SYSTEMS MANAGEMENT: A GENERAL OVER VIEW
Part I - The Underlying Concepts and Approaches

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This is the first of a three part article concerning Systems Management. In Part I the conceptual systematic framework underlying the subject is discussed together with various current approaches adopted to translate the ideas into reality. The role of system dynamics in this framework is emphasised. In Parts II and III, to appear later, the author explores the breadth of application of system dynamics through a series of examples and presents a case study of the application of system dynamics to national development planning in the Lebanon.

1. INTRODUCTION

In the beginning management simply meant the owner of a business telling his subordinates what to do. With the emergence of unions, labour relations became more sensitive and it became necessary for the owner-manager to define the function of each employee in detail. With the advent of the "scientific management" movement pioneered by Frederick W. Taylor, the problems of management functions and management-employee relations in the era of mass production seemed to be solved.

As is often the case, the solution of one problem created a new one. Principles of scientific management such as work-simplification methods undoubtedly helped to foster such innovations as standardization and the division of labour. As the idea of division of responsibility worked its way upward from unskilled to skilled workers to supervisors, a complex hierarchical organizational structure emerged which was not amenable to treatment using Taylor's straight-forward approaches. Management's answer was, and still is, specialization – replacing the entrepreneur with the organization man. Specialization set the stage for what is called the traditional or classical areas of management – manufacturing, marketing, finance and accounting, personnel, research and development, etc.

Management has achieved professional status. Its study has been formalized in thousands of schools and colleges throughout the world. Its practice is respected as an intellectual challenge, based on an underlying structure of principles rather than on rules of thumb.

Three individual schools of thought have emerged to establish the foundation upon which the management profession can grow. The first may be called the management theory approach. It perceives management as a process of achieving objectives with and through people organized in the traditional or classical areas mentioned above, which are seen to be as essentially the same whether in business, government, or any enterprise. Further generality is achieved in that the principles of the management theory approach – tasks, functions, activities – are seen to be the same whether at the level of president or foreman in a given organization.

A second school of thought which we shall call the empirical approach identifies management as gaining experience by drawing generalizations from the study of successful and unsuccessful case histories.

The third approach we will refer to as systems management. The objective of this paper is to describe this relatively new way of thinking about management that should be helpful to developing countries' executives and decision-makers in both public and private sectors, irrespective of the size of the organization, or the nature of the goods or services.

II. SYSTEMS: THE CONCEPTUAL FRAMEWORK

2.1 The Systems Age

Six thousand years ago, men began to produce food rather than to look for it and this was the beginning of farming as a profession. The use of irrigation and the construction of the permanent communities that followed ushered in the profession of engineering. The new irrigation towns permitted a certain degree of specialization, creating the first social classes consisting of farmers, buildings, doctors and administrators, thus institutionalizing the first professions – agriculture, engineering, the military, medicine and management. Professional practice was simply the art of using accumulated experience to help satisfy the obvious physical needs of mankind. The approach was to provide a technology in the form of a product, an artifact, a service or a process which represented the solution to the problem at hand.

A society achieves the trappings of a civilization when a portion of the populace is freed from the necessity of guaranteeing its own survival – finding food, shelter, protection, etc. Only then is there time available to interpret the movement of the stars, to study nature, and to ponder existence. The first pure sciences were astronomy, physics, mathematics, philosophy, and religion. Whereas prehistoric man discovered by finding, civilized man discovered by finding-out. But discovery is a subjective event that acquires importance only if applied practically. The pure sciences were to have little or no impact on the professions for centuries; the accumulation of scientific knowledge was to exist as an end in itself. The Renaissance Period marked the separation of science, religion and philosophy, making possible the liaison between physical science and the professions which culminated in the Industrial Revolution and the beginning of the machine age.

