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SOCIAL SYSTEMS ANALYSIS

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CONTENTS

INTRODUCTION

Throughout the world our social systems are in crisis. Local communities no longer serve their traditional functions of focusing diverse individuals on common objectives or of providing continuity and communication between one generation and the next. The industrial corporation, which has been so effective in raising the standard of living in the western democracies, is under attack; it has served its purpose of organizing human effort for efficient production but may be failing in meeting the human aspiration for independence, individual importance, and self fulfillment. The larger, older cities are falling into distress with costs rising and revenues declining, while all corrective actions seem to accelerate the downward spiral. On a national scale, inflation, economic stagnation, and an increasingly visible gap between rich and poor all suggest that we do not understand the interrelationships between fiscal and monetary policy, price stability, unemployment, economic growth, and equal opportunities for all citizens. On the international scale, military conflict, international trade, international monetary policy, and the failures in economic development of the less advanced countries suggest that these larger systems are also in disarray and failing to serve mankind. On the global scale, growing population, pollution of the environment, and the conflict between a rising standard of living and limited natural resources again demonstrate that mankind has not yet come to terms with the systems within which he lives.

Are these difficulties unavoidable? Are we managing the best we can? Are we the victims of circumstances beyond our control? Or, are these difficulties of our own making because we have created systems unsuited to our purposes?

In this report we suggest that natural forces are at work that produce systems ill-suited to our objectives. The very manner in which man interacts with his systems tends to degrade those systems, to lower their performance, and to cause the systems to serve man less and less well. This occurs because a person's judgment and intuition have been shaped by his experiences with simple systems. All of our social systems, from the community to the world-system, belong to a category which we here call "complex systems". Complex systems in many ways behave the opposite from simple systems. The lessons which have shaped intuition and judgment cause men to react to crisis by altering the structure and policies of our social systems in ways that in the long run increase rather than reduce the difficulties.

But a new science and methodology for dealing with complex systems is emerging. A theory of complex systems is being developed. The perceptive strengths of the person can now combine with the computational strength of electronic computers to generate new insights into the behavior of our social systems. We are entering a new frontier in human endeavor--the frontier of understanding the dynamic behavior of our social systems.

Past eras of mankind's development have been characterized by a sequence of frontiers in understanding man and his environment. There have been periods when the focus was on developing new forms of government. At other times the excitement and challenge has been the exploration of geographical frontiers. Some eras have been characterized by the development of great literature. Another stage in human progress has been the development of religions and man's relationship to the unknown. More recently the challenge was science and technology and the use of nature to raise the material standard of living. But now the focus is changing to exploration of our social systems, understanding their behavior, and learning to design social systems that better serve humanity.

CHAPTER I

PERSPECTIVE ON SOCIAL SYSTEMS

Before discussing design of improved systems, a perspective on evolution in our social systems will show how we come to our present doubts and distresses.

A. Historial Evolution

Man's history is a history of experimentation and development in social organization. It is a history characterized by growth in size and complexity of our social relationships. Most of that history relates a continuing conflict between man and the social system within which he lives. As the systems have grown, the conflict has intensified. As the social systems have increased to fill the land they occuply, the conflicts have proliferated and expanded.

But the issues which we face today in our social systems are of relatively recent origin. Until a thousand years ago the social relevant to an individual was small and lay within the purview of a single individual. The mechanisms and relationships were visible. The conflicts tended to be over tangible issues such as oppression or the forthright contests for land and resources.

But it is only in the last few hundred years that our social systems have developed a complexity which is understood by no one. The conflicts have become more frustrating. Less often is the enemy an individual tryant or an invading army. More often the enemy surrounds the individual but is invisible. The individual feels caught in a

system which guides his life in multitudes of intangible ways, a guidance which seems to lead to deeper futility.

Our present Western civilization has followed an evolution which started with the authoritarian structure of the primitive tribe. The authoritarian structure grew and developed until countries operated under a ruling monarch. Abuses of authoritarian organization led to violent, revolutionary changes that established democrat-capitalist systems which interrelated political and economic structure. But these contained incentives and opportunities for some individuals to abuse the system and their fellow citizens. The reactions to these abuses were not to alter the incentives to generate pressures in other directions but instead to add restrictive prohibitions against the abuses. The restrictions required enforcement. Enforcement meant expanding government. The result was a proliferation of restrictive regulations and a growing governmental bureaucracy to enforce and administer those restrictions. A silent and gradual political revolution converted the democratic-capitalist social system toward what we might now call a bureaucratic-socialist system. In this latter system the network of restriction and regulation reduces individual incentive and opportunity to a point where the individual is no longer the mainspring of economic and social action. As private individuals and organizations are inhibited from meeting the needs of society, pressures mount for government to intervene and meet those needs. But as government begins to intervene to generate the goods and services which men need, numerous unexpected by-products are created.

As a first by-product, measures of relative efficiency are lost because government usually operates as a monopoly and comparisons in effectiveness cannot be made against competing organizations. Effectiveness declines and the organizations become increasingly self serving.

As a second by-product, the provision of more and more services by government restricts the choices and priorities that can be exercised by the individual. If the government provides transportation, education, health services, or welfare, it must do so under rules that treat all individuals equally. The nature response of the individual is then to maximize his benefit under the system. He is influenced to maximize his consumption of each separate governmental service because he does not have the option of trading one for another. His only choice is to take what is available or to forego it. His best strategy is to get all he can. The bureaucratic-socialist system tends to move to ever greater governmental services in a setting which maximizes individual consumption of those services. Maximum consumption in turn calls for higher taxes and a reduced opportunity for the individual to make choices of goods and services which remain in the free market. But this evolution tends to standardize individuals and their resource allocations and denies the individuality which is the hallmark of personal freedom. The evolution sets up an increasing conflict between each individual and the bureaucratic-socialist system on which he begins to focus resentment.

A third by-product of growing complexity in our social systems is the increasing likelihood that the consequence of new laws, policies,

and programs will produce results quite different from those anticipated. We build highways to reduce travel time but travel time is seldom reduced, the result is an increase in traffic. We put pressure on automobile companies to develop safer automobiles but the consequence is a raising of the speed limits, faster travel, and little change in the rate of fatalities. Rising land prices are used as an argument for allowing higher buildings in our cities; but zoning which permits higher buildings raises land prices still further and the result is not economy but congestion. Welfare systems are established to relieve the plight of the poor, but the consequence of the welfare program is often to actually generate welfare cases and to prevent escape from welfare status so that the result is to increase the welfare load rather than to reduce hardship. In a number of situations the increase in expenditure for police departments and crime control has aligned the public and the anti-social element against the police and thereby increased the crime rate by reducing cooperation between the community and the police.

A fourth by-product of the changes in our social systems is to increase the emphasis on short-run considerations. But in the long run this is counterproductive. In general a policy change in our social systems will produce a change in the short run which is opposite from the direction of change produced in the long run. A policy which produces improvement in three to ten years sets in motion forces that reverse improvement into degradation at a later time. The short run is visible and persuasive. Several decades of catering to the short run produces a burden of long-term depressants which can no longer be counteracted by short-term manipulation.

B. Traditional Design Processes in Our Social System

This paper is on the design of social systems. A proposal to design improved social systems is sometimes viewed as immoral based on the assertion that one should not tamper with the natural human environment. But our social systems have not been given by nature. They have been designed by man. We already live in systems that have been designed. Constitutions of countries, laws, tax regulations, and religion combine to become the design of a social system. If we are not pleased with the way our social systems are operating, it implies that we prefer a different design. But before discussing new methods of designing systems we should understand how present systems have been designed.

Traditional design has been a process of responding sequentially to pressures as they arise. A social system exhibits a mode of behavior characteristic of its policies and structure. But every mode of operation of a social system carries with it certain inherent internal pressures. If we are not willing to live under the pressures that characterize a particular mode of behavior, we respond by changes aimed at alleviating those pressures. If we succeed, a new mode of behavior is triggered which has its own characteristic and inescapable pressures and disadvantages. Some modes in our social systems are more stable and harder to alter than others. The tendency is to gravitate toward the most stable and inescapable modes. These very stable modes of behavior tend to be ones with a short time-horizon and policies aimed at short-term goals. The sequence of evolutionary design changes in laws and

government structure degrades the long-run future in an effort to relieve the present short-run pressures.

