theory of systems.

- This theory may be a valuable means for aiming at more exact theory in nonphysical fields of science.

- The goal of the unity of science can be brought closer by the development of unifying principles running vertically through the several individual sciences.

- The consequence of the above four aims can lead to a more integrated science education.

In developing the concept of GST, Von Bertalanffy notes that there is some confusion about relationships between GST and cybernetics and control theory; both key concepts in this monograph.

> Systems theory also is frequently identified with cybernetics and control theory. This again is incorrect. Cybernetics, as the theory of control mechanisms in technology and nature and founded on the concepts of information and feedback, is but a part of General Systems Theory; cybernetic systems are a special case, however important, of systems showing self-regulation. (Von Bertalanffy, 1968, p. 17)

Recognition of this frequent association has been made in this paper by treating these three concepts initially as if they are independent. This writer's strong view that while General Systems Theory, cybernetics theory, and control theory can be considered independently of each other when considered together or in a condition of wholeness serve as the fundamental basis for developing the field of educational evaluation. One restriction has been made and that is to put particular emphasis on control theory as it relates to the management function of controlling in organizations as this function is normally understood. The balance of this section is to be devoted to a presentation of selected systems concepts as they a · elved in contemporary thinking. This section is then succeeding by those of cybernetic and control theories.

Basic System Model

Correlative with the development of the concept of system has been the gradual emergence of a graphical model to facilitate the understanding of structure and function of systems. In its basic form, the schema is given as Figure 1. The system is represented by the rectangular box. At the left is an arrow moving towards the box representing what are "inputs" to the system. At the right is a second arrow representing

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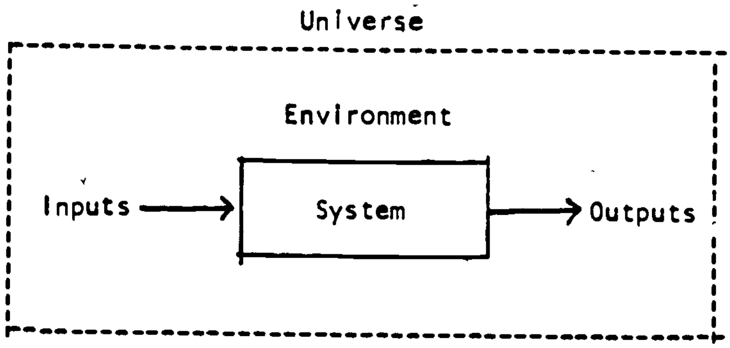

Figure 1 - Basic System Model

what are considered as "outputs" from the system. In concept, the system (box) represents a transformation agent in that it functions to translate or process a stated set inputs into a defined set of outputs. Thus, the function of the system is defined. Most writers agree that it is necessary to include both inputs and the outputs as a necessary part of the description of any system. Surrounding the box are two other rectangles. The area founded by the solid line represents the "environment" of the system. It consists of those events, disturbances, and forces not considered to be in the system but having direct bearing upon it. The dotted line represents the "universe" surrounding the system. It contains remote events and forces which have no immediate or discernable impact on the system.

While it is convenient in the abstract to talk about the environment of system, it makes little sense to do so if one accepts the basic idea that a given system is simply a subsystem of some more complex system and/or interacts with other systems; that is, it is a part of a larger system. In discussing systems, it has become a matter of convenience to state that what lies outside the boundary of the defined system is its environment. Thus the distinction between environment and universe is not in terms of substantive differences, but rather in terms of immediacy, impact, and relevance.

The rectangular box can be viewed as consisting of a set of interrelated and interdependent elements and relationships organized in a configuration designed to accomplish the function of translating inputs into outputs. The concept of a "black box" is sometimes introduced at this point. The concept is generally attributed to Ashby (1956). Using the example of a series of switches and buttons as input, a series of lights as an output, one could develop over time an understanding of what button to push to turn on what light. It would not be necessary to fully comprehend how the balck box accomplished this process. To the extent that one could understand the elements and functions making up the blackbox, the better the predictions of input-output relationships can be made.

By linking two or more systems with their input and outputs as outlined in Figure 2, we can create a still higher level or more complex system with its associated inputs and outputs.

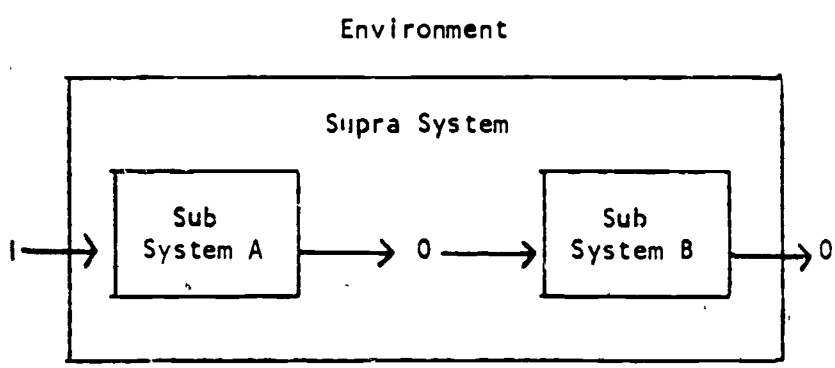

Figure 2 - Simple Supra System

In such a case, the elements now inside the larger box would be viewed as subsystems of the still larger system, which might be called a supra system. Thus, the concept of hierarchy and levels is introduced into systems thinking.

The basic model presented earlier allows for the introduction of the concepts of open and closed systems. Open systems are those permitting a transfer of environmental events across the boundary of the system and, in turn, the system puts out its products to the environment. Thus, there is a constant stream of interaction between the system and its environment. A closed system is one where no events enter or leave, in contrast to an open system where there is an importation and exportation process occuring.

A distinction between open and closed systems has limited utility since most systems are open. Some systems in daily life are nominally considered as closed (e.g., a cooling system in a car that recovers the coolant overflow when heated and returns it to the radiator). The characterization does provide a vehicle for describing what is an open system. To have an open system, there must be a closed system. It is somewhat like saying that if there is an up, there must be a down.

Concepts of Structure and Process

When referencing the basic system model and accompanying definitions, mention was made that the rectangular box was a process unit consisting of a series of elements or components, which can be referred to as its structure. Let us take a look at these two rather fundamental concepts of structure and process.

Structure. The internal arrangment of the components viewed as making up a system in a given time and space is its structure. A structure may remain fairly fixed over a period of time or it may rapidly change. Since almost all systems are considered to be in a dynamic

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state, the structure can be perceived as changing. While picturizations can be made of a given system's configuration, at time now and then again at some subsequent time, such pictures may show change in structure but will not necessarily reveal the speed of movement or the attraction of one component for the next as noted by Miller (1978).

> This (structure) always changes over time. It may remain relatively fixed for a long period or it may change from moment to moment, depending upon the characteristics of the process in the system. This process halted at any given moment, as when motion is frozen by a high speed photograph, reveals the three-dimensional spatial arrangement of the system's components as of that instant. (p. 22)

Several interesting ideas are contained in the above quotation. First, any given system has a structure that can be viewed as a three-dimensional entity moving through a fourth dimension-time. Second, the structure may be stable or quickly changing. Third, the structure consists of components parts. Fourth, our discussion is limited if we hold to the idea that systems are stable. They are constantly changing.

In addition to a system having structural components, they also have levels, echelons, or hierarchies. Smaller subsystems are viewed as making up still larger subsystems <u>ad infinitum</u>. It is generally considered a principle of GST that changes in one of these smaller structural units has some degree and rate of impact upon the other structural components. Each of the structural components has a specific function or task to perform.

Structures can and have been characterized along many different attributes or traits. Color, size, complexity, stability, function are among some of the terms employed.

Miller (1978) perhaps gives a most useful meaning to the concept of system structure when he notes the uniqueness of its meaning suitable for our purpose here.

> The word (structure) is not used to mean stability, or to mean generalized patterning among any set of variables. It refers only to arrangements of components of subsystems in three-dimensional space. (p. 23)

Process. As stated earlier, the basic definitions stressed that system not only had structure but had a function or mission to perform--that of transforming inputs into outputs. The system, therefore, is to be viewed as a processing unit, a transformation mechanism, a transducer, an operator, or any similar characterization implying that its inherent activities involve modification or change.