The interacting role between the pure physical sciences and the applied professional sciences is referred to as the technological cycle. The activities in the loop are research, discovery, analysis, invention and design. Classic examples abound in science and engineering: Hertz, a scientist, established the theory of radio waves enabling Marconi, an engineer, to develop the apparatus that sent the first transatlantic wireless message. Similarly, the cycle can be, and usually has been, initiated by engineers. Thus, when the French scientist, Carnot, laid the foundation for the laws of thermodynamics, he took as his point of departure the steam-engine, the invention of James Watt, an engineer.

The professional sciences – agriculture, engineering, medicine and management – have evolved from purely art to the adaptation of physical science to human needs. But what are mankind's needs? For the last 100 years a new breed of scientist, the social scientist, has been seeking answers to this question.

The history of civilization is the history of technology. Historical periods are identified and classified according to the dominant technology, such as the Bronze Age, the Iron Age, the Machine Age, etc. The Technological Era was dominated by three positive feedback loops that generated and continue to generate exponentially increasing growth in fundamental knowledge of nature, in fundamental knowledge of society, and in technology. Why then is it so hard for us to solve contemporary problems?

One of the paradoxes of the Machine Age is that in spite of the rapid pace of technological change and growth in fundamental knowledge, solving contemporary problems has not become easier. The reason is overspecialization – the tendency for professionals to narrow their focus and for scientists to compartmentalize their knowledge. The results were inevitable: (1) within disciplines, there is needless replication of research and duplication of effort; (2) between disciplines, we find authors tending to differentiate their findings with contrived superficiality rather than contributing to the unity of science; and (3) throughout the professions and the scientific disciplines, there is a lack of social concern simply because the social need rarely expresses itself in a form to which the specialists' knowledge is simply and directly applicable.

Historical eras and ages do not have precise beginnings, but around the World War II years the systemic concept began to assert itself in scientific-technological thought. The Systems Age might have started with the pioneering work of the Radio Corporation of America in the 1930's; with operations analysis which was used so effectively by the English in the Battle of Britain in 1940; with the Manhattan Project in the U.S. which produced the first atomic bomb a few years later; or with the publication of "Cybernetics" in 1948. In any event the technological and cultural age associated with individual machines – The Machine Age – ended, and it was replaced by the Systems Age.

2.2 Systems Concept

The idea that the dispassionate and yet clear mind of the scientist can aid in problem solving is by no means new. Plato had it many years ago when he formalized his thoughts on the model for a city-state in his treatise, The Republic. While its roots are as old as science, the systems approach is still in its embryonic stage leading to an honest lack of agreement in the definition of terms, as well as a lexical laxity in their usage.

A system possesses several important characteristics: structure, wholeness, openness, function and purpose. Considering each: a system is a set of interrelated elements; its structure is often, but not necessarily, hierarchical. Second, a system possesses wholeness; it is more than the sum of its parts. For example, an all-star team is seldom as good as the best team in the set from which the players are selected. Third, a system is open; it interacts with its environment – influences it and is constrained by it. Functionally, a system may be viewed as a process converting inputs to outputs according to certain established rules of transformation. This fourth characteristic of a system provides the basis for the "black box" concept in which the grouping of the details of the input-output transformation in a transformer or "box" as if the system were devoid of structure, becomes a matter of convenience either because a knowledge of the structure isn't necessary or because it is too difficult to deal with. Purpose, the fifth characteristic of a system, is perhaps the most significant. Systems are self-organizing and self-renewing. They are self-renewing in the sense that an element may be replaced over the lifetime of the system without the system losing its identity. Self-organization permits a system to select goals and objectives and the means of achieving them.

The basic tenet of the Systems Age is that a "systems approach" can be used to advantage on any definable system. The systems approach is the modus operandi for dealing with complex systems. It is holistic in scope, creative in manner and rational in its execution. Thus, it is based on looking at a total activity, project, design or system rather than considering the efficiency of the component tasks independently. It is innovative in that rather than seeking modifications of older solutions to similar problems, new problem definitions are sought, new alternative solutions generated, and new measures of evaluation are employed if necessary.