The ultimate result of a series of short-term responses is faltering performance of a social system. Unless the nature of the process is perceived and unless unlikely and counterintuitive actions are taken, a nonreversible sequence results which produces growing stress, conflict, and futility. Traditionally, this process of system degradation has been terminated by revolution, collapse, war, or capture by an outside force. Unless we adopt more rational design procedures we will continue to be committed to the same violent consequences of our ineptness in social system design.

CHAPTER II

DESIGN OF SOCIAL SYSTEMS

A new approach to the design of social systems has come to be known as "industrial dynamics" after the book of that name by Jay W. Forrester. * The name is a misnomer. Potential applications cover the full range of complex systems from those in science and technology to management, medicine, psychiatry, economies, ecology, education and government.

"Industrial dynamics" and its application to the design of social systems is the present embodiment of a sequence of developments pioneered at the Massachusetts Institute of Technology beginning in the 1930's. Initially the emphasis was on the dynamics of feedback processes (or servomechanisms) in engineering. First the mechanical and later the electronic differential analyzers were part of this development. During World War II the Servomechanisms Laboratory established by Professor Gordon S. Brown, organized the theory of feedback systems and applied that theory to the design of remote control devices for radar antennas and gun mounts for wartime application. Postwar extensions were rapid into chemical plants, aircrafts, multitudes of engineering systems, and spaceship control.

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* Jay W. Forrester, Industrial Dynamics, the M.I.T. Press, Cambridge, Massachusetts, 1961.

From 1946 to 1956 Jay W. Forrester directed the early development of digital computers at M.I.T. and pioneered their application to military control systems and to simulation of complex man-machine interactive systems. In 1956 he moved to the Sloan School of Management at M.I.T. and began to extend feedback system theory and system simulation to corporate policy systems and later to broader social systems.

A. The "Industrial Dynamics" Approach to Social System Design

A new professional field is now developing which for lack of a more appropriate title has come, world-wide, to be called "industrial dynamics". This approach to social systems is based on the feedback structure of systems and on a particular philosophy of model building and digital computer simulation.

Like the practice of any profession, success depends on an underlying body of principles and theory and on the professional skill and judgment used in applying those principles to a particular social system. As in any profession or the pursuit of any field of science, the principles can be applied well or badly. There are no rules which guarantee successful practice of a profession. Being a professional field in its early stages of development, there are as yet no recognized measures of competence. As yet very few have demonstrated notable ability at handling our more complex social relationshiops.

The industrial dynamics steps in dealing with a social system might be simplified as follows:

1. Purpose and objectives.

The first step is to clarify the purpose and objectives of a social system investigation. What mode of behavior is of interest? In what way is the system undesirable? In specific detail, what improvements are sought? What are thought to be the symptoms of difficulty, the causes, and the probable solutions? It is surprisingly difficult to force people to distinguish sharply between symptoms, causes, and corrections. If one asks a company president what is his problem, the answer might be, "the training of better managers." But if anything, training managers is not a problem, it is a solution. If one asks the mayor of a city what is his difficulty, he may answer that it is to raise more money or to expand the boundaries of a metropolitan government. But these are actions which he hopes are corrections to a difficulty. They are neither symptoms nor causes. One of the greatest difficulties in studying any social system is to establish and to gain acceptance for a clear goal for the study. (These steps can be illustrated by reference to the book Urban Dynamics by Jay W. Forester, M.I.T. Press, 1969. In the book, the first step corresponds to selecting the urban life cycle of growth through stagnation as the behavior that is to be clarified and altered.)

2. Observation

The next step is to examine the particular system in detail. The examination must extend in many dimensions. It covers

all of the hierarchies in the government of the system. One examines the alleged, the apparent, and the true motivations at all levels and control points in the system. One explores the interaction of economics, psychology, technology, sociology, and humanistic influences. One looks for contradictions and conflicts. This exploration starts by being freewheeling, unstructured, uncommitted to anticipated results, and open-minded in search of facts which can later be fitted together into a relevant structure. This exploration is done against a background knowledge of many other system structures and how structure gives rise to dynamic behavior. Knowledge of the underlying theory of structure and behavior in dynamic systems points to some aspects of the system that are likely to be more relevant than others. This observation and information gathering is done in the real system. It is accomplished primarily through discussions which bring forth the knowledge and observations possessed by human participants in the system. One is searching here for the relationships between the human components of the system. One needs to understand the information flows, the policies, fears and aspirations which cause the system to function. (For Urban Dynamics this step of gathering information consisted of several weeks of discussions with men who had intimate knowledge of cities and the pressures that cause them to change.)

3. Structuring.

As the information gathering proceeds, structures and relationships begin to suggest themselves to an investigator who has sufficient background in dynamic behavior of complex systems. This stage of system structuring might be called the stage of generating a theory of behavior. It is the stage at which various hypotheses are established which relate structure and policies to probable behavioral consequences. (In Urban Dynamics this phase had largely been accomplished when Figure 2-4 took shape.)

4. Detailed Modeling.

The next stage in a system study is detailing the fine structure of the system and writing equations to describe all relationships within the structure. This stage requires asserting exactly what policies and relationships are being assumed. The equations are the model of the real-life system which is to be examined and modified. Actually, the structure and equations representing the details of the model undergo continous change as one pursues the following steps in a system analysis. (The equations and the relationships in Appendix A of Urban Dynamics represent the culmination of this stage.) The model which results at this stage describes every policy or decision-making point that is considered relevant in the system. The statements of policy describe how that point in the system will respond to the ensemble

of information inputs available to that point. In other words, if the apparent information inputs are specified, the policy states how that point in the system will react. The reactions cause the state of the system to change and the new system states continuously present new information to continue to activate the decision-making processes. The model is recursive in the sense that at any point in time actions are computed, the effects of these on the system are computed, and the new system states are used at the next point in time for the computation of new actions. Such a model is not subtle nor is it properly described as "mathematical". It is an explicit set of rules describing how each point in the system is assumed to function. Instead of a computer-executed model one could, except for the tedious nature of the exercise, assign a person to play the role of each part of the described system with instructions to follow the specified rules as the information and the system within his purview begins to change. Each person could then act using a five-minute period to represent a week, a month, or a year in the real-life system. Such group role-playing exercises have been done. The results confirm those from computerized simulation and from real systems.

5. Simulation.

With the simulation model in operable form, the next step

is to compute the behavior over time of the system described in the model. Behavior of the model is then examined in terms of the behavior of the real-life system. Impossible behavior, improbable interactions, and discrepancies between the model and the actual system all give clues for recycling through the earlier steps to refine the model structure and equations. (In Urban Dynamics this stage is represented by Chapter 3.)

6. Policy design.

After confidence in the model has been established the next step is to explore policy changes in search of ways to improve the system. Many of the popular proposals for system improvement will be found to be ineffective or even detrimental (as shown in Chapter 4 of Urban Dynamics). As one works with the model and checks its reactions against the actual systems, insights will be gleaned which lead toward the sensitive influence points in the system. Changes in policies and system structure will be found which change the character of the system and improve its performance. (For example, see Chapter 5 of Urban Dynamics.)

7. Implementation.

The final stage is implementation in the actual system of the policies which can give improvement. Those policies must be chosen which can be introduced into the actual system. Very often these will be contrary to the folklore

and conventional wisdom. Ordinarily an extensive educational program is required so that the proposed changes are understood by those who must implement the changes and who will be affected by them. Very often the educational process requires retracing, with those who will be affected, all of the preceding stages in the system analysis. As confidence is established, actual implementation can begin.

B. Formal Models Versus Mental Models

The use of models as a basis for policy design in social systems is not new. All human action and decision making is based on models. The mental image which one uses as a basis for decisions is a model. One does not have a real country or a real city in his head, butonly an abstraction of that real system. Each person has a different model and a different process and capability for estimating what the model implies for the future.