It is not uncommon in discussion of system theory to have some confusion between the concepts of function and process. For example, evaluation can be viewed as a function or process. In business organizations, one often hears various departments referred to as functional units -- sales, marketing, engineering, etc. These are perhaps best referred to as structural units rather than functions. What each one of these "functions" does, in terms of how its component parts interact to change its inputs into outputs, can be referred to as process. To provide for a common discussion base, the activities involved in producing change shall be identified here as "process".

If the basic element of a system, alone or in conjunction with other parts, is to transform, a question then arises as to what is transformed. Most writers in GST identify three major categories of inputs which are processed or transformed by the system. These are matter, energy, and information. Matter is usually used to reference mass occupying physical space. Thus, steel bars to be machined would be considered as matter. Energy is the ability to do work. Recognition is given to the idea that mass at times can have kinetic energy. Because of this, writers like Miller (1978) often use the term in a hyphenated manner, e.g., matter-energy. Information has both a common interpretation and a technical interpretation. It is also confused at times with meanings. Further, there is some confusion over the use of the terms data and information. The discussions on these concepts have occupied many tomes. It is not possible to clarify all such points in this monograph. It is, however, an interesting aside that several contemporary definitions of evaluation stress the role of "information". Perhaps, a useful way of looking at the concept is again provided by Miller (1978). He notes that what is basically involved is the degrees of freedom available in a given context to choose among or select from a wide variety of messages, signals, patterns, or symbols those to be transmitted. This offers some help with the data-information problem. If one accepts the idea of the symbols and so on as data, the selection out and transmittal process transforms them into information. The activity of selecting out from the many symbols and signals by the system and their subsequent utilization in processing becomes important to successful system operation. It is quite common today to hear individuals talk about "not getting the right signals". When you have a spare moment, watch the transmittal and use of signals between a batter and a third base coach. One of the major concerns of systems adherents is the problem of information overload. Here the situation is that too many signals are present and there is no adequate mechanism to enable the system to sort them out and thus stress is induced causing operating or process breakdown.

Another useful way to look at information is to view it in terms of uncertainity. Information could be viewed as leading to order, regularity, pattern, predictability, and similar terms. Uncertainty, on the other hand, can be viewed as noise, randomness, disorganization, and unpredictability. The reader is referred to the writing of Miller (1978) for further elaboration of this distinction and role of information.

In addition to the in-taking of inputs, process activities produce outputs. In contrast to inputs, there is not a systematic classification of output types. There are, however, classifications in the sense that there are desirable and undesirable outputs. Some times the word waste or by-products are used to describe undesired outputs. Interestingly, information can be considered both an input and output. Again, one should note that many current models of evaluation note that their principal output is information which becomes input to a decision-making or policy setting system or processing unit. There can also be one or more outputs from a system. For example, a grade-processing unit in a university can output not only the student's individual grade card, but also a list of grades by course, by department, if desired.

The assessment of the output, whether one or many, intended or unintended, desirable or undesirable, is a major procedure to determine if the system is operating as it should. The concept of statistical quality control is one mechanism that focuses upon this assessment. A major attribute of quality control systems is that they use sampling procedures and hence statistical inference. The results of the assessment are then used to modify the system in terms of both process and input as needed in order to secure the desired output. A simple conceptualization of this idea is presented in Figure 3. A detailed discussion of the idea is contained in subsequent sections on cybernetic theory and management control theory.

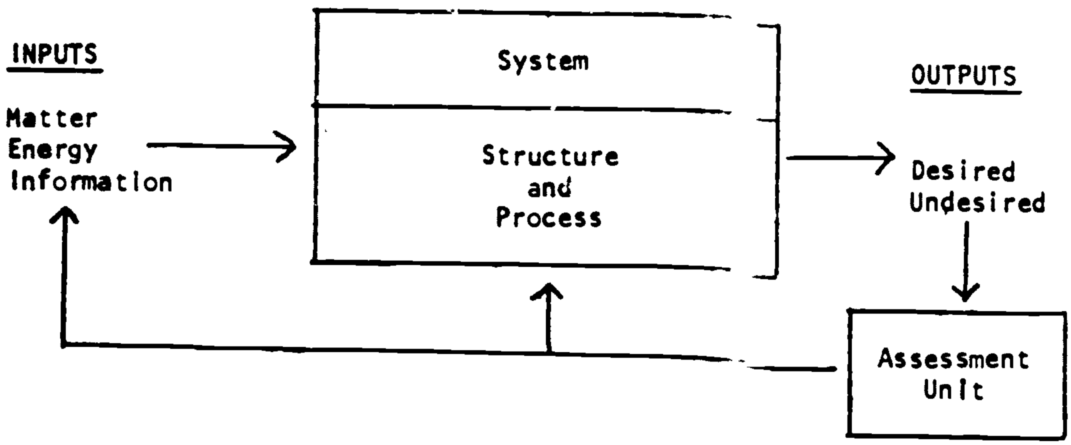

Figure 3 - Simple Structure of Output Assessment

The relationships existing between input, structure and process, and output are fundamental to understanding a given system and to improving that system in terms of its assigned function, purpose, or objective.

Selected System Concepts

In addition to the fundamental terms presented above, there are other concepts and terms used in discussions of systems that should be highlighted. Since the number of concepts is rather large as noted by Ackoff (1971), a somewhat arbitrary selection has been made of several based upon the author's experience in writing and reading about systems theory plus encountering them in operating contexts. The reader is referred to the bibliography for additional terminology, particularly the writings of Young (1964), Hall and Fagen (1956), Miller (1978), Ackoff (1971), and Maccia (1962).

State The state of a system is the relevant properties that a system has at a particular moment in time. The state of the system is described by assigning values to its properties (on-off, awake-asleep). In addition to two properties as noted, we may be interested in several properties at the same time.

In addition to the general concept of state, the terms steady-state and state-determined are often encountered. The concept of steady-state refers to a system's ability to be in a state of dynamic equilibrium. That is, it operates in a manner such that it draws sufficient inputs to retain its basic structure and operations while still carrying out its basic purpose. Thus, a system can maintain its function and operate at an efficient level. There are circumstances where the state of the system can be disrupted by external forces or conditions and its equilibrium is interrupted. The system must then adapt or die. Kart and Rosenzwieg (1976) note that the concept of steady-state is closely related to the concept of negative entropy discussed below. The concept of state-determined refers principally to the condition when the variables composing a system can be fully described or identified, the resulting future or path of the system has been determined because of the presence of the variables regardless of how the initial state was established.

Entropy This term has reference to the random, disorder, disorganization, or lack of patterning in a system. Systems, as defined, will tend toward decay or disorganization when left alone, unless there is an effort made to maintain the system in some desired state. Positive entropy is used to describe the trend toward randomness while negative entropy refers to the effort to sustain organization or non-randomness. Information and entropy are related in the sense that antonyms can be used to describe each. For example, Miller (1978) points out that signal, accuracy, and order can be used to reference information while noise, error, and disorder can be used to characterize entropy.

Integration This concept refers to the actions that one system has upon the other in a bilateral sense -- that it, there is a mutual effect. Thus, we talk about the interaction existing between two units of an organization, say personnel and evaluation. In contrast, the term isolation is often used to refer to the absence of any mutual impact between systems of the same, lower, or higher order. Terms often used along with these two concepts are those of interdependence and independence.

Centralization From a systems perspective, this concept means or is interpreted as referring to the condition that one major element or component plays the major or prime role in the system's operations. In some cases this is by designation while in others the central unit may emerge from among the system components. In a sense, this is a form of leadership. Centralization is needed in order that the system can function optimally in its processing activities. Its opposite, decentralization, means that leadership in the system is spread over many components and thus there is no leading part. The importance of a centralized, leading component plays a major role in the living systems theory which is presented later in this section.

Equilibrium Commonly, this concept is said to refer to things to be in balance, that is, maintain a state of equilibrium. From a systems perspective, it generally refers to the movement of a system back to a given position or point after being disturbed by the forces from the environment. As a concept, it is similar to that of homeostasis and self-regulation. The similarity focuses upon the idea that the system attempts to maintain a certain steady state or balance and acts and behaves in a manner to do so.

The language of system theory is constantly evolving and reflects the meaning given to words by a variety of authors. It is suggested that the reader interested in reviewing systems terminology consult a reference by Young (1964). The synthesis attempted by Ackoff (1971) is also quite useful.