The systems approach is an amalgam of scientific approaches to conceptualizing problems and solving them through research, design (or synthesis), and analysis. In order to interpret the systems approach in these terms, it is instructive to consider again the "black box" concept of a system. The system design task is to find the system which will produce a specified output from a given input. The other two activities – research and analysis, can be described in a similar manner. The objective of science in this context is the discovery of the laws affecting the transformation from input to output for the phenomenon being studied. The task of systems analysis is to determine the output for a given input or to find the input which will achieve a certain output.

A true appreciation of the systems approach and its potential application to management, engineering, or the social sciences cannot be gained simply through semantic definitions, journalistic circumlocution, or the assembling of a potpourri of anecdotes and recipes illustrating the various tools and techniques. An understanding of how problems in the Systems Age are viewed ("systems philosophy") and conceptualized ("systems methodology") is needed.

2.3 Systems Philosophy

A problem is a known unacceptable situation which can be improved by various actions. Successful solving requires finding the right solution to the right problem. The problems we select for solution and the way we formulate them depends more on our philosophy than on our science. One of the most profound differences between Systems Age thinking and Machine Age thinking is our interpretation of problems.

In discussing these differences it must be borne in mind that the Systems Age is attached to an intellectual framework that is superimposed on the one it replaces. Machine Age thinking still prevails. It is analytic which means cutting problems down to size, solving the sub-problems, and assembling the solutions. Systems Age thinking is synthetic in that a problem is not approached by taking it apart, but by first viewing it as part of a larger problem. Systems analysis is always performed within this context.[1]

Under Machine Age thinking a solved problem was put to rest. We know now that this is indeed a naive and erroneous assumption. One generation's solution to a problem may be totally unacceptable to the next generation. Even benign solutions require continuous maintenance.

In order to understand the Machine Age view of problems, one must try to ascertain the motives which have led men to the investigation of philosophical questions. Two groups of motives were those derived from religion and ethics, and those derived from science. Most of the philosophers of the past may be classified in one group or the other depending upon their main interests; only in a few do we find both groups of motives strongly present. The dominant opinion was that it is from science that philosophy should draw its inspiration. The scientific philosophy of the Machine Age aimed only at understanding the world and not at improving it. While proclaiming itself as the science of the general, its essence as thus conceived was analysis, not synthesis. The approach was the division of traditional problems into a number of separate and less baffling questions. The maxim of success was: "Divide and Conquer". The ultimate end was the conceptualization of the world as a whole and the unity of science. But one does not accomplish either through reconstruction of the pieces into which they have been disassembled.

Machine Age philosophy is wrong because it assumes that the structure of nature, society, and the world is isomorphic with the structure of science. Nature, society and the world are not disciplinary and the phenomena and the problems they present to us are not divisible into disciplinary classes. In other words, nature, society and the world are not organized in the same ways that our knowledge of them is. Our academic disciplines may be more convenient ways of organizing our knowledge than applying it. Whereas Machine Age disciplines seek to distinguish themselves from each other and to develop new disciplines from within in keeping with the doctrine of reductionism, Systems Age disciplines adhere to the doctrine of expansionism that leads them to strive to incorporate new phenomena, with new disciplines formed through merging[2].

One impetus for the system sciences, including its charter members – cybernetics, operations research, computer science, automatic control engineering etc.; its hybrid disciplines – social psychology, social engineering, biochemistry, bioengineering, etc.; its fellow travellers – ecology, ergonomics, philosophy and mathematics; and its professionally-oriented derivatives – systems engineering and systems management, is to put back together again a world that generations of analytic science have taken apart. This movement is referred to as general systems theory. Because the applied system sciences in their inception relied to a large extent on tools and techniques of the traditional disciplines, combined with the practioner'sexperience and intuition, a theoretical foundation from which methodological procedures could be derived was needed. One of the objectives of general systems theory is to provide such a foundation. What has emerged is less a body of doctrine than a point of view for uniting specialists and conditioning generalists.