One should compare the formal computer simulation modeling of a social system, not with perfection, but with the available alternatives. The alternatives are the mental models which are otherwise used by managers and political leaders. But these mental models are incomplete, they are unclear, they are shifting in structure, and they are hidden. Furthermore, they are naively simple compared to the computer models which are now possible and which have been demonstrated. But above all, the mental model is deficient for having no reliable way to establish the

dynamic consequences of a given model structure. The human mind is good at perceiving the parts of a social system. The human mind is a good observer of the pressures, fears, objectives, information sources, governing policies and actions at any one point in a system. But the human mind is misleading and ineffective in estimating what happens when a multiplicity of system components interact with each other.

Studies of industrial corporations have repeatedly shown that the very steps being taken to solve some major corporate problem can interact in such a way as to cause that problem. Good intentions are not sufficient. The behavior of complex systems is counterintuitive. The steps adopted as corrective action often cause further degradation. This is true even when the individual parts of the system are well known and properly perceived.

There is no conceptual possibility of proving that a system model is correct. There are no proofs for any of the theories in the social sciences or the physical sciences. Theories rest on the absence of a disproof.* Likewise here, one should not ask if a model of a social system has been proved as valid. Models, like other theories, are used because we have more confidence in them than alternative models. A formal computer model competes with the mental models which would otherwise be used. It is persuasive if it is clearer, more precise, more accessible, more complete, and more in agreement with available

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* For a discussion of model validity, see "Industrial Dynamics--a Response to Ansoff and Slavin" by Jay W. Forrester, Management Sciences, Vol. 14, No. 9, May 1968.

knowledge than alternative models. Confidence is established to the extent that the model behaves like the real-life system it purports to represent. But the choice is always between alternatives. In general it is easy for one having professional skill in the dynamics of social systems to create a system model in which people develop far more confidence than the mental models which are the alternatives.

C. Humanistic Values and Considerations

Often the modeling of social systems is accused of being mechanistic, impersonal, and without human values, but such allegations are without foundation. Any consideration can be introduced into a system model which can be stated. A humanistic consideration or moral value which cannot be expressed has very little content. Setting numerical values for "goodness" or for expressions that describe human reactions do not make the system more or less humanistic but only clearer and more explicit. The process of modeling does force clear and explicit statements, but it does not restrict the nature or range of those statements.

As to values and objectives, some of these are built into a model. Others are reserved to be used as the basis for judging alternative policies when the policies produce different behavior in model simulation. Desirability of a social system is multi-dimensional. Seldom can a single criterion be established. But, given alternative policies and the resulting system behavior, the desirable and undesirable aspects of each alternative are exhibited and human values can enter into the discussions of desirability.

D. Contrasting Approaches to Systems Analysis

Several professions have developed ways of approaching complex systems. The philosophy and methods differ widely. Also there is great difference in the promise and practical effectiveness which they offer. It may help the reader if we compare briefly industrial dynamics with other well known ways of trying to understand systems.

1. Servomechanisms theory.

Industrial dynamics includes and uses the same body of theory that defines servomechanisms, or feedback systems, as developed in engineering. This is the same theoretical body of knowledge as was once designated by the term "cybernetics", although cybernetics has since become corrupted so that its meaning is now closer to "general systems theory" which is discussed below.

Industrial dynamcis, like servomechanisms theory, deals with the feedback structure of systems wherein action and information flow in a continuous circular pattern. Industrial dynamics goes beyond engineering servomechanisms. Most of the engineering work in servomechanisms analysis is limited to linear systems. But in social systems the major phenomena depend on nonlinearities. In general, it is not possible to obtain explicit mathematical solutions for nonlinear systems. Therefore, much of the mathematical analysis found in engineering is useful as background, but is not directly

applicable as one moves to the more complex systems found in social structures.

Servomechanisms theory is one of the parent fields from which industrial dynamics springs. Industrial dynamics extends the ideas of feedback systems to include nonlinear, high-order, multiple-loop structures having positive feedback as well as negative feedback loops. Very little of servomechanisms theory in engineering recognizes positive-feedback-loop behavior, but all processes of growth depend on positive feedback. The major stresses in our social systems often result from the suppression of positive-feedback behavior in the transition from growth to equilibrium.*

2. Engineering models.

The work "model" has now become so widely used that it is almost meaningless. A model is any simplified representation of a real system. There are many approaches to model building, and these differ widely in terms of sources of information, model structure, and objectives sought. Industrial dynamics has more philosophical kinship with the models in engineering than it has with the models and philosophy found in the social sciences.

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* Jay W. Forester, "Industrial Dynamics -- After the First Decade", Management Science, Vol. 14, No. 7, March 1968.

Engineering models over a wide range of embodiments but all follow a similar approach. One may have a physical model, such as that of an airplane, to be used in a wind tunnel. Or the model can be in the form of equations representing the aerodynamic behavior which are solved or simulated in a computer. In all, the model reflects knowledge and assumptions about the specific parts of the system and how these parts interact with each other. Information about the separate parts comes from direct observation and measurement of those parts and from theory that describes the behavior of the parts. The model is built from a substructure of parts into an interconnected whole. The model is used to determine the behavior characteristics of the composite engineering system. In other words, the model is used to determine system stability and performance. The model is used to determine if the system is "good" by the relevant standards of judgment. In the same way, industrial dynamics models of social systems reflect knowledge and assumptions about the separate parts of the system and the way these parts are interconnected. The engineering model and the industrial dynamics model are both used for system design. They are not primarily aimed at merely understanding an existing system, but, instead, are intended to yield behavioral information about new system structures and policies which have not previously

existed in real life. In each case, part of their validation rests on their ability to behave like present actual systems when set up to represent the components and interactions of present systems. But the objective lies beyond present systems. The object is to determine how revised structures and policies would change the behavior of the system. The model exists to help find improved designs for future systems. Engineering models and industrial dynamics models are both constructed to bring a representation of the real system into the laboratory where experimentation on the behavior of the system can be conducted. Where the complexity of the system is great, classical mathematical analysis is not possible, and the only available approach is experimental.

3. Case studies.

Several professions rely heavily on case studies to deal with complex systems. The case study approach to management education is perhaps the best known. Medicine and law both rely heavily on case studies.

Industrial dynamcis has much in common with the case study approach to systems. The case study is an attempt to interrelate the parts of a system by careful consideration and discussion. In a case study analysis, the system is viewed from various perspectives. A group discusses the various aspects of the system and the relationship which they perceive. A case study discussion attempts to select

the important from the irrelevant. In a case study analysis, the interrelationships between the parts of a system are identified. The case study method corresponds very closely to the beginning of an industrial dynamics study as described in sections II.A.1 through II.A.3 above. This part of a case study uses the human mind effectively. Only the human observer perceives the many aspects of a system and only the human is capable of picking the important from the unimportant to generate an initial hypothesis about the system structure.

But in the past, the case study approach to systems has had to rely on the human mind for interpreting the dynamic consequences of a presumed system structure. Work with computer modeling of complex systems has shown that the human mind is not suited to anticipating the dynamic behavior which will result from even a completely known structure. The case study approach to systems analysis runs into the same self-deception which we observe in our actual social systems. The discussion group in a case study is very likely to agree on a behavioral consequence which does not follow from the assumptions about components and system structure.

On the other hand, an industrial dynamics study can validly determine the dynamic consequences of a given set of assumptions about system structure. An industrial dynamics study requires an explicit computer model description of the assumptions drawn from the observations of the real-life system.

The clarity imposed by the process of constructing a computer model forces more orderly and organized thinking than occurs in a verbal presentation drawn from the same background of observational information. After the model has been precisely described, computer simulation allows one to be certain of the dynamic consequences which follow from the assumptions in the model. Here industrial dynamics departs from the case study method. The human mind is unsuited, and can be demonstrated as completely unreliable, in estimating the dynamic consequences of a complex system structure. But computer simulation yields dynamic behavior easily and inexpensively. The validity of simulation in going from the specified structure to the dynamic behavior is beyond question or doubt in contrast to the extreme unreliability of this step when conducted by "mental simulation". The value of this last formal computer step lies in the frequency with which the human investigator is surprised. The systems often do not behave the way he anticipated. New insights are gained which would never have been available through a case study discussion.