System Properties and Actions

In addition to the definition of the system concept and the terms that help to describe systems (integration, entropy, etc.), it is feasible also to describe systems in terms of the properties and actions they possess. Perhaps one of the most useful statements of such properties for educators was that generated by Maccia (1962) in an analysis of the utility of General Systems Theory for development of an Educational Theory Model. It is not possible to reproduce the rather extensive list of properties and actions reviewed, but some typical statements are presented below. The reader is encouraged to review the Maccia report for a more extensive discussion.

Properties

A system is adaptive, if exchanges between the system and its environment lead to continuance of the system

A system is stable, if change in certain system variables remains within definite limits

A system is degenerate, if it has independence in relation to all of its entities

A system is centralized, if an entity or set of entities dominates the system

A system is in progressive systemization, if, in time, independence tends toward wholeness

Actions

As a system grows, the proportion of its parts cannot remain constant

There is always a constant characteristic alteration between input of a system and its output

The action of a system is effected by the amount of its output

If a system does not feedback some of its output, its stability decreases until the system degenerates. (pp. 3-7)

Properties of systems similar to those presented in the section on system concepts are summarized by Hall and Fagen (1956). They note that several properties commonly noted among systems writers on systems theory are as follows:

- If a change in one part of a system effects other parts, the system is said to behave as a whole or coherently
- If a system changes over time moving from wholes to independence, the system is undergoing progressive segregation
- Progressive segregation can take the form of decay or creation of subsystems reflecting differentation of function (e.g., growth)
- A system moving towards wholes is said to be in the process of progressive systemization
- If one element or subsystem plays a dominant role, in the operation of the system, the system may said to be centralized.

The above statements on system properties and actions are not designed to be an all exclusive list. Rather, they are presented to reflect the kind of statements that have been and can be made about systems. In the discussion on the application of systems theory to the practice of evaluation, we shall return to many of these properties.

Up to this point, an attempt has been made to provide a basic orientation to elementary ideas about systems. With this background, let us now turn our attention to some contemporary writings on systems theory that more nearly fit the context in which evaluation personnel work. This movement will be done by presenting a simple taxonomy about types of systems. An emphasis will then be given to the concept of "living systems" developed by Miller (1978).

Categories of Systems

Like many areas of science, taxonomies or classification schemes exist to characterize various systems encountered. Descriptive labels such as natural system, mechanical system, open system are encountered. Regretably, no one typology or taxonomic scheme is fully accepted by systems writers. In the Ackoff (1971) article noted earlier, he does attempt to synthesize current terminology. Rather than attempting to present the full range of existing system categorization schema, the writings of Miller are used as the focus of a classification scheme presented here. First, because a simple classification is used. Second, reference will be made in subsequent sections to his concept of "living systems". The work that Miller has done n this area will also serve as a s. ong base, for much of what is to be said in this monograph about contributions of system theory to evaluation. The major systems types to be summarized are conceptual systems, and abstract systems. Emphasis is given to his classification of living and non-living systems.

Conceptual Systems. The basic units of a conceptual system are terms, symbols, or other numbers. These units are in relationship to each other and are ordered in a particular way. Examples of conceptual systems are observed in scientific theories, books, and computers. The particular sets and units (called variables) included are those selected by the observor for his or her own purposes. The conceptual scheme, so devised, may be precise and elaborate or loose and simple. The conceptual expressed system may be logical or mathematical symbols and may have some sort or intended to have some isomorphis with an empirically determined relationships. The role of such conceptual schemes is noted by Miller:

> Science advances as the formal identity or isomorphism increases between a theoretical conceptual system and objective findings about concrete or abstract systems. (p. 17)

Concrete Systems. In contrast to a conceptual system made up of words and symbols, a concrete system is a " . . . nonrandom accumulation of matter-energy in a region in physical space-time, which is organized into interacting, interrelated subsystems of components" (Miller, 1978). The units making up the concrete system are also concrete systems and stand in space, time, and causal relationships to each other. Similarily, in the case of the conceptual system, the observor establishes an organized concrete system from unorganized entities but separates the organized concrete systems from unorganized entities by using criteria such as unit similarity, physical proximity, common fate, and recognizable unit patterns. Within this description, Miller presents the nature of open and closed systems noted earlier. For our purposes, Miller establishes within the concrete system category two additional system description - nonliving and living systems.

Non-living systems are those concrete systems not having the characteristics of a living system. Living systems are a subset of all possible concrete systems and possess the following characteristics:

a. are open systems

b. maintain a steady state of negentropy

c. have a certain minimum degree of complexity

d. possess a genetic materials which provides a blueprint or template or program so that the structure and process are determined at origin

e. have a decider; the essential critical subsystem controlling the entire system

f. have other critical subsystems or have a relationship with other living or non-living systems to provide for processes for which they lack a subsystem

g. then subsystems are integrated together to form a self-regulating, active, developing unitary system with goals and purposes

h. can exist only in certain environments and if changes and stresses are produced with which they cannot cope, they cannot survive. (p. 17)

Abstracted System. This type of system is composed of units selected by the observor in the light of his or her particular interests, bias, or viewpoint. Relationships may be determined empirically or be simply concepts. While spatial arrangements are emphasized in concrete systems, this is not the case with abstracted systems since relationships are the major focus. Miller points out that a fundamental difference between an abstract system and a concrete system is that the former can cut across the boundaries of concrete systems to establish a conceptual region. Concrete system boundaries, on the other hand, are set at regions such that all the units and relationships of are included. Abstract systems also differ from conceptual systems in the former has its units and relationships determined while it is not true for the latter.

Supra and Subsystems. The suprasystem for any system is the next higher system of which the given system is viewed as a component. The suprasystem is differentiated from the environment of the system so that the system's immediate environment is the suprasystem minus the system and the complete environment consists of the one system plus the suprasystem and systems at higher levels. To survive, the system must interact with and adjust to the other parts of the suprasystem.

The subsystem consists of a unit identifiable within a system that carries out a defined process along with another unit having a defined structure. The sum of all the structures carrying out a particular process is known as subsystem. Subsystems are variously referred to as parts, components, or elements.

Artificial Systems. There is a category of systems not normally included in categorization of system types which, in the opinion of the author, has high relevance to the context of this monograph. The term "artificial" was introduced by Simon (1969). Simply put, the meaning is that of being "man-made" as contrasted with being natural. Simon's basic proposition or question is whether or not the methods of studying (i.e., science with a focus upon analysis and description) natural phenomenon is adequate or appropriate for studying man-made phenomenon where the emphasis is upon synthesis and normative. This contrast is given emphasis in his writings:

> As soon as we introduce "synthesis" as well as "artifice" we wnter the realm of engineering. For "synthetic" is often used in the broader sense of "designed" or "composed". We speak of engineering concerned with "synthesis," while science is concerned with "analysis". Synthetic or artificial objects--and more specifically, prospective artificial objects having desired properties--are the central objective of engineering activity and skill. The engineer is concerned with how things ought to be, that is, in order to attain goals, and to function. (p. 5)

The focus upon goals and functions above is consistent with systems theory in the sense that systems generally are considered to have functions to perform or goals to be achieved. Simon goes on to provide four signs or indications to assist in distinguishing natural from artificial phenomena:

1. Artificial things are synthesized (though not always or usually with full forethought) by man.

2. Artifical things may imitate appearances in natural things while lacking, in one or many respects, the reality of the latter.

3. Artificial things can be characterized in terms of functions, goals, adaptation.

4. Artificial things are often discussed, particularly when they are being designed, in terms of imperatives as well as descriptives. (pp. 5-6)

A major point is made by Simon of the third characteristic - the role of functions, goals, and adaptation. The accomplishment of purpose in his view requires relationship between three elements; namely, the purpose or goal, the character of the artifact, and the environment in which the environment performs. This view presents the idea of inner and outer environments as Simon identifies them. This dichotomy is quite similar to the concept of system, boundary, and environment presented earlier. Simon points out more clearly the nature of an artifact and its relationship to both environments as referring to it as an "interface".

> An artifact can be thought of as a meeting point - an "interface" in today's terms - between an "inner" environment, the substance and organization of the artifact itself, and an "outer" environment, the surroundings in which it operates. If the inner environment is appropriate to the outer environment, or vice versa, the artifact will serve its intended purpose. (p.7)

The relationship between goal or purpose and the two environments is set forth by Simon by noting that the outer environment sets or determines the condition for attainment of goals. If there is proper design of the inner system, it will be adapted to the outer environment and its behavior will be determined in large part by the latter environment.

The concept of artificial system is useful to us and we shall return to it later. It is introduced here because most of the contexts in which evaluation takes place is within artificial or man-made systems; particularly organizational structures called schools.