Unlike traditional science, no sharp dividing line can be drawn between "pure" and "applied" system science. There are no high priests exclusively responsible to their own inclinations. Another safeguard against superficiality is the tendency for systems practioners to be "T-men" – professionals who preserve depth in their original area of expertise (the vertical stem of the T) while striving for breadth (the horizontal cap of the T). Unlike his traditional counterpart, the systems scientist does not take refuge in a well-tended little plot of specialized knowledge; he realizes that society is served only when his insights are shared with others outside his disciplines and when their combined insights are brought to bear on a real-world metaproblem.

A metaproblem entails variables from more than one academic discipline, involves the necessity to impose some sort of balance between two or more apparently competitive ends, and is generally susceptible to ethical interpretation. These are the problems that are *not* sought by the traditional discipline-bound scientists because they won't and can't solve them; these are the problems that are *not* brought to the systems scientists because they can, and (hopefully) will, solve them. There are three reasons for metaproblems tending to remain outside any formal problem discipline: (1) normal science's conceit, (2) bureaucratic arrogance, and (3) technocratic apprehension[3].

First, metaproblems escape scientific attention because the disciplinary sciences are not prepared to attend to them. Neither the traditional approaches in the soft sciences nor the hard sciences suffice for solving metaproblems – the former are verbal, qualitative and do not permit manipulation; the latter are wrapped obscurely in the mathematics of calculus and are only useful for simpler sub-problems. Then there is the disclaimer that value-ridden issues are not the proper province of science anyway – a self-serving excuse for avoiding complicated, intractable problems so as to concentrate on simpler questions that guarantee quick completion experiences.

Second, metaproblems and their issues are never analyzed through the manipulation of fact and quasi-optimal trade-offs.

They are conveniently framed as mere value-disputes (e.g. energy versus environment, stockholders versus customers, inflation versus unemployment, guns versus butter, tuna versus dolphins), instances of inescapable and irresolvable differences of opinion that can only be accommodated through inspired compromise. The search for leadership is not for system scientists who can give the issues rational attention, but rather for organization-men and charismatic administrators who can weigh the relative affection that different constituencies display and if necessary influence them. The rationale is: there are no social problems, only political pressures.

The manipulative posture adopted in the private sector is closely akin to that which we find at the governmental level. The conventional wisdom is the same: stick with the solutions used in the past in similar cases by predecessors. In both the public and private sectors, scientific incursions are permitted condescendingly in that management tends to impose a sort of quasi-systems discipline on the lower level operations while tackling the far more complex and critical functions with raw speculation and casual deductions. It is the "principles of management" school of the administrative sciences in action – the school of thought that sees management as little more than the casual distillation of experience. When applied to metaproblems which can only be interpreted in a systems context, the basic and highest order goals are inevitably established by those organizational members who have the least comprehension of modern systems techniques, the rhetorical executives who still dominate most corporate and governmental enterprise and who are either indifferent, or downright hostile, to systems analysis.

The third reason why society absolves the most critical issues affecting it – its metaproblems – from the formal problem-solving disciplines of the system sciences might be described as fear of the "technocratic fix". Clemenceau expressed it when he stated that "technology was too important to be left to engineers". Many administrators, unschooled in quantitative techniques themselves, rally popular support by proudly proclaiming their innocence of mathematical sophistication as a mark of humanism. They become the defenders against those who would impose upon us a managed society. As if societies had not always been managed! At issue is that for perhaps the first time we have the opportunity to take our destiny out of the hands of those least willing to be informed – the anti-intellectual bureaucrats.

2.4 Systems Methodology

The intellectual framework of the Systems Age rests on the Machine Age. The old framework has not been destroyed or discarded; it has been adapted and extended. What was "all" in the past has become a "part" of the present. And so it is that systems methodology rests on the classical approaches to the pursuit of scientific truth, including the Leibnizian, the Lockean, the Kantian, and the Hegelian Approaches. Thus, from the German mathematician, Leibniz, comes the assumption that truth is analytic. Applied to system analysis, one attempts to reduce any problem to a formal mathematical representation. Mathematical programming models are systems techniques derived from this approach. From the English philosopher, Locke, truth is experimental, and therefore a model of a system is necessarily data-based. From the German philosopher, Kant, comes the proposition that truth is synthetic – that is, experimental data and theoretical base are inseparable. Just as a model of a system cannot be built without observations and evidence, useful data cannot be collected without a model that tells us what data to collect. From the German philosopher, Hegel, comes the precept that truth is conflictual. For example, data is not information; information results from an interpretation of data.