4. General systems theory.

A body of literature is developing in an area called "general system theory". Much of this reflects activities of founders and members of the Society for General Systems Research. This body of knowledge does not represent a unified theory. It

is a confederation of viewpoints, philosophy, mathematical techniques, methods of analysis, and models contributed by people who have a general interest in systems. This general systems theory literature is variable in quality, and is in no sense unified into a consistent approach, theory, or methodology. Parts of it overlap with each of the other categories of systems analysis discussed here.

5. Management science and operations research.

Management science has dealt with fragments of systems compared to the industrial dynamics approach. For the most part, management science has dealt with the decision making process in systems, not with the closed-loop structure that surrounds decision making. This partial approach means that certain information inputs are assumed and a decision process is developed to maximize some output. But, the consequences of the new decision-making policy on the input assumptions are not included in the analysis. Substantial harm is now being done to business corporations by the management science viewpoint and techniques. The analysis methods focus on the shortrun. The criteria being maximized apply only to minor subsystems. The consequences are leading to employment instability, loss of market share, increases in hidden expenditures, and organizational structures which obscure the broader systems considerations. For the most part, management science deals with static systems, with

linear systems, and with open (non-feedback) systems. Each of these would individually prevent the methodology from addressing the fundamental nature of our social systems.

6. Input-output analysis.

Input-output analysis has become popular. It has received world-wide attention. It gives useful insights into the constraints imposed by resources within a system. It fails, however, to deal adequately with the dynamic structure of a system. It does not provide for the interactions of physical flows with the other subsystems involving psychology, information, legal, and motivational aspects of a system.

7. Econometrics.

Very different approaches to model construction are taken in industrial dynamics and econometrics. In both, initial assumptions are made from theory and observations about the structure of the system being investigated. But the two differ in the extent to which a theory of structure guides the permissible structures. Industrial dynamics is based on a theory of structure* which is believed to be general with respect to all systems which change through time. This industrial dynamics structure asserts that in actual systems there are two, and only two, types of variables--levels and rates. The level variables are integrations that produce the time-dependent behavior of a system. Levels are caused to change by the rates of flow; and

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* Forrester, Jay W., Principles of Systems, Preliminary edition, Wright-Allen Press, 238 Main Street, Cambridge, Mass. 1968

levels never depend directly on other levels. In industrial dynamics the rates of flow depend only on level variables, never on other rates, are algebraic in form, and contain no time-lagged inputs. The two variables, levels and rates, are necessary and sufficient to represent any dynamic system. By contrast, it appears that econometrics makes no such orderly assertion about structure but often tends to interrelate rate variables only, without the intervening level variables. Dynamic behavior arises in econometric models because the past values of rate variables are used in the generation of current rates.

Econometric models, because of the mathematical methods used, tend to be limited to linear formulations. On the other hand, industrial dynamics models admit the full range of nonlinear hypotheses. Experimentation with models in the laboratory shows that many of the major phenomena observed in our social systems arise directly out of nonlinear interactions within the system. The linear, or nearly linear model would be unable to generate many of the observed modes of real-life behavior.

The industrial dynamics and econometrics approaches differ most sharply in the way parameters (coefficients) in the models are established. In industrial dynamics, each coefficient relates directly to an identifiable real-world

motivation, influence or relationship. In the industrial dynamics model each coefficient can be discussed with practitioners familiar with that part of the real system and the plausibility of the coefficient can be argued in terms of the wealth of observational data available. In econometrics the coefficients are far more abstract and can not be directly identified with influences on the real-world, decision-making processes. This lack of alignment between coefficients of the model and real life arises partly because the econometric model structure itself does not coincide with the theory of structure which seems to describe real systems.

Whereas the coefficients for industrial dynamics models come directly from observations of behavior in the actual system, the coefficients for econometric models come from statistical analysis of observed aggregate behavior of actual systems. In other words, the gross behavior of a system is observed and, from the resulting time series, an attempt is made to work backwards to the underlying motivational forces within the system. Generally speaking, the derived coefficients for and econometric model fit into a linear structure. At best the coefficients would represent relationships within the system under the particular mode of behavior from which the data was collected. The method could not be expected to obtain information about the very important

nonlinear coefficients which change their values as the system moves from one mode of behavior into another. This is a serious weakness because a system design aims at changing the mode of behavior and the new mode can be expected to involve relationships which in industrial dynamics are taken as variables but which in econometrics are taken as constants.

Industrial dynamics and econometrics make very different presumptions about the importance of having accurate values of coefficients. Most econometricians seem to take rather lightly the assumption about structure and place heavy emphasis on the derivation of the values for coefficients. Industrial dynamics models are constructed on the belief that structure and nonlinear relationships are of the greatest importance and that the numerical values of coefficients are generally of secondary significance. The insensitivity of models to changes in coefficients can be demonstrated with industrial dynamics models in the laboratory. (This insensitivity to the values of coefficients is treated extensively in Appendix B.3 of Urban Dynamics.)

CHAPTER III

THE NATURE AND NEED FOR URBAN SYSTEM ANALYSIS

The preceding sections have discussed the need for dynamic analysis of our social systems and have described the industrial dynamics approach which begins to make this analysis possible. The city is a social system whose behavior has created alarm. The book, Urban Dynamics*, shows how the general industrial dynamics approach can be applied to a specific case.

A. Urban Dynamics

The book, Urban Dynamics, shows how a social system can be structured into a model that allows examining alternative policies. The book deals with the interactions of business, housing, and people and how these produce growth and decline of an urban area. The book develops only one of many important social systems within the city. A similar approach applied to welfare, crime, or transportation could clarify these other major urban subsystems.

Only the highlights of Urban Dynamics will be mentioned here. The book should be considered a part of this report and read by those who want more detail. The book interrelates motivations for the construction of industry and housing and for the mobility of people. These motivational influences are assembled into a system structure to show that well known and easily identifiable factors can produce urban growth and decline. The book shows how various policies can be examined to determine their effect on the revival of an urban area.

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* Forrester, Jay W., Urban Dynamics, The M.I.T. Press, 1969

A number of presently popular proposals are tested--a job training program, job creation by bussing to suburban industries or as jobs created by the government, financial subsidies to a city, and low-cost housing programs. These are all shown to lie between neutral and detrimental in their effect on a depressed urban area.

The study shows how a declining urban area generates a mismatch between housing and jobs. As industrial buildings age, employment and the average level of wages decline. As housing ages, population density tends to increase. The result from declining jobs and rising population is an excess of people compared to the available income-earning opportunities. Under these conditions too much land area is devoted to housing compared to land devoted to income-earning opportunities. The excess housing creates a social trap. Housing beckons low-income people into the area which is already deficient in economic opportunity. Upward economic mobility declines while the low-income population rises. Falling opportunity and rising population both reduce the percentage who can escape the social trap. The frequency of escape is so low that opportunity seems non-existant and frustration rises.

An appropriate model of a social system shows how fundamental causes produce the symptoms of distress. Urban Dynamics does this for the city by showing how the very policies which produced urban growth carry an urban area forward into an equilibrium condition that produces stagnation. But other policies are available to an urban area. Urban Dynamics shows that the economic health and the high mobility for the low-income group which characterized the growth phase of the city can

continue into the equilibrium phase. An equilibrium phase is unavoidable because a time comes when land area becomes fully occupied and population growth must cease. But there are many kinds of equilibrium. Some serve people far better than others.

Urban Dynamics, in Chapter 5, shows a new equilibrium created by policies that each year remove a small percentage of the most deteriorated housing and at the same time encourage more industrial development. Housing and jobs are brought back into balance. The low-income residents who were originally in the area are given upward economic mobility into the middle-income class. Industry and middle- and upper-income housing appear spontaneously in response to private demand. The area begins to draw and accept a larger low-income inward migration than before as the area recovers the socio-economic converter potential that it had during its original growth phase. In this new kind of equilibrium, a housing shortage replaces a low standard of living as the negative factor that regulates the population density in the area.

As shown in Chapter 5 of Urban Dynamics, the policies that result from short-term political influences and humanitarian motivations are often the very ones which degrade the performance of the system from the viewpoint of every population class. The counterintuitive nature of social systems often produces popular support for programs which in the long-run are detrimental. The way in which human intuition and judgement have been formed by experience with simple systems leads a person, when faced with a complex system, to take action which is apt to be ineffective, irrelevant, or harmful. Very often the unfavorable result will occur in

some part of the system quite different from the point where improvement was being attempted.