As stated earlier, one of the more significant categories of systems is the "living system" as presented by Miller (1978). His writings on the concept are voluminous. An attempt will be made in the next section to provide highlights of the basic ideas he elaborated upon in his text.

Temporary Systems. There is one category of systems not normally included in the numerous taxonomies of systems types, that identified as temporary systems. Since these types of systems occur quite frequently in the work of the educational evaluator, a brief characterization is desirable.

A general description of the nature and properties of such systems as they occur in education has been presented by Miles (1954). He notes that most discussions of systems focus upon an assumption that they are permanent, on-going structures. There is, however, a set of structures with associated processes that assume from the start that they will eventually cease to exist. Typical of such temporary efforts or systems are conferences, task forces, ad hoc groups, research and development, and projects. The principal dimensions covering them can be either one or a combination of three aspects. One is time or duration, a second is the achievement of a certain event, or third, an achievement of a desired condition or state. Miles further notes that the functions of such systems may vary from compensation or maintenance to the inducing of change. It is on the latter function that much stress is placed. Further elaboration of such systems by Miles is made in terms of their input, process, and output characteristics.

As noted, there are a wide variety of ad hoc, temporary types of efforts. Evaluators are often asked to assist in determining if such efforts or systems are accomplishing their function both during their process stage as well as the accomplishment of the final output. One of the more common types of temporary efforts in which evaluators play a major role is that of a project. In several different papers, Cook (1967, 1969, 1971, 1975) advances the position that a project is a temporary effort, or in this context, a temporary system. It has a definable life cycle of creation, operation, and cessation. Over the past several years, a common characterization of what identifies a project has evolved. A project is stated to consist of a specified objective with accompanying specifications to be accomplished with pre-determined (schedule) and cost (budget) constraints (Cook, 1971; Webster, 1978). In order to develop a perspective regarding the nature of projects, Cook (1967) conceived of them as having system properties. Given a task with associated goals as input, a team is assembled to process or operate upon the task, and once the task is completed or output achieved, the team is disbanded. The principles and techniques of management brought to bear upon these situations is now referred to as project management (Cook, 1971).

Projects from both management and evaluation perspectives are of interest because of their unique and temporary nature. Each project is different from another. Thus, the management aspects of structuring the team and conducting operations is modified or made contingent upon the individual case. The one-time nature of such efforts also has implications for evaluators in that evaluation designs are also contingent upon the nature of the effort. The CIPP model for evaluation developed by Stufflebeam (1971) and the concepts of formative and summative evaluation imply implicitly if not explicity the unique and contingent nature underlying projects or temporary efforts.

The impact of projects and their typical focus upon inducing change is consistent with the ideas not only expressed by Miles but also by Toffler in Future Shock (1970). In that writing, he notes that in the future the use of ad hoc groups to solve problems, or the project management concept, will take the place of the permanent, on-going bureaucracy. It is to be replaced with a concept of ad-hocracy or temporary systems.

Living System Theory

General systems theory as normally presented refers to a wide variety of simple and complex structures identified as systems--mechanical, biological, natural, and so on. As noted earlier, Miller (1978) has classified systems into the major categories of living and non-living. The purpose of this section is to highlight the major aspects of the general theory of living systems as set forth by Miller. A decision to provide this emphasis was made on the basis of two general criteria. First, educational evaluation takes place with the general context of a living systems as defined. Second, the essential subsystem critical to a living system is that of a decider. In-so-far as this subsystem is emphasized, there is a strong relationship to many current definitions of evaluation stressing the acquisition and utilization of information by a decision-maker. It is felt that this important relationship could be further developed by looking at selected dimensions of Miller's theory. Since the concepts of cybernetic theory and management control theory reviewed in subsequent sections also put a stress on the communication process involving transmission of information to a decision subsystem, analagous statements between the three theories can be used to facilitate a better understanding of the role of evaluation in the educational context.

Levels of Living Systems. In addition to identifying the major elements of the systems concept as presented above, Miller sets forth the proposition that there are seven levels of complex structures carrying out living processes and are hierarchically arranged as follows: cell, organ, organism, group, organization, society, and supranational systems. He further sets forth the proposition that the systems at each level are composed of a series of 19 critical subsystems. Each system at each level either possesses each subsystem or is parasitic to another system which provides for the missing or absent subsystem.

Of the seven levels noted by Miller, the focus here will principally be upon the level of organizations. Lower levels such as groups and higher levels such as society and supranational systems do have relevance for this paper but time and space tend to prohibit a full discussion of each. Additionally, in this writer's opinion, the current focus in evaluation is upon the use of evaluation results by formally constituted organizations--local school districts, legislative bodies, policy-setting establishments. Society is a rather general descriptor and hence lacks a focus unless one talks about a specific segment of a society. Supranation is a complexity somewhat inconsistent with the thinking of American educational personnel in view of their often expressed strong feelings against national systems of education. Before turning to examination of the organization as a system, a brief description of each of the nineteen critical subsystems identified by Miller will be reviewed.

<u>The Critical Subsystems</u>. In developing the classification of subsystems, Miller gives attention to the role or function of the individual subsystems--does it process matter-energy, information or both? A brief description of each of the nineteen subsystems and its function along with what it processes is presented as Table 1.

For the purpose in this monograph, particular attention needs to be given to the decision subsystem because of its criticality as Miller notes:

> The decider is the only essential critical subsystem and it cannot be parasitically or symbiotically dispersed to any other system. The reason for this is that, if another system carried out the deciding function, everything it controlled could, by definition, be a subsystem or component of it. As the sign on President Harry Truman's desk said, 'The buck stops here'. (p. 67)

The importance of this subsystem cannot be too highly stressed particularly in the case of cybernetics and management control theory since variation from planned direction must be eventually corrected and/or modified through the actions of a "decision" system. The qualitative and quantitative nature of the decision subsystem both in terms of structure and process becomes important in terms of how it chooses to act or not act upon the information presented to it.

The Critical Subsystems and Organizations. As noted above, organizations are considered as one of the seven levels of living systems. In discussing the application of the living systems critical subsystems concept to organizations, Miller recognizes that there have been a wide variety of taxonomies and classification schema developed with regard to organizations. For our concern, schools, universities, state departments of education, and similar agencies fall within the concept of organization as presented. In characterizing organization, Miller advances a distinction between a group and organization that can be helpful to us. He notes that, "Organizations are systems with multi-echelon deciders whose components and subsystems may be subsidiary organizations, groups, and (uncommonly) single persons." (p. 595) He goes on to state that the critical difference between a group and an organization is the structure of the decider subsystem in that the latter always has at least two formally designated echelons or levels in a hierarchy.

Noting that there is no one fully accepted taxonomy of organizations,

Table I - Structure and Functions of 19 Critical Subsystems of a Living System

Structure	Function	Processes: Matter-Energy	Processes: Information
Reproducer	Gives rise to similar systems	X	X
Boundary	Holds components together; protect from stress; allows entry of matter-energy and information	X	X
Ingestor	Brings matter-energy across sy[illegible] boundary	X	
Distributor	Carries inputs from outside or outputs from inside to system components	X	
Converter	Changes inputs into forms for more useful or special processes	X	
Producer	Forms stable associations; provides energy for moving outputs to suprasystems	X	
Matter-energy Storage	Retains deposits of matter-energy for different periods of time	X	
Extruder	Transmits matter-energy output in form of waste products	X	
Motor	Moves system or parts in relation to each other or environment	X	
Supporter	Maintains spatial relationships among components	X	
Input Transducer	Sensory system takes information and transforms to matter-energy suitable for transmission		X

Table 1 continued

Structure	Function	Processes Matter-Energy	Processes Information
Internal Transducer	Receives from components information about alterations, changing them to matter-energy so can be transmitted		X
Channel/Net	Route in physical space or multiple routes by which information markers are transmitted		X
Decoder	Alters information code through input transducer or internal transducer into private code		X
Associator	Carries out first stage of learning process, synthesizes bonds		X
Memory	Stores information for different periods of time		X
Decider	Executive subsystem receiving information from all other subsystems and transmits to them information that controls entire system		X
Encoder	Alters private code to public code interpretability by other systems in environment		X
Output Transducer	Puts information markers, changes markers to other matter-energy forms to be transmitted over channels		X

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Miller notes that many taxonomies are built upon processes rather than structure. With regard to the latter, he outlines some ways of differentiating on the basis of structure: number of persons, number of echelons, structure of the decider (proportion of system's components involved in the decision-making), ration of administrative to production personnel, the presence or absence of particular subsystems, and similar criteria. As for process taxonomies, Miller notes that this is the traditional way of classifying organizations. Such classifications of process as economic, political, educational, recreational, charitable, would be instances of organizations classified as to process or function.