The requirements of systems methodology are tailored by the purpose of systems analysis – solving complex metaproblems possessing social, technological, economic and political issues. We will often refer to them as S–T–E–P problems. Obviously, metaproblems possess social implications. One of the major factors underlying the advancement of civilization has been the ability of humanity to develop social organizations for the achievement of its goals. Over the same period technology has made inestimable contributions to progress, made possible by social institutions. However, these same institutions must take the bitter with the sweet and shoulder the blame for technology's undesirable side-effects. Moreover, many problems such as water pollution have long since passed from the realm of the technological to essentially economic and political problems. I should be clear by now that the S–T–E–P issues facing a systems analyst cannot be discussed in isolated categories. Moreover, they are in an order to magnitude greater than conventional problems of profit-maximization that appear in the private sector. The economic issues encountered in macro- or large-scale systems include the difficult task of income distribution as well as resource allocation. Last and foremost, metaproblems involve public concern and invariably raise conflicts of interests and other legal, legislative, and political issues. Ideally, systems methodology should include accountability mechanisms for policy-level decisions.

Systems methodology is the body of procedures, tools, and techniques that are employed by the system science disciplines in solving metaproblems through a "macrosystems approach". "Procedures" refer to a certain order of action in problem definition and solution that are derived from an orderly sequence of reasoning – both deductive and inductive. The "tools" of systems methodology are the elements of communication necessary for accomplishing the steps in the procedure. These tools are verbal, graphical and mathematical constructs for conceptualizing the problem. "Techniques" refer to the formal approaches to obtaining solutions, once the problem is conceptualized. They range from the algorithmic to the heuristic and include techniques of optimization and simulation.

The actual application of systems methodology to a metaproblem is a creative endeavour, not the blind execution of a set of unique steps. Some system analysts identify needs analysis, information collection, idea generation, value system design and system synthesis as elements of problem definition. Others may not refer to these explicitly. It should come as no surprise that no sharp line exists as one moves through the process from definition to solution.

The way that we define problems is the way that we will solve them. Sometimes purely semantic differences affect the attack on a problem. Tom Sawyer didn't look at "100 yards of board fence eight feet high" and say to himself: "How can I whitewash this fence?" On the contrary, he defined the task as: "How can I get this fence whitewashed?" The needs of mankind haven't changed; they are still food, shelter, clean air and water, good health, etc. What is changing is the broader manner in which we interpret these needs. For example, when we address ourselves to the problem of health, which of the following do we mean?

(1) Is it Webster's health which is "the conquest of disease and pain?"

(2) Is it WHO's health which is "the state of complete physical and mental well-being?"

(3) Is it, broader still, the ability of a purposeful system to fill its needs and pursue its objectives with a level of efficiency displayed by other systems of the same type in a similar environment, with the absence of desire to decrease its own or another's ability to be healthy?[1]

If we accept the first definition of the problem, our approach to the solution is the conventional one – corrective medicine. If we start with the second, we broaden our attack to include preventive, as well as corrective, medicine. If we interpret the problem according to the third, we have a definition that applies equally well to organizations as well as organisms, and it permits us to make ethical comparisons between smokers, terrorists, drug addicts, vigilantes, etc. Now if we recall the third characteristic of a system, the environmental context, we can even put limits on the health problem. Thus, the bottom line is this: an individual from any species can be no healthier, ultimately, than its environment. This sort of steady state analysis is a very important part of systems methodology.

Basically, the application of systems methodology is sequential and iterative, with consideration given to the following in the problem-definition phase:

(1) The vested-interest groups between which value issues inevitably arise: users, providers, the community, the environment.