The city system is replete with processes which cause consequences of an action to differ from those anticipated. Highways are built into the city in response to pressures for reducing commuting time, but the consequence is almost always to increase the total traffic, to keep the commuting time approximately constant, and to increase the congestion in the center of the city. Pressures develop to raise the standard of living of the low-income group in a city and welfare programs are established, but the result is not an increase in the standard of living which is controlled by other social processes. Instead the result is further migration of low-income residents to a city which becomes progressively less able to give them opportunity, while escape from poverty becomes more difficult. Economic success of a city leads to rising land prices and the argument that higher prices must be compensated by zoning changes that permit greater building heights; but higher buildings justify and permit still higher land prices with consequent crowding and overloading of the service capabilities of the city. Rising crime rates can lead to changes in law enforcement methods and attitudes which divide the police from the public, produce aid and sympathy for the criminal element, and increase the crime rate. A subsidized urban transportation system may be justified by economic activity and by the need for transporting lower income workers to jobs; but the results can be to connect the central city with the suburbs to the detriment of the intervening areas which are allowed to decay. The history of our social

systems tells us that the consequences of changes in policies, laws, and programs are often not as intended. Models of those same social systems in the laboratory demonstrate the same counterintuitive behavior. The average person, even when the structure of the system is fully explained to him, will more often than not suggest corrective actions which are ineffective and counter-productive. In the laboratory the reasons for failure can be deciphered. In real life the failures are usually explained away on the basis that the action was insufficient or that other events happened simultaneously to defeat the effort.

B. Urban Concepts

Out of the urban dynamics research thus far have come a number of important fundamental concepts. Other guiding insights can be expected to emerge from future work.

1. Attractiveness.

The "attractiveness" of an urban area is a concept that combines all of the influences that encourage a person to move to the area. If the composite attractiveness of a particular area is greater than the surroundings, net migration toward that area will occur. But almost every component of attractiveness will be diminished by a rising population. Greater population crowds housing, fills jobs, overloads schools, places demands on urban resources, produces pollution, reduces recreational space, and degrades the "quality of life" aspects of a city. Because most components of a city are degraded by rising population

density, the effects combine and only small rises in population and small decreases in each of the attractiveness components are sufficient to reestablish the attractiveness equilibrium between areas.

It follows that in equilibrium, all urban areas must be equally attractive to a particular class of population. An area that is more attractive draws population away from other areas. Unattractiveness can be created by crowding, by high prices, by lack of job opportunities, and other causes. No area can be permanently more attractive than other areas with which it communicates. If this is doubted, try the following thought experiment: assume we have a city with open spaces, little crowding, high wage rates, excellent job opportunities, high quality of housing, readily available housing, no pollution, excellent schools, low prices, and superiority in every other aspect of the human environment. What happens? Inward migration will occur until the desirable characteristics have been reduced sufficiently to eliminate the attractiveness differential between the area and its surroundings.

It may seem pessimistic to assert that in equilibrium all urban areas will be equally attractive. However there are alternatives still open. Areas can be produced which differ from each other in the particular combinations of attractiveness

components. An area can be high in one or more attractiveness factors if some other factor is made low enough to compensate. To alternative conditions of equilibrium for an urban area are illustrated in Urban Dynamics in Figures 3-1 and 5-16. In the first after the area has stagnated, an excess of housing draws low-income population into the area until the falling standard of living becomes sufficiently repelling to limit the inflow. In Figure 5-16 a different equilibrium exists. Job opportunity and upward economic mobility are excellent and inward mobility is kept in check by a sufficiently severe housing shortage. The equilibrium in Figure 5-16 has a larger low-income inward migration than in Figure 3-1 and provides quicker opportunities to the low-income group for economic advancement.

2. Negative counterbalance.

Alternative kinds of urban areas might be defined in terms of the negative counterbalance which is chosen to establish population equilibrium. A negative counterbalance must exist. It might be the composite effect of low quality in all components of attractiveness. Alternatively, a few components might be chosen to carry the burden of population control so that other components could be improved.

A rigidly controlled green belt around a city might forestall urban sprawl, commuting from the suburbs, and expansion of population beyond that which the city streets and services can support. Press reports indicate that an enforced green belt has helped preserve the character of London.

Land zoning to intermix residential and commercial areas more intimately, to limit the heights of buildings and the population density of residential areas, and to preserve much larger land fractions in green space could give a unique and probably desirable character to an urban society. Zoning that establishes excess commercial land rather than the existing practice of excess residential land might force continual residential renewal and prevent blight.

Shifting taxation more heavily onto residential real estate should be carefully reexamined in the light of a system analysis. This is a reversal of present trends. Furthermore, taxation on a basis other than market value should be considered. Perhaps residential property tax should be based on square feet of floor area, regardless of market value. This would create one incentive to replace old and declining buildings at an earlier time.

A negative counterbalance might be created by curtailing the transportation system of a city or by charging high fares on public transportation and high tolls on highways. The unique character of a city like San Francisco has perhaps been created by its location on a peninsula without connecting bridges during its early development. Curtailed transportation might induce compactness and would favor certain kinds of activities over others and thereby give a resulting special character to that particular city.

A city might develop a unique character if it could hold to a high per capita tax rate (levied on individuals) and thereby sustain high quality in schools and cultural attractions. Such a city would draw people and businesses for whom educational and cultural components of attractiveness were the most important.

More attention must be paid to the concept of attractiveness and how some components must be reduced enough to achieve population control. The effort to relieve one deficiency after another in a city is futile, because rising population compensates for the effort. The total net attractiveness can not exceed the attractiveness of the surrounding social system with which the particular area communicates. In the broadest interpretation of "attractiveness," immigration restrictions and other legal con-

trols are part of attractiveness. Such restrictions usually operate differentially on various classes of persons. Immigration of the more skilled people to an advanced country may operate to the detriment of both the source and destination countries. It may remove needed skill and leadership from the less advanced country and at the same time fill jobs in the more advanced country that would have otherwise drawn in lower-income local residents and given them greater upper economic mobility.

3. Modes of urban behavior.

A city can operate in any one of many modes of behavior. each mode is characterized by certain social, economic, psychological, or enviromental pressures. If we select a certain urban mode we are implicitly selecting the pressures that go with that mode. For example, the depressed stagnation mode of a city is characterized by the pressures of a low standard of living and unemployment. By contrast, the revived mode illustrated in Figure 5-16 of Urban Dynamics is characterized by a tight housing situation, especially for the underemployed population. Likewise, other modes will each be characterized by its particular set of pressures. A city must understand the inherent coupling between a certain style of city and the corresponding deficiencies that appear as pressures within the system. The pressures which go with the chosen mode must be cher-

ished and preserved if that mode is to continue to function. To alleviate the inherent accompanying pressures means that the area will shift to a different mode with a different character and a different set of pressures.

Certain conditions of the city represent stable modes of behavior. Each of these stable modes has its ensemble of accompanying conditions. Certain modes must be recognized as imaginary, unachievable utopias. The history of urban evolution has often been a continuous search for utopia, pursued by attempting to eliminate one set of deficiencies and pressures after another. But this process leads not to utopia but to a stable and almost irreversible depressed mode illustrated by many of the cities in the northeastern quarter of the United States.

C. Past Approaches to Urban Design.

In the past urban design has stressed architectural and geometric factors. It has not adequately dealt with the interacting dynamics of people, industry, housing, the aging of buildings, and the pressures for expansion. In short, our cities have not been designed by city planners. What planner would lay claim to having designed the depressed areas now visible in many North American cities? At best, urban planners launch only the initial phase in a cascade of changes through which an urban area thereafter relentlessly falls.

In a very real way, our cities are being designed by the dynamics of the urban system itself. Human psychology and the

nature of our society have set in motion a self-directing system that can lead to various forms of urban crisis. A city is not designed in advance. The present design procedure for urban areas is to respond sequentially to the social pressures that develop. As each pressure develops, the symptoms of difficulty are assaulted by direct action programs designed to relieve the visible pressures.