In recent time, several writers have called attention to the concept of "loosely coupled systems" when discussing the application of "living systems" to organisms, particularly organizations. Typical of such writings is that by Glassman (1973). To develop the meaning of what is a loosely coupled system, he contrasts that with the concept of "tight" or fully-joined system as noted by Ashby (1960). The fully-joined system is one where the elements are so tightly related to each other that in the case of a disturbance on any one variable, adjustment is required of all other variables that make up the system. A loosely coupled system on the other hand is one that has more independence or autonomy among its components and thus can better handle disturbances. Coupling is viewed not as an either-or-case, but rather a case of degree.

Such systems handle disturbances in two ways according to Glassman. One way is to have a subsystem that is tightly coupled and which serves to adjust for a given input by using negative feedback. A second way is to create an arrangement wherein only selected variables are allowed access to the system. The former process is an active one while the latter is viewed as being passive. In either case, the result is to permit the system to maintain stability in the case of certain inputs.

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Regardless of how one classifies organizations, the role and function of the several critical subsystems are important. At some risk, the author agrees with Miller that the most important of these is the decider subsystem. Detailed comments regarding the structure and process involved in this subsystem are presented below.

<u>The Decider Subsystem</u>. In terms of structure, the decider subsystem often can be identified through the use of traditional organizational charts. Typically, such charts are ordered in a hierarchical fashion with the chief decider (president, chairman, director, commander) placed in the uppermost box. It should be noted that there are several levels and each of these levels can in turn contain or operate as decision centers. For example, a building principal is at a lower echelon than a superintendent, and makes or should make decisions relevant to that component of the structure known as the building. While such charts are traditionally shown in a vertical hierarchy, there may be and are other forms of arranging the components making up a system. Centralization of decision-making as contrasted with decentralization of decision-making would be illustrative of the latter.

As for process, the decider subsystems carries out a wide variety of tasks as noted by Miller:

> The decider processes of organizations include the development of purposes, goals, and procedures as well as the direction of subsystem processes to implement the system's purposes and goals. In carrying out these processes, decider components adjust organizational inputs and outputs; allocate resources, including money, artifacts, and human subsystem components; set standards for task performance; evaluate the performance of human and other components; determine and administer rewards for and punishments; develop plans; solve problems related to all organizational processes; resolve intraorganization conflicts; and direct the organization's relationships with other systems . . . (p. 644)

As noted, a wide variety of processes falls under the jurisdiction of the decider. While accomplishing these, the decider is also responsible and accountable for them. Because of this, the role of power, authority, and influence become paramount. Numerous interpretations of the nature of these concepts and how they are acquired in organizations have been the focus of many writers. Again, space does not permit a full discussion of these concepts.

In addition to the wide variety of activities carried out by the decider subsystem, Miller also outlines a series of stages and/or phases to the decision process. A brief summary of each is presented below:

1. The establishment of purposes or goals, clarification of objectives, the achievement of which is to move them ahead by a decision;
2. Analysis of information pertinent to a decision including measurements of status, deviations, alternative solutions, and decision-making;
3. Developing a solution which is most likely to assist in achieving the goal;
4. Setting forth commands or signals to implement the chosen decision.

A careful review of the above steps reveals that the process involved is quite common to many discussions of the nature of decisions and decision process (Miller and Starr, 1967; Simon, 1960; Eilon, 1969 are representative). In a recent paper, Cook (1979) synthesized several sources to demonstrate that the concepts of planning, problem-solving, and designing have both structural and process similarities. There is an isomorphism existing between the decision steps or stages presented above and those contained in the paper noted.

The purpose in emphasizing the structure and function of the decision-maker subsystem is to highlight its importance in a living system and provide a background for subsequent discussions of cybernetics

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and management theories as stated earlier in this section. The importance of obtaining information (viewed as the reduction of uncertainity with regard to situations, choices and outcomes) and using it for either system maintenance or adaptation cannot be easily ignored. We shall return to the practical applications of the concepts presented by Miller and others in a subsequent section of this monograph.

Summary

The aim of this section has been to introduce the reader to the general nature of the systems concept. It cannot be considered as full treatment of the concept or of the emerging theory of systems more commonly known as General Systems. It was necessary to introduce the ideas because of the view that the task of evaluation takes place within a system possessing structure, process, and function. Further, many evaluation schema or models are systems designed with function, structure, and process in mind and thus are systems themselves.

Some emphasis or highlighting was given to three more or less related system categories or types--artificial temporary and living. This was done because the context in which evaluation takes place is within man-made, organizational settings, many temporary in nature (projects and program), as well as within settings viewed as more or less permanent (on-going instructional programs) but dynamic or adaptive living entities.

The reader interested in pursuing the systems concept, principles, and theory is referred to the references cited in the text and included in the bibliography.

CYBERNETIC THEORY - AN OVERVIEW

Any review of Cybernetic theory must recognize a condition similar to that existing in the case of General Systems Theory. The basic conceptual nature has been in existence for a long period of human history but society has only recently recognized certain landmarks or milestones. Thus, VonBertalanffy's writing is considered landmark or seminal for GST. In the case of Cybernetic Theory, the writing of Wiener (1948) is considered a landmark in Cybernetics. Credit for the introduction of the term, cybernetics, goes to Wiener circa 1947. The word itself is considered to derive from the Greek word meaning "steersman" and the Latin word "gubernator" which is the forerunner of the current "governer".

A tracing of the development of the basic ideas of Cybernetics in man's history is presented by Beer (1959) and Parsegian (1973) and in the contemporary sense (since approximately 1930) by Wiener.

Defining Cybernetics. Wiener is generally given credit for defining the term as currently used--the science of control and communication in animals and machines. Communication as used here references areas other than the common meaning of the term. The basic referents have to do with message/noise problems in communication engineering, particularly in transmissions. Beer (1975, p. 194) defines the concept as the science of "regulation and effective organization". In a more elaborate definition, Johannsen and Page (1975) in their dictionary of management stress its role in systems:

> Theory of communications and control mechanisms in living beings and machines; or the means of keeping a system or activity self-balancing and positively directed toward a prescribed goal by constant rebalancing of its subsystems or subactivities usually by feedback concept. (p. 97)

One highlight of the definition is the notation about feedback, a concept to which we will return shortly.

A slightly different definition is given by Ashby (1956, p. 6) when he states that "Cybernetics might . . . be defined as the study of systems that are open to energy but closed to information and control--systems that are information tight." This definition is quite similar to the others if one is willing to accept information and communication as being similar to each in usage. Ashby introduces the systems concept and it is interesting that he does. Some controversy exists over the relationships existing between Systems Theory and Cybernetics Theory in the form of their interaction. There are supporters taking the position that these two concepts were and are independent even though contemporary writings on Systems Theory almost always include references to the function of Cybernetics in systems processes, especially that of feedback. It should be noted at this point that Wiener and others early on perceived Cybernetics to be a new science of an interdisciplinary nature. Beer in his book Cybernetics and Management presents the arguments for calling this new concept a science. For those interested, it is suggested that this source be consulted.

Basic Characteristics

Definitions are not always useful since they only define a concept often using other words needing still further definition. A most useful question is what basically characterizes the nature of Cybernetics? Ashby (1956) gives a clue when he states that the most basic concept in Cybernetics is that of "difference or change" that is, two things are recognizably different or there is a change over time. Closely correlated words are variety and complexity along with regulation and control.

Before moving to an elaboration, it might be helpful to point out that Cybernetics deals with the way that machines and animals, to reference Wiener, behave or what they do, not what it is. For this reason, Cybernetics is viewed as being functionally and behaviorally oriented. As Ashby (1956) notes, "Cybernetics deals with all forms of behavior in so far as they are regular, or determine, or reproducible." (p. 1)

Returning to the basic concept of difference or change as characterized by two things being different or one thing changing over time, the idea of ystem becomes helpful. Let us assume a system composed of a set of variables. Now assume that some disturbance from the environment acts upon the system. This disturbance acts upon a variable producing a change or a "transition". If there was a condition wherein the same disturbance could cause several different transitions to occur, each with a given variable, the result would be called a transformation. Thus, one disturbance, given a complex system, could create a variety of transitions. Thus, the system could behave in many different ways. In this sense, the disturbance could create a difference or change in system state.