(2) The identification of the relevant values associated with each group – the irreducible qualities upon which individual and group preferences are based. For users they include such factors as safety, health, shelter, independence, mobility, privacy, and comfort; for providers, economy, opportunity, and impartiality; for the community, security, civil order, accessibility, and amenity; for the environment, quality, peace, conservation, and visual order.

(3) The listing of goals corresponding to the values. These are idealized, desired states – qualitative, subjective directions applied to the set of values.

(4) The translation of goals into objectives – operational specifications describing a measurable state that can be compared to the actual state (the system outputs) so that corrective action can be taken.

(5) The description of the immediate system outputs – the value-added to the resource inputs by the system.

(6) The identification of resource inputs and resource catalysts required to enable the system process to function. These include material, financial, energy, capital and human resources.

(7) The determination of longer-term benefits resulting from the immediate system outputs – the immediate outputs integrated over time.

(8) The description of the laws of transformation, the policies, by which inputs are converted to outputs.

(9) The description of system structure, organization, and logistical patterns which determine system performance.

(10) The establishing of measures of system effectiveness such as system efficiency and system productivity. Internal efficiency is the relationship between a system's output and the corresponding inputs that went into producing them. The system's external productivity is the relationship between the cumulative benefits derived from it over a given period and the corresponding inputs used earlier in producing these benefits. Often these two measures are referred to as the cost-effectiveness and the cost-benefit ratios, respectively.

(11) The elaboration of alternative courses of action which consist basically of the following self-organizing alternatives of a system:

- varying the resource inputs
- varying the resource catalysts
- varying the policies (the system transfer function)
- varying system structure
- varying the objectives
- varying the goals

The above eleven features of a system and the relationships between provide the conceptual framework for systems analysis, in general, and systems management, in particular (see Fig. 1).

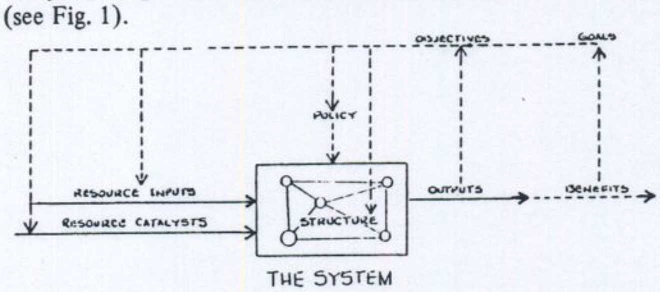

Figure 1. Conceptual Framework for Systems Analysis

III SYSTEMS MANAGEMENT

3.1 Approaches to Systems Management

It has been indicated in Part 2 that the pervasiveness of the systems approach leads one to believe that there ought to be some general systems theory in which to relate the findings of various disciplines – particularly engineering, planning, economics, and management – to one another. One purpose of this paper is to identify systems management. Much insight towards satisfying this objective can be gained by drawing a parallel to systems engineering.

Just as systems engineering is the application of the systems approach to engineering, systems management is the application of the systems approach to management. One difference is that in systems engineering the emphasis is on technological systems (usually physical ones) whereas in systems management it is on a particular type of abstract system – a decision system. Of course, the decision system is invariably superimposed on a physical system. The decision system which is designed or analyzed using systems management may govern a technological process which was designed or analyzed using systems engineering.

Management is the process of converting information into action – decision making. It follows that the systems approach to management, systems management, includes the design of decision making systems (system design), the analysis of decision making systems (system analysis), and the conception of organizations as systems and/or the management process as a system (research, science, general theory, etc.)

Managers use decision systems to manage organizations which are themselves systems. Therefore the systems manager views his firm, factory, department, etc. as consisting of four interrelated subsystems: technological, functional, information and control. Another way of looking at it is that an organization is distinguished by four essential characteristics: content (men, machines, material); structure (production, marketing, finance, personnel, engineering); information (communications between its elements and with its environment); and control (adaptive and self-organizing). Generally speaking, it is the last three characteristics that are subject to purely managerial manipulation since the first is more an engineering function.