But this approach seldom reaches the true causes of difficulty and almost always produces changes which generate new pressures. In searching for causes, the public looks close to the symptoms of difficulty. By nature, a complex system produces an apparent cause that is near to the visible symptoms. But this apparent cause is usually a coincident symptom and is not a lever through which the fundamental difficulty can be corrected. By accepting the apparent cause that the system presents, governments are misled into action that merely shifts the symptoms of trouble to another point. The actions fail to reach the true causes that lie deeper and more remote within the social system.

Actions to relieve one set of symptoms cause yet another set of symptoms to arise. The structure of the social system itself determines a sequence of pressures which lead people from one action to the next, each action creating the next trouble point.

This pattern of public reaction to one pressure after another is itself a social-system-design procedure. But it is a defensive procedure. It leads to an undesirable result. The society is led through a sequence that is generated by the structure and policies of the society itself. A city that reacts in this manner is not working toward desirable goals. Unless the characteristics of complex

systems become understood and recognized in city planning, cities will continue to fail to fulfill their potential.

Most city development plans violate one or more of the requirements imposed by the fundamental dynamic nature of an urban system. By attempting the impossible, by adopting policies that have the reverse of the intended effect, by seeking utopia with means that produce disaster, and by attacking the very pressures that must accompany desired urban behavior, frustration with our urban systems is sustained while the urban environment worsens.

Many cities have been developing "master plans" in volumes that describe "Goals for City X". The substance of these plans can be summarized as Christmas lists giving more and better of everything to everyone. As such they set impossible goals. The attractiveness concept tells us that a city cannot be better than its environment in every respect.

The current crop of plans for cities will not alleviate the urban difficulties. They will fail at one of two stages. First, most of them depend on huge infusions of money, money which will probably not be available, so the plans fail by not being implemented. Second, if such plans were to be implemented, most appear to be dynamically unsound. They do not contain the necessary negative counterbalances to compensate for other proposed improvements. Without the negative counterbalances included as part of the plan, the urban system will generate unfavorable factors in unexpected directions to create an equilibrium in population density. In short, the utopian

plans are not viable and contain the mechanisms for their own destruction.

Our social systems are so complex and are of such a nature and structure that there is almost no possibility that effective policies can be established only by judgment, argument, and compromise. Even a person well trained in social system dynamics does not correctly anticipate the behavior of a laboratory model system, although he may have complete knowledge of the structure and policies of the model. Only by going through extensive computer simulations (that is, an examination of the system in the laboratory under a variety of circumstances) does he develop insights about how the particular system behaves.

Urban leaders and city planners in the past have certainly acted with good intent and to the best of their ability. But the consequences of their not understanding the dynamics of our complex social systems are evident in the older cities. Planners and politicians cannot be blamed for past failures because no methods were available for doing otherwise. But methods are now becoming available for understanding social systems and to ignore them will, in the future, become a breach of public trust.

D. Dynamic Design of a City

It is time to enter a new phase in urban planning. Rather than deal with incremental changes and improvements, it is necessary to think of the urban system in its entirity and interrelate the

major forces at work. This is not an impossible job. The major forces are limited and within the range of present modeling techniques. The big hurdle is to develop the necessary theory of social,psychological, humanitarian, and economic interactions. Furthermore, the emphasis must shift from growth to equilibrium. Western societies have focused on growth in geographical area, population, standard of living, and technology. But all of these are encroaching on upper limits set by the carrying capacity of the earth.

1. Emphasis on urban equilibrium.

City planning should shift its emphasis from launching new urban areas and should instead consider questions of equilibrium and continuous self-renewal. An urban area is a combination of physical design, legal and tax structures, and social forces. Unless these interact to maintain a viable social system, degradation will set in. A social system in equilibrium is one in delicate balance. If dynamic design has been happenstance, a city is apt to be characterized by a delicate balance between growth pressures acting in equilibrium with forces that have halted the growth in population density and economic activity. Such an equilibrium is precarious. If can easily degenerate into a downward spiral of forces that mutually accelerate decay. Stable equilibria are probably the ones which press hard against some limiting factor in the system. We must come to know more about these factors. They are related to the characteristic

pressures mentioned previously. The form of equilibrium chosen for a particular city should represent not only an array of attractiveness components which will appeal to a particular mix of people for whom the city is intended, but it must also have the corresponding negative aspects. It must be a stable equilibrium, otherwise it will not last. A stable equilibrium is one which is not easily upset or converted into some other equilibrium mode.

2. Urban goals.

It is appropriate that different cities have different goals. Different cities can have different styles and characteristics; they can appeal to people of different preferences. But if this diversity is to happen, each city must arrive at its own goals for the future. If a goal is not established and maintained, then the goal for the evolution of the city remains implicit and shifts with the changing pressures that the social system itself generates. But it is clear that these pressures will probably lead to urban conditions which, in retrospect, are considered undesireable. It therefore behooves the public, the political figures, the philosophers, and the theorists to seek realistic and achievable goals. Such goals, for a particular city, can probably not be optimum for every kind of person. The city which attempts to cater to everyone probably succeeds in pleasing no one. This surely can not be

preferred over an array of cities, each of which gives preferential treatment to certain tastes, styles, and ways of living. A group of cities can probably meet the preferences of most individuals in a society. But the biggest problem will be to develop realistic urban goals and to forthrightly face the impossibility of a particular urban area meeting the needs of everyone.

The conditions and attitudes in a democracy are not well adapted to developing goals which favor one segment of the population over another. But further study of our social systems will probably demonstrate that the only stable modes contain various kinds of discrimination. Clearly a high-income residential suburb will not be stable when surrounded by chemical plants. A retirement community with few job opportunities will be unsuitable to younger, low-income people needing employment. Certain proportions of various populations are stable in a viable relationship to one another, whereas other proportions of those same groups are not.

Not only should long-term goals for an area be adopted but it is important that they be sustained unless the dynamics of a goal shift are carefully explored. An area which gives up one set of goals and attempts to move to another can easily be trapped in some intervening mode from which it may not have the resources, the wisdom, or the political

unity to escape.

3. Laws, taxes, and incentives.

The design of an urban system exists in the laws, taxes, traditions, and cultural heritage under which it operates. These influences, which constitute the design of the system, must be consistent with the goals toward which the system is moving. The design of a social system means the alteration of constitutions, laws, and tax regulations to encourage desirable action by individuals within the system.

Incentives must encourage individual action that is consistent with the common welfare of all. By incentives, we do not mean here financial payments by tax concessions or other means. The incentive can be in the form of increased freedom to take desirable actions. Incentives can take the form of reducing the restraints standing in the way of desirable action. Legal and tax structures can be altered to reduce the incentive for undesirable action. For example, it seems clear from Urban Dynamics that the depressed condition of cities in the northeastern United States has been brought on largely by legal and tax incentives that encourage the public to take undesirable actions. Under certain circumstances the income tax laws allow depreciation of buildings several times over as a deduction against ordinary income. This effectively converts rental income into capital gains and encourages the continuation

of buildings beyond the time they should be demolished. Likewise, the trend away from real estate taxes reduces the incentive to replace aging buildings. Furthermore, real estate taxes levied on the basis of market value causes the tax to decline as the condition of the building deteriorates. An example of an alternative would be taxes levied on the basis of floor area independent of building value or condition. Such would produce an earlier end to economic life and would force modernization or replacement at an earlier date. Such economic pressures on old buildings would help to generate urban revival. Extension of public-supported highways and rapid transit systems into suburban areas can be another example of tax and legal sanctions that encourage urban decline. An improved transportation system allows the older, inner area to be ignored and skipped over by people who live in the suburbs and work in the core of the city. Tax and expenditure combinations that subsidize municipal services that would not otherwise be self-supporting produce a tax burden on the more mobile citizens and industries. The mobile elements are thereby encouraged to depart from the city.

Not only are the laws and the tax policies causing deterioration of the cities, but they also are preventing diversity in the styles of urban areas. As laws become more restrictive and more mandatory, there is less and less

opportunity for cities to adopt differing laws and tax policies and thereby to create differing styles of cities. If we are to have a diversity in cities there must be sufficient freedom within national policies to permit local areas to differ substantially from one another.