Given that the simple system operates as above, the problem of variety becomes confounded in the case of complexity. Thus, one of the chief concerns of the cybernetician is how to deal with the variety produced in complex systems. To some degree, we can make a relationship between this position and the typical laboratory experiment. In most cases, the experiment is interested in only one outcome or behavior (the principle of the single variable). In reality, the introduction of a treatment can cause a variety of outcomes. By using laboratory settings, the researcher can control the number of disturbances (potential influential variables) so that the variety of outcomes is reduced to only one state or condition. It is this problem of control the variety of outcomes, given a set of potential outcomes when disturbances impinge on a system, that is the basic focus of concern in Cybernetics. Note that some outcomes are considered "bad" and some as "good" for the system involved.

How is this reduction or variety of outcomes handled? In a most elementary sense, it is done by the insertion of a "regulator" between the disturbance and the potential outcomes or behaviors. A simple example of this step can be presented. To fly effectively, a plane must have its yaw, pitch, and roll maintained with a set of given limits. These dimensions can be effected by such disturbances as wind gusts, shifting of loads (e.g., passengers walking from fore-to-aft in cabin) and so on. The pilot along with devices such as rudder and elevator controls are the regulator which keeps the place from going beyond the limits set in advance for the variables of yaw, pitch, and roll. Two important conditions are to be noted. First, that a desired range is set and second the efforts to maintain conditions with the desired limits. It is also to be noted that the chosen limits are selected from a set of still larger possible values. Thus, the pilot and allied equipment serve as a regulator whereby the variety between the disturbance (wind gust) and the resulting system behavior is controlled. The regulator serves to block the transmission of variety from a disturbance to essential variables. How well it does this can be viewed as a measure of the regulator's effectiveness. If in our example, we were to include not only yaw, pitch, and roll, but also that of speed, altitude, and direction, we would need a still more complex regulator.

Feedback

One of the concepts most commonly related to both Systems Theory and to Management Control Theory, as well as being a very popular concept in society, is that of feedback. While often associated with Cybernetics, the term actually derives from the area of engineering control and related fields as noted by Wiener (1948). The following description of feedback is presented in one of his major writings:

> ...When we desire a motion to follow a given pattern the difference between this pattern and the actually performed motion is used as a new input to cause the part regulated to move in such a way as to bring its motion closer to that given by the pattern. (p. 6)

The mechanisms that carry out this restoration operation can themselves be referred to as a feedback system as Suskind (1962) notes:

> A feedback system is a collection of devices that measure a set of output signals, compare them with an appropriate set of reference signal inputs, and generate a set of error signals. The error signals (or functions thereof) are used in order to control the output variables in accordance with prescribed performance criteria. (p. 285)

It should be noted at this point that we are closely approaching in the above characterizations an idea that Ashby noted above that the basic nature of Cybernetics is difference and/or change. The function of the regulator is to note this difference or change usually caused by external system disturbance, and to reduce the effects, or the variety of the outputs. Feedback is the concept that involves the detection and subsequent correction of the difference or change in order to restore the system to its original path, standard, or criterion as long as the latter serves as the base from which differences or changes are noted.

Feedback Types

In most discussions of feedback, one encounters two commonly used terms, negative and positive feedback. Terms like linear and non-linear are also used but referring principally to mechanical/electronic devices and are beyond the scope of this paper. A brief examination of each of the two concepts is presented below.

Negative feedback. In the common vernacular, negative feedback is often viewed as consisting of telling a person what they have done wrong or saying bad things, and this is something to be avoided. Negative feedback as viewed by the cybernetician and other systems persons has a different emphasis if not focus. Most generally, it refers to the basic idea of feedback. If a system moves in one direction and if the feedback tends to oppose what the system is doing, then it is referred to as negative feedback. The nature of negative feedback can be noted in a discussion of equilibrium as noted by Ashby (1956):

> A specially simple and well known case occurs when the system consists of parts between which there is feedback, and when this has the very simple form of a single loop. A simple test for stability... is to consider the sequence of changes that follow a small displacement as it travels round the loop. If the displacement ultimately arrives back at its place of origin with size and sign so that, when added algebraically to the initial displacement, the initial displacement is diminished, i.e., brought nearer the state of equilibrium, then the system, around that state of equilibrium, is (commonly) stable. The feedback, in this case is said to be "negative" (for it causes an eventual subtraction from the initial displacement.
> (p. 80)

The function of the negative feedback is therefore to keep the system in a state of equilibrium or stability under an assumption that the direction of system behavior is in some desirable direction although the concept can be equally applied to a system headed in some undesirable direction.

Positive feedback. If we accept the prior viewpoint, positive feedback can be described in terms of a correction which is algebraically added in contrast to subtraction from an initial displacement. It is closely allied to the concept of amplification with an amplifier being a mechanism which when given a little, will emit a lot. Thus, a stereo receiver or power brakes can be viewed as amplifiers. They take small signals and make a lot out of them -- loud music and quick stops. Another way of looking at the contrast is to consider an input as being positive and the feedback as being negative. In this case, the feedback would serve to restrict the output of the system. In the positive feedback situation, the input and feedback would combine to amplify the displacement into a still larger displacement. If not checked, the system could in the latter situation ultimately destroy itself if the the limits of the system were not reached first. In order not to have the system destroy itself, negative feedback would be employed as a mechanism for correction. Parsegian (1973) summarizes the difference between the two concepts particularly as they relate to system stability:

> When the feedback opposes the direction of the initial change that produce the feedback, the system tends to be stable. In contrast, when returning feedback cf energy supports the direction of initial change, the system tends to add to the initial energy g[illegible] and to be unstable. (p. 67)

Thus, negative feedback can be correlated with opposition and positive as support.

Role of Feedback

Given the above characterizations of feedback, its role can be summarily described as a mechanism for handling or correcting displacements of the system due to external disturbances. One encounters more frequently the use of negative feedback since it focuses upon restoring or returning a displaced system to its original or desired state. Positive feedback is encountered less often since it deals with amplification which provides for certain mechanical advantages (such as in the case of power brakes) but can lead to a system reaching its limits or destroying itself if there is no negative feedback present to restore to the desired state.

As noted, the concepts are used quite frequently in discusssions of stability and equilibrium of systems. A system is considered to be *adaptive* if it operates to maintain itself within a defined set of limits. Feedback is a necessary correlate of this adaptiveness since it provides for displacement correction. One of the more interesting questions focuses upon the extent to which a system spends its energy in maintenance of the stable state. If most of its energy goes into maintenance, then it has little opportunity to move beyond the limits or change and grow or to develop.

Summary

Cybernetic theory is viewed as being developed separately from systems theory yet contemporary discussions often integrate the concepts. Cybernetics focuses upon the processes and mechanisms involving information and communication, both in man and animal, that enable systems to maintain desired states. The importance of feedback, a fundamental concept of Cybernetics, is stressed in the next section presenting an overview of management control theory.

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Management Control Theory - An Overview

In a previous paper (Cook, 1971), a major position was taken that the development of new evaluation models was not really necessary since existing management control theory provided a sufficient conceptual framework into which evaluation activities could take place. This section reiterates that same position and hence could be omitted by the reader familiar with the earlier publication. For the person unfamiliar with the general concept of management control and its theoretical base, this section is designed to provide an overview or brief introduction.

Nature of Management

It would perhaps be helpful to introduce this section by providing a general definition of management and the functions managers perform.

Several years ago, Koontz (1961) attempted to seek a meaning to the concept of management and referred to the wide variety of definitions as a "management jungle". One writer noted that the many definitions of management applied equally well to the management of General Motors as to a house of ill-repute. Most definitions stress that management is concerned with efficient and effective use of resources to accomplish objectives. To do this, managers are involved in making decisions about both the goals and how resources should be applied to them. Given recognition to the wide interpretations of the management concept, the term here will be used to refer to that person (or entity) that is in the position to make such decisions. Thus, the President of the United States functions as a manager as does an individual who has to make decisions about how his or her resources will be allocated. It is not used in the "elitist" sense that House (1978) refers to in his characterization of evaluation models. Thus, the person, entity, or agency which makes decisions is a manager and engages in management. This view is consistent with that held by Simon (1960) and others. It also reinforces the importance of the "decision" subsystem identified by Miller noted earlier. The absence of a decision-maker or manager, as used here, leads to inefficiency and ineffectiveness.