In the systems management approach, the firm is conceived as a set of functional subsystems, interrelated by means of an information system, which feeds a decision system, which in turn operates the functional system. Each of these are related to the environment. Feedback characterizes the entire closed-loop system which is why many management theorists, particularly those with a background in the physical sciences and engineering find a useful analogy for an organization in the so-called servosystem or feedback system.

In systems management every organization is a decision system which can be conveniently viewed as a closed-loop control system. Thus every organization has policies and procedures whereby it reaches decisions and takes action to attain its goals, although not always successfully. This transformation of decisions into results takes place through a complex goal-seeking process which is often difficult to follow because of "noise" and "delays" which tend to obscure cause and effect. Since decision making is a response to a gap between the objectives of an organization and its apparent progress toward these objectives, a bias in the information channels that translate the real situation into the apparent one can cause the actual decisions in an organization to be made on a faulty basis.

Three methodologies which assert that organizations are most effectively viewed and managed from this systems management decision system perspective are the management science/operations research approach, the management information and control system approach, and the system dynamics approach. These will be discussed briefly in the following sections.

3.2 Management Science/Operations Research

Tactical approaches to problem solving using systems management are sometimes described by the terms "operations research" and "management science". We will make no distinction between the two here. Both tend to focus on decision-making, as opposed to policy formation, with the appraisal resting on economic effectiveness criteria within a mathematical model. These three elements – decision-making, effectiveness criteria, and modelling – have a simple underlying structure, although in actual application the relationships may become quite formidable. The principal steps are: (1) establish the goal, (2) determine the objective, (3) determine alternative courses of action, (4) decide on a measure of effectiveness, and (5) identify the uncontrolled (impact) and controlled (decision) variables.

The usual goal is resource, sectoral, or areal development. The usual objective commensurate with the goal is to minimize entropy as expressed by some measure of disorder such as cost, time or distance. It must be understood that this objective must be chosen so as to trade-off conflicting interests, or sub-objectives. Thus, the objectives of the owner will often differ from those of the user of a system. This dichotomy should be reconciled in the choice of a measure of effectiveness which will act as a common denominator, expressing conflicting objectives in like measures of utility or performance values. When the measure of effectiveness is a total cost (to be minimized) or a profit (to be maximized), the uncontrolled variables may be unit costs – capital, operating, hourly rates, etc. A solution to the problem requires finding the values of the controlled variables, x_i, for a given set of uncontrolled variables, c_i, that optimize the objective function (measure of effectiveness or measure of disorder) z.

The exact approach varies according to the nature of the development phenomenon and the model selected. For example, if the mathematical model chosen enables precise computation of what will happen to one variable if a specified value is assigned to another variable, the approach and the model is said to be deterministic. This may be contrasted with a stochastic approach or model, in which allowance is made for the probability of a variable assuming various values.

3.3 Management Information and Control Systems

This approach views information as the essential factor within an organization since information is the substance from which managerial decisions are made. Alternatively referred to as Management Information Systems (MIS) and Total Information Systems (TIS) as well as Management Information and Control Systems (MICS), the functions of the general approach appear to be the following: (1) providing optimized process control for the lower levels in the hierarchy, (2) supplying management with information based on the principles of management by exception, and (3) furnishing information to all levels of management for planning. In a physical sense, a

MICS has come to be known as hardware, computers, communications, physical files, software. and input/output devices.

The objective of an MICS, stated as simply as possible, is to make those decisions which can be programmed and to provide information to assist the manager in making those decisions that cannot be made automatically. Programmed decisions are those that are repetitive and routine and are based on factors that can be quantifiable. These are decision problems for which management scientists have developed models and algorithms which can be executed by a digital computer.

Although most of the decisions made by a manager are of the routine type capable of automation, the most important decisions a manager makes are not. To assist the manager here, information is needed about the state of the system (such as available resources), the environment (such as government activity) and policy constraints.