Diversity in local laws and tax regulations is also desirable in order that the differences between cities can serve as experiments to demonstrate which urban management policies are superior.

A society should adopt an experimental attitude. Social systems certainly do not appear to be perfect. Why not then try variations in search of improvement? If the natural tendency of political systems is to gradually adopt laws which depress the effectiveness of a system, then there is little risk in allowing experimentation. The opportunities for improvement are probably more numerous than the opportunities for further degradation. Experimentation and an active search for better systems is probably far less risky than continuing the present course.

E. Other Urban Models

The urban system is by no means fully represented by the model presented in Urban Dynamics. Urban Dynamics presents a life-cycle model showing how a city grows and deteriorates. It paints the city with a broad brush. It deals with the interactions of industry, housing, and people; but it does not include many important subsystems within

the city. Other models of social and economic structures need to be established. Additional models would represent theories of behavior about other aspects of the city. Such models would allow organization, clarification, and improved validation of many of the existing theories about the economics and sociology of the city. The following brief sketches illustrate models which should be developed to clarify other aspects of the city. These models should be of the style and built in the philosophy represented by Urban Dynamics. They should be able to generate the processes whereby the particular subsystems generate difficulties and pathological behavior. Each should be designed to show how policies within the subsystem can be changed to improve behavior of the subsystem. But a word of caution, the criterion for success within a subsystem should be established in terms of how the subsystem contributes to the larger urban system of which it is a part. Many of our present difficulties come from optimizing subsystems according to criteria that are not consistent with the behavior people would like to have from the larger social system.

1. Welfare dynamics.

   As public welfare becomes more institutionalized and the welfare system develops an administrative bureaucracy, many people are beginning to suspect that the welfare system actively creates the people on welfare which the system serves. Furthermore, there is growing evidence that a welfare system actively prevents the escape of welfare

recipients from the welfare category. But little is known about the psychological, monetary, and sociological interactions which determine the dynamics of the welfare system. Fragments of theories exist. A wealth of observational material exists but it is reasonable to assume that no one knows the implications of the total welfare system made up of these known fragments. A welfare model would first of all be a clarification of relevant theory. The behavior of the resulting model system could then be compared with real-life systems and would lead to validating some theories and discrediting others.

2. Crime dynamics.

Many social interactions are observable in the rise and fall of urban crime. Relevant concepts would include relationships between the public, the educational system, the stability of the neighborhood, the police, the extent of community self control, and the size of social units. We can expect that the information available from observers of the urban scene and from those involved in crime prevention could be assembled into a dynamic model which would give us a new and more powerful theory of the forces that increase or decrease crime rates. One observes in actual situations that shifting allegiance is created between the public, the police, and the antisocial elements of a community. What causes the public to align with and assist the police or, conversely, to align with the criminal element in such a way that the police task becomes impossible?

3. Technology in the city.

Science and technology have contributed immensely to the growth and development of the modern city. But we should not be misled by 150 years of technological advancement. Technology appears to be beneficial when it is contributing at an accelerating rate and keeping the attractiveness of the city ahead of the processes of innundation which come from rising population. But technology itself produces rising population. It increases transportation systems, it allows taller buildings and increases population density. Medical advances reduce death rates and increase total population. The ultimate equilibrium effects of rising technology have not been evident until recently. But now increasing population, rising pollution, standards of living above what the human requires, and the traumatic environment from crowding, noise, and smog all make us realize that technology is simply one of the components of urban attractiveness. As already discussed, when one component of attractiveness increases, others must decline unless the entire world with which the city communicates rises in its absolute level of attractiveness. As technology contributes to a city, people are attracted and the disadvantages appear as crowding, pollution, and psychological stress. During the century when technology and urbanization went hand-in-hand, technology appeared as the servant of mankind. But now we see that more technology

produces its reaction by lowering a whole array of "quality of life" variables in the environment. The construction of highways literally increases the number of automobiles with the consequent crowding and air pollution. The city has used tax money to subsidize technology to produce the very changes that now characterize the cities' difficulties. A dynamic model could help organize our knowledge of how technology, standard of living, human happiness, and the urban environment may be interrelated.

4. Land prices.

Rising land prices are part of the economy and psychology of a city. Rising land prices are used to justify changes in zoning, but changes in zoning affect land prices. Prices and zoning influence population density and the uses to which land is put, but these all interact with one another. Rising prices justify taller buildings, which justify transportation systems which bring people to those buildings, which in turn create forces for still greater congestion. A dynamic model built around pressures that affect land prices might show important ways to gain control over urban development. Who should reap the rewards of land price appreciation caused by public expenditure on transportation and city services? In North America the appreciation goes usually to the land owner, creating strong pressures toward land speculation. In some European countries the appreciation is seen as having been

created by the State through public expenditure for roads and urban services and price appreciation is largely taxed away to reduce incentives for speculation. What are the long-term social implications of two such different policies? Is the choice important in determining how a city develops? Such questions need illumination.

5. Transportation systems.

A model focussed on the dynamics and theory of public transportation systems might help in guiding future governmental expenditure. It is becoming clear that improvement of transportation systems can actively accentuate the difficulties of a city. Again, transportation is one of the attractiveness components of a city. As transportation is enhanced, other components such as crowding and rising land prices will compensate. What therefore is the proper balance of transportation in the total setting of the city? To what extent does transportation create the tone and style of a city? What kinds of cities should improve and extend their transportation systems? What contrasting kinds of cities should limit or curtail their transportation systems lest the goals of the city be defeated?

6. Size and population.

A dynamic model of a city might focus on the size of the

metropolitan urban area and its population density. How large should cities be? Is the expansion of a metropolitan boundary a way to solve the cities' financial problems or merely a postponement and intensification of ultimate urban disaster? How should an urban area be related to farm land, forest land, and the recreational area? What distribution of population should be encouraged? How will the pressures for population control be generated short of the urbanization of so much farm land that the nation cannot support itself?

7. Subsidized urban services.

Most cities are contributing to their own difficulties by subsidizing activities and public services which on their own would not be self-sustaining. The more this is done, the more the city attracts those population segments who want to take advantage of those services available at unnaturally low and subsidized prices. At the same time the city drives away those people not wanting the particular service and being unwilling to help support it through tax assessments. How do subsidized services tend to generate a particular type of city? Subsidized services have a selective effect on population. As population changes, so does political power. In the worst cases, a runaway situation can be created where subsidized services

attract those who use the services, who then develop sufficient political power to vote still greater services. These comments apply to transportation systems, to welfare, to cultural activities, to sports stadiums, and to school systems. The creation of municipal subsidy, municipal monopoly in providing certain services, and municipal bureaucracies for the delivery of service, all have important dynamic implications for the evolution of the urban system. Some of these evolutionary processes lead down roads which will be most difficult to retrace. The dynamics need to be explored before the road has been travelled too far. Again, a dynamic model that interrelates the relevant fragments of theory is the only possibility except to experiment blindly with our cities. Computer experimentation suggests that there are far more unsuccessful experiments than successful ones. Real-life experiments should be limited to those which at least show promise in the laboratory.

F. Urban Affairs and the Nature of Complex Systems

Chapter 6 of Urban Dynamics discusses the nature of complex systems and need not be repeated here. That chapter should be read as part of this report.

Of special significance is the counterintuitive nature of

complex social systems. The process of human evolution did not until recently face man with the need for consciously understanding complex systems. A complex system is a high order, multiple loop, non-linear system. It has special characteristics not encountered in hunting and fishing and tribal life. Only with the development of concepts about feedback systems and the availability of the computer for simulation with models has it been possible to examine the nature of complex systems. It is now possible, in the laboratory, to demonstrate the failure of human intuition even when faced with an explicit model of some process already familiar to the individual.