A distinction is made here between administration and management even though many would not make such a distinction. Administration is used here to refer to the implementation of decisions made by managers. Thus, the school board is the manager while the superintendent is the administrator. This is not to say that administrators cannot or should not influence the managers. In many cases, the managers look to the administrators for the information they need in order to make wise decisions.

Management Functions

The concept of management control theory is perhaps best put in the framework of the traditional functions associated with or carried out by managers. Numerous writers, including Anthony (1965), Koontz and O'Donnell (1968), Johnson, Kast and Rosenzweig (1967) have outlined these functions in detail. Generally, the functions can be classified into four general sets of activities as follows:

> Planning: the identification and setting of goals, purposes, objectives, targets along with the development of means to accomplish them, including choosing between alternatives means.

<u>Organizing</u>: establishing the components, processes, and structures along with differentation of functions necessary to accomplish or implement the results of planning.

<u>Directing</u>: the development of policy and procedures giving direction and/or motivation to personnel to accomplish the objectives.

<u>Control</u>: the assessment by various means of progress against standards set in the plan and taking corrective action needed to restore to plan and/or develop a new plan.

Various writers stress these several functions to different degrees while others differentiate or divide them further. Some contemporary writers reject or reduce the traditional functions and stress the role of manager as leader, communicator, coordinator, and other similar behavioral dimensions. These roles are not rejected here. For purposes of the monograph, emphasis is given to the more or less traditional functions as the appropriate context. It should, perhaps, be noted that management requires a large kitbag of skills and that specialists exist in each dimension. Some specialists deal only with the development of planning processes. Others specialize in creating more efficient and effective organizational patterns and relations; sometimes called "organizational development". Still others focus upon the problems of motivating persons. Another group focuses upon the function of control and its role in organizational behavior.

Even though the importance of the organization as a "living system" with its critical systems was highlighted in a prior section, a fuller discussion of the function of organizing is omitted here

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except in so far as it eventually relates to the role of evaluation. Suffice it to say that many organizations have established a differentiated unit within its structure and assigned to it the responsibilities normally associated with evaluation. Similarly, a complete discussion of the function of directing is not needed. Consistent with the theme of this paper, the prime emphasis will be upon the concept of control supported by reference to its necessary precedent function of planning.

The Control Concept

It might be helpful to examine some contemporary definitions of the concept of management control before examining a generalized theory regarding this concept.

In a recent dictionary on management, (Johannsen and Page, 1975), the concept was characterized as follows:

> Process of measuring and monitoring actual performance in comparison with pre-determined objectives, plans, standards, and budget and taking any corrective action required. Some control activities are automatic, as in automation. (p. 87)

This same idea of assessing performance against standards is contained in a discussion of management systems by Johnson, Kast, and Rosenzweig (1967).

> We shall define control as that function of the system which provides direction in conformance to the plan, or in other words, the maintenance of variations from system objectives within allowable limits. (p. 72)

The same idea is perceived in an extended discussion of the control concept by Koontz and O'Donnell (1968).

> The managerial function of control is the measurement and correction of the performance subordinates in order to make sure that enterprise's objectives and the plans devised to meet them are accomplished. (p. 639)

If the reader desires a comprehensive review of current concepts of controlling, a suggestion is made to read the brief monograph on planning and controlling systems by Anthony (1965). In an appendix, some 29 difinitions of these two functions are presented.

A review of the above definitions reveals that a strong and imperative relationship exists between the functions of planning and controlling. This relationship has been well stated by Koontz and O'Donnell as follows:

> Since control implies the existence of goals and plans, no manager can control without them . . . It is the function of control to make the intended occur (p. 639-640).

The development of systems to accomplish either or both of the above functions have been elaborated upon by LeBreton and Henning (1961) for planning and by Anthony (1965) and Emery (1969) for both planning and controlling.

Cybernetic Relationships

The prior section outlined the general nature of cybernetics theory with emphasis upon feedback to restore a system to designed or desired standards. Relationships between management control theory and cybernetics are quite strong as was noted by Koontz and O'Donnell.

> Managerial control is essentially the same basic process as is found in physical, biological, and social systems. . . In the science called cybernetics, Wiener shows that all types of systems control themselves by a feedback of information on disclosing error in accomplishing goals and itiating corrective action (p. 642).

The relationship between the three concepts forming a basis for this monograph has been put succinctly by Beer (1966) in the statement "Cybernetics is about control, which is the profession of management." The interaction between management and cybernetics has been further

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elaborated upon by Beer in his early monograph on Cybernetics and Management (1959).

Control Theory Elements and Processes

While definitions are useful as means of alerting a reader to emphasis, there is a need to pursue further the concept in more operational terms. What does one do when one controls? Perhaps, this question can be answered by looking at the elements of the concept and the processes relating to them.

> Elements: In order to have control, four essential conditions or elements must exist. One or more might exist in a given context, but effective control requires that all four be present.

First, there must be some "thing" to be controlled. That is, some condition, characteristic, behavior, or object must be identified. In brief, what is being "controlled"?

Second, some device must exist to measure the current state of the controlled entity. Rulers and reports are both devices for measuring the state of a controlled item. It becomes important to stress that even though an object or condition is identified, failure to develop or create valid and accurate measuring devices can lead to ineffective control of the designated condition.

Third, some unit or device must exist to compare the measured current performance to the planned or desired performance and cause some element to take responsive action. This author refers to the earlier part of this statement as comparing "intention to performance" or "shoulds to actuals" as noted in the former case by Greniewski (1965) and in the latter case by Kepner and Tregoe (1965). The second part stresses that such comparisons are not useful unless the result initiates some action.

Fourth, the activating unit noted above must be capable of bringing upon change, either by restoring to intended conditions or setting forth new statements of shoulds and intents along with accompanying standards.

It should be noted that these four elements could be diversified throughout an organizational structure and often are. Using Miller's echelon concept, decisions regarding conditions to be controlled could be established by higher levels of management and decisions about corrective actions taken at that same level. The development of instrumentation and the actual comparison of shoulds to actuals could be handled by lower levels of management.

Control Process

The processes of control are derived from the elements of control. Some writers have referred to the "control formula". Basically, there are three essential steps, each simply labeled, but involving many tasks and activities to be accomplished.

The first step is to set standards. These are basically the criteria against which results are to be assessed or measured. Standards may be either quantitative, qualitative, or both. The more specific the work to be controlled the more specific the standard can be. Thus, the development of standards is more advanced in high technology areas than it is in human service areas such as education where the goals with their accompanying criteria of accomplishment are not so readily defined or conceptualized. The selection of standards is not easy because it requires choices among possible alternatives. Factors such as ease of obtaining, costs associated with obtaining, availability of instrumentation, and so on are involved in the decision to set the criteria or standards.

The second step is to assess performance against the standard. As noted, the conduct of this step in the process requires the development of techniques and tools to conduct the assessment. Again, the nature of the context determines how this process can be carried out. It should be noted that measures of performance in the absence of any standard become, for all practical purposes, "so whats"! Problems associated with this step are many running from the frequency of assessing to that sampling of units involved. Does one measure once a month, once a week, or once a day? Does one assess every tenth unit or every one hundredth unit?

Differences between performance and standard are generally referred to as deviations or discrepancies. The degree of deviation and its consequent importance can be facilitated by the establishment of limits or boundaries of acceptable error. Thus, if our gas gauge is off by a tenth of a gallon or so, we would perhaps be less concerned with initiating action to fill-up than we would be if the gauge was in error by a gallon or more. Regardless of limits, deviations call for corrective action. It is quite common in management literature to refer to the observed deviations as "problems". The basic idea of deviation between performance and standard led Provcus (1971) to develop an evaluation model utilizing this basic process step.

The third step is to correct the discrepancy. The essential activities here are to engage in a problem definition and solution behavior. Knowing that a deviation or discrepancy exists does not tell its cause. The manager must have skills to first limit the

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deviation and then seek to find out why it occured. Having established the cause, alternative solutions can be considered and an eventual choice made. In some situations, alternative choices can be simulated on computer models to see if a desired choice will actually restore performance to plan.

Information and Control

While outlining the basic elements and steps in the control concept, there is a need to give emphasis to selected concepts previously noted in other sections.