Unfortunately, possibly because of the misdirected enthusiasm for the computer, this approach to systems management has taken on a sort of huckster appearance in which the claims have far exceeded the accomplishments. Part of its lack of effectiveness can be traced to the erroneous assumption that management suffers from a lack of information when actually managers have so much more information than they can cope with that they sometimes go to the extreme of developing procedures which are less information dependent. Similarly, improved communications between managers does not necesarily lead to improved organizational performance if the structure is deficient.

The MICS approach to systems management has not been successful because it is still a hardware oriented approach that does not fully consider the decision system that the information and control subsystems are to serve or the importance of the structure of the organization in the transformation of decisions into results.

3.4 System Dynamics

System Dynamics, the third approach, stems from work initiated and directed by Professor Jay W. Forrester at the M.I.T.'s School of Industrial Management. The results of a decade of work in a variety of applications of key management problems are described in three of Professor Forester's books: (1) Industrial Dynamics[4], (2) Urban Dynamics[5] and (3) World Dynamics[6].

Among other things, system dynamics overcomes the two shortcomings mentioned above in the MICS Approach which are lack of consideration of the decision making process and the structure of the organization. In this respect we can describe system dynamics as a methodology for analyzing and designing organizational policy. It is a way for studying the behaviour of socio-economic decision systems to show how structure (in the function sub-system), delays and noise (in the information subsystem), and policies (which govern the control subsystem) are interrelated to influence growth and stability.

An important characteristic of system dynamics is the universality of application of approach. First of all the system structures and behavioural phenomena that are studied by the system dynamics methodology are present at all management levels of the organization. Secondly, it integrates the separate functional areas of management – production, marketing, research, personnel, etc., for example in the case of an industrial organization. Lastly, identical structures are seen to recur as one moves between apparently dissimilar fields allowing a wide diversity of different types of systems to be studied – from the original work on industrial organizations to the development of models of urban complexes. All this is accomplished by reducing the basic functions to a common basis by recognizing that any social-economic activity consists of flows of organizational resources such as materials, money and manpower integrated by an information network with decisions viewed as the controllers of these flows.

System dynamics is based on the foundations of (1) decision making, (2) feedback systems analysis, and (3) simulation. Considering each briefly here and then in more detail later, decision making is stating how action is to be taken. Feedback deals with the way information is to be used for decision making. Simulation permits decision makers to view the implications of their decisions over the future. System dynamics, then, is a method of analyzing problems whose variables change over time, which permits the analysts to determine how the system (a firm, a city, a country) responds to factors within the decision makers control such as policy, organization and system structure, and outside of the decision makers control such as seasonal fluctuations, random variations, competition, and sudden changes due to external shocks.

3.5 Focus of the Approaches

Referring to the conceptual framework of systems management depicted in Fig. 1 we may conclude based on the approaches discussed in this section that most of the traditional administrative effort has been concentrated on the lowest level of the decision-making hierarchy – on the resource self-organizing alternative. Indeed, management to most practitioners is simply using resources to achieve purpose through organization. This is not to say that it isn't important. There is no doubt that the rationale used for allocating resources (personnel, budgets, and space) will be a strong determinant of the character and quality of the organization. Two very different philosophies that come to mind are: (1) response to and equalization of various organizational pressures which tend to move new resources where the supply is already greatest, and (2) allocation as part of a conscious effort to create a pre-determined character of the organization. Taking the path of least resistance can sometimes be misleading in that it can yield a high internal efficiency without realizing that the external productivity is low. This is simply a case of doing the wrong things – but doing them very well. Overcoming a trend like this may require the very difficult managerial process of de-emphasizing, even discontinuing, activities for which there is still demand while supporting little known activities that have yet to mature.

Systems management is the application of systems analysis to the managerial problems inherent in the self-organizing alternatives of a system as identified in the previous section: resources, policy, structure, and goals. The problems range from tactical, such as those dealing with resources, to the strategic – those that emphasize policy, structure, and goals. System dynamics has proven to be the most effective and versatile of the approaches discussed, and will be described in more detail in Part II of the paper.

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