A following experiment that illustrates the counterintuitive nature of systems was conducted several years ago in a second-term graduate course in industrial dynamics taught by Jay W. Forrester. A model of the growth dynamics of a new, technically-based corporation was constructed. This was done over a period of six weeks, during which time the nature of a growth company was examined in detail and statements were set down constituting a theory of how the actions within such a company were interrelated. The model included personality and leadership characteristics of the founders, management power structure relationships, internal corporate stress generation, resource allocation, internal dynamics of the market, the dynamic characteristics of the product stream, and the interactions between company and market. The model was a careful

detailing of attitudes, policies, and relationships which are readily recognized by anyone familiar with the internal operation of such a company. At the end of six weeks the students had participated in the development of every concept within the model and had complete information about policies and interrelationships. They were then able to simulate the resulting system on a computer and obtain any amount of time history as generated by the model on as many of the internal variables as desired. The system was about three times as complex as the one described in Urban Dynamics. As initially set down, the model showed one of the classic modes of behavior of new technical growth companies--there was a strong growth trend interrupted by repeated, severe crises, spaced some five to seven years apart. At this point the graduate management students were given the task of changing policies within the model system to reduce the intensity of the repetitive crises. After another six weeks and some fifty changes in the system, no one had found any policy modification which substantially altered behavior. The growth trend had not been appreciably increased nor decreased. The severity of crises had not been eliminated. The students had been making desperate changes. Policies were restructured, coefficients and nonlinear table relationships had been changed by factors of five and more, all to no avail. As one watched their efforts one realized that they were making changes in the laboratory company of exactly the same kinds that

managers make in real companies. The changes do not work in real companies and they were not working in the laboratory. In real companies the failures are blamed on inadequate execution of the policy, or on other events that changed at the same time. But in the laboratory there were no such extenuating circumstances. It became clear that defeat of the policies lay within the social system itself. The structure and nature of the system was compensating for the policy changes without appreciable modification to the overall behavior of the system.

It is characteristic of our social systems that they inherently resist and defeat most changes in policies that one might happen to choose. Furthermore, the subtle nature of the systems is such that, if one points out a sensitive influence point to a participant in the laboratory, he is most likely to make his initial modification in the wrong direction. In so doing he is merely following the folklore of real systems with the same detrimental results.

But complex systems are seen always to have influence points through which changes can be introduced. Very often the direction of influence is opposite to what would be commonly supposed. For example, it has been considered self-evident for several decades that construction of low-cost housing would alleviate some of the difficulties of a city. Practice has shown that this is not true. The model in Urban Dynamics in Figure 4-8

shows why a low-cost housing program depresses the city and makes it less desirable for every population class including the low-income population. On the other hand, removal of slum housing without replacement with low-income housing is seen in Figures 5-10 and 5-16 to set in motion the processes of internal revival. The resulting revival is again better for all urban residents, including the low-income group for whom it provides economic opportunities and upward economic mobility into the middle-income class.

In urban affairs special attention should be given to Section 6.6 of Urban Dynamics on the way corrective programs imposed from the outside can be counteracted by the system. An externally applied program from the outside which is designed to alleviate the symptoms of difficulty in a social system can have several unexpected results. First, as the outside action begins to alter the conditions of the system, the system relaxes its own internal processes aimed at the same result. The system thereby throws the burden ever more on to the outside force which is attempting to produce a correction. In other words, the outside program reduces the internal incentives toward the same end. The outside source of money and effort is left to carry the load alone. Furthermore, the outside effort may generate internal reactive pressures which increase the difficulty of getting the job done. Beyond all of this, the outside program does not

address itself to the original causes of the difficulty which are still left at work within the system. The final result is that two major forces have been pitted against one another. The social system by its internal structure and policies is still so designed as to generate the undesirable behavior. The external force is trying to overwhelm that behavior. But the external effort will usually be insufficient and in the face of failure will become frustrated and will be withdrawn. Before a governmental unit embarks on housing programs, slum renewal, public health services, transportation, or even expanded education, the resulting dynamics should be explored. Programs which may be good up to a point can become ineffective or even detrimental if carried too far.

The comments in Section 6.7 of Urban Dynamics about long-term versus short-term response in a complex system should be especially noted by political leaders. After a policy change in a social system, the short-term response is apt to be in the opposite direction from the long-term effect. This is especially treacherous. A change which improves matters in the short-run often sets in motion forces which lead to worsened behavior in the long-run. The converse is also true. Policies which are effective in the long-run often must be pursued through a short-run period when they appear to be detrimental. Examples are all around us. If an agricultural country is to industrialize, it must accumulate railroads, factories, and steel mills. This capital accumulation can only be done by foregoing consumption and reducing the standard

of living may rise at a later time. If a company faces declining earnings because its products are obsolete, it must invest more heavily in product research and incur even deeper short-term losses if it is to recover in the more distant future to a profitable product stream. A student foregoes short-term earning opportunities by attending college in order to increase his long-term earning capabilities.

The short tenure of men in political office favors decisions which produce results quickly. After these results have been obtained and the ensuing decline sets in, there is a strong tendency to look back to the earlier improvements and redouble the apparently successful earlier reactions. The result is to deepen still further the future difficulties. Many of the social systems in the world around us are showing growing burdens created by an accumulation of short-term policies with detrimental long-term consequences. These effects can be examined in laboratory models of social systems and we find that the laboratory results correlate well with history and real behavior.

As mentioned earlier, the complex system has a tendency to react in quite a different direction from that expected when a change is made. Highways are built to reduce travel time but the result is higher traffic instead. Money ban be appropriated for more police, but under some circumstances the public begins to align with the ciminal element to actually raise the crime rate.

Minimum wage laws are established to help the low-income group but may have the effect of making the unskilled worker uneconomic and unemployable with the result being a rise in welfare rolls. Every proposed program should be examined in the context of the system with which it interacts to see what results might be anticipated. Capital investment may be encouraged from outside countries in order to build up industrial capability and standard of living, but the result can be to reduce internal initiative and entrepreneurship, and in the long-run an economy which is not self-sustaining.

CHAPTER IV

BEYOND URBAN SYSTEMS

As one looks away from the city he sees both larger and smaller social systems on which a country depends. These extend from the community and the corporation to the national economy and the interrelationships between the country and the outside world. All of these are complex systems having the capacity for perverse behavior. All interlock to give a country its standard of living, its economic growth and its stability.

The general characteristics of complex systems as described in Chapter 6 of Urban Dynamics apply to our social systems of all sizes.

The counterintuitive nature of complex systems raise disturbing questions about the democratic process as systems become larger, more bureaucratic, and more short-range in viewpoint. Many trends in our social systems are producing a shorter time horizon in people's thinking. Many decades ago in a rural community a farmer planned for his own retirement and later years. In fact, he looked beyond his own lifetime by developing land and constructing buildings for future generations. Likewise, in the earlier days of the corporation, a founder-manager started an enterprise as a life career. He saw in it a family enterprise to be carried on by his sons. But in our present society of large corporations, men are transferred from one position to another every few years. A man inherits problems left

by his predecessor and leaves his long-term mistakes for his successors. The empasis is increasingly on short-term success. The discrediting of nepotism has come as a byproduct, and has hastened the destruction of long-term foundations in our enterprises.

The top executives of most corporations are professional managers who come into their positions only a few years before retirement. Their places will be taken by men whose identity they do not yet know. The incentives are to make the best of the present and let the future take care of itself. But if, as discussed in Section 6.8 of Urban Dynamics, the short-term responses of a system tend to be opposite from the long-term responses, then this growing emphasis on the near future leaves a growing burden in a more distant time. The short-term organizational and economic pressures then begin to couple into the value and morality structure of a country and draws the society away from its most fundamental long-term human values.

Television locks together more closely than before the emotional reactions of a country. If experience and intuition gained from simple systems are misleading when applied to complex systems, a public consensus is likely to lead toward deepening difficulties through a process of unwise changes in the legal, financial, and governmental structures. A country can become an unstable society. If democratic processes are to remain successful, a high level of public education in the nature of social systems

appears necessary. In considering the dynamics of social systems, special attention should be drawn to the tendency of the systems to drift to low performance. If the sequence of design changes in a system tend in time to degrade its performance, it follows that our systems are operating at far from optimum effectiveness. The low performance implies that the system is not best by any standard of measurement. Some important consequences follow. If a system is not optimum for any purpose, improvement in that system can be obtained without penalty or price. The work to date in social systems suggests that, as a first step, a social system can be improved in many of its characteristics without degrading other characteristics. For example in a company, a change in inventory policies can increase the stability of employment and reduce the frequency and extent of layoffs without