In his concept of living systems, Miller put a stress on the flow and transmission of information within and without the system, in our case and educational organization. The review of cybernetics, with its focus on concepts of communication, information, and feedback leading to a system's ability or capacity for self-regulation, provided a strong foundational relationship for the current section.

The importance of information and communication is stressed by a variety of authors when a discussion of control arises. Without a developed flow of information, the various elements and process steps could not be achieved. Thus, the development of systems for delineating, obtaining, and providing information as Stufflebeam (1971) noted become keys to the effective management of a system.

Control could not fundamentally exist without an information flow. As a consequence, there has developed a strong arena of management activity identified as "management information systems". The development of such systems focus not only upon the control function but also upon providing information relative to other management functions. Because of the nature of management concerns, such systems tend to become highly computerized putting out much quantitative data. While important to managers, such s stems are not fully capable of presenting similar quantities of information regarding less quantifiable objectives such as organizational morale, attitude changes, and similar ambiguous goals and objectives. Because of their importance in the operations of systems and control by management it is necessary to take a brief look at some assumptions underlying MIS as it is commonly called.

The linkage between information systems and control systems has been set forth by Ackoff (1967) by stating a series of assumptions commonly made with regard to the role of management information systems. His several assumptions are summarized below.

- Managers suffer from a lack of relevant information
- Managers know what information they need and want it
- Manager's decision making will improve if information is provided
- Organizational performance will improve if better communication exists between managers
- Managers only need to know how to use information and not on how the system works (p. B-150)

Perhaps, the most fundamental assumption is that the more information provided, the better the decisions; the better the decisions the more effective the control. Ackoff presents these relations well in the following statement.

> One cannot specify what information is required for decision making until an explanatory model of the decision process and the system involved has been constructed and tested. Information systems are sub-systems of control systems. They cannot be designed adequately without taking control into account.

The assumptions listed plus the above statement put an emphasis upon decision making. This highlights two additional points. First, it gives emphasis to Miller's idea that the most critical of his 19 sub-systems is the decider sub-system. Second, there is a need to better understand the nature of decisions and the decision making process.

Variety and Control

It was noted earlier that the control concept involves the identification of "things" to be controlled. In a given context, such as educational organization, there are obviously many things which can be controlled or might be the subjects of control. The idea that there are many things that could be controlled leads to a need to introduce a major point of discussion the Law of Requisite Variety as formulated and presented by Ashby (1956).

Without getting into a highly technical discussion, the essential idea is that variety is related to the number of distinguishable elements contained in a given set. For instance, the set consisting of the following:

c, b, c, a, c, c, a, b, c, b, b, a

while containing 12 elements contains only three distinct elements, a, b, and c. Thus, it can be said to have a variety of three. If a set is said to have zero variety, then the elements are all of one type.

For purposes here, the idea that the greater the variety existing in a given set, and if there is a desire to regulate that set and its elements, there is need for a control mechanism to deal with the existing variety. Thus, the more variety, the more control mechanisms are needed. Perhaps, a simple example might provide some insight.

Let us say that a college offers only one undergraduate bachelor's degree (B.A.). The monitoring of the degree is easy since there is

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little or no variety. But let's say that a BS degree is to be offered. Thus, increasing the number of degrees to two. Then there is a need for a system to monitor this new degree. Whereas we had one staff member monitoring only one degree, we now might have to have two staff members, each one monitoring a separate degree. Thus, the more variety in the set, the greater the control mechanism. Beer (1975) provides a somewhat similar example in showing the relationship between the number of autos on the road and the number of policemen needed to monitor their behavior. Fortunately, the culture issues a set of rules of the road which are obeyed by most drivers thereby reducing the needs for having a police force that would involve a one driver-one policeman relationship. The implications of this Law of Requisite Variety take the form that the more variety there is the more there is a need for a control system to monitor the variety as may be noted in the following comment by Beer.

> Whatever element of a system needs keeping in control . . . this element is capable of generating a certain amount of variety. The measure of variety is the total number of states available to that element. Requisite Variety in the control of a system entails a capacity to match that number of states for the system at large. Every quirk, every change of mind . . . each would be monitored and checked . . . Unless a regulator can attain to Requisite Variety, it will not be effective - that is Ashby's Law. (p. 195)

The accomplishment of this can be obtained in Beer's thinking by one of three ways. First, establishing a one-to-one correspondence between controller and controlled. Second, to reduce the variety available to the "runaway" elements of the system (e.g.) fingerprinting as a way of reducing suspects. Third, amplifying the control variety. The latter consists of increasing the amount of information available to the controller. Thus, the more a policeman knows about a criminal and modus operandus the more likely a narrowing down of suspects can take place. Variety reduction in the controlled and variety amplification in the controller are on opposite sides of the same coin and involved, as Beer notes, the basic commodity of information. A major task is that of selection of information. Beer illustrates this idea in the statement below.

> If the criminal can select out the times and location of police surveillance, there might as well be no police at all. If the police can select out the suspects who have not committed a crime, the actual criminal has no chance at all. (p. 196)

Decision-Making

An earlier paragraph noted that a strong relationship existed between information and decision-making. Let us return to this idea and briefly review the nature of decision-making. Before doing so, the point of view is taken here consistent with that of other writers such as Simon (1960) that the basic managerial role and function is that of a decision-maker.

Eilon (1969) in writing about the nature of decision notes that while there has been much written on decision theory there has been few clear attempts to define a decision. He notes that a decision involves a conscious choice to do something. In most cases, this choice is judgemental in nature only occurs after some deliberation of alternatives. He then goes on to present a schematic model for the process of or mental activities involved in decision-making. The basic steps in the process are (1) the presence of information input, (2) an analysis of the information, (3) the specification of performance measures for determining possible courses of action, (4) the creation of a model of system behavior for which a decision is to be made,

(5) the establishment of a set of alternatives, (6) the prediction of outcomes, (7) the establishment of a criteria for choice, and finally a resolution. The process steps presented are quite common although various authors will vary in the number of steps. Some contemporary concepts identifiable with the above steps are systems analysis, cost-benefit analysis, and economic analysis.

In many discussions of decision-making characterized by the above process sequence, writers often noted that the process can vary from a rather automated one to being highly personalistic. For instance, Simon (1960) notes differences between programmed and non-programmed decisions. In the former, choice or resolution is made by previously established rules while in the latter each decision is rather unique in the sense that there may be no or very few rules to assist in making the choice. To some degree, this dichotomy perhaps is best represented by a certainty dimension. The more certain we are about consequences, the more likely we can operate by rules. The less sure we are about consequences, the more uncertainty operates and thus makes decision-making a risky business. Regardless of how structured the process becomes, a major question centers around the amount of what Ofstand (1961) refers to as personalistic control that the decision-maker retains in the process of decision-making. The importance of personalistic control has been highlighted by Eilon (1969).

> We have already seen how a data processing facility can encroach on the decision-maker's domain by taking over parts or the whole function of analysis. Similarly, when the decision process as a whole becomes more and more impersonalistic, it simply follows the rules, and the rules are sufficiently detailed to cater for an ever increasing number of contingencies to obliterate the effect of the individual decision-maker. In the extreme case, when control is completely impersonalistic,

> the decision-maker ceases to have a meaningful role; he ceases to be a decision-maker. (p. B-189)

In order to assist the decision-maker, a wide variety of techniques have been made available, the details of each being beyond the scope of this paper. Beer (1966) in his book Decision and Control provides an excellent summary. In introducing the several approaches, he notes that decision theory consists of the knowledge base relevant to the process of selecting the best decision or optimization of the result. The general approaches noted by Beer are (1) Geometric (search theory), (2) Statistical (Markov processes, queue theory, inventory theory, etc.), (3) Algebraic (linear programming). Most of the techniques are highly quantitative in nature.

Given the above nature of decision-making, what is its relation to control theory which is the thrust of this section? It is asserted here that the basic nature of control theory involves the basic elements of decision-making. First, choices have to be made as to what is to be measured, what standards are to be set, how measurements will take place, how deviations are to be noted, and most particularly, what choice of corrective action shall be taken to restore the system to its original or new state. In the final analysis, we may only be able to separate out theories of control and decision for purposes of better understanding of each but in reality these are highly overlapping processes.

Summary

The purpose of this section has been to present an overview of the management function of controlling as it may be distinguished from that of planning or organizing. Discussion of information-processing and decision-making were included because of their relevance to the steps involved in the control process. The next section of the monograph presents an integration of the three sections on systems theory, cybernetics theory, and management control theory in terms of their practical application in the evaluation setting.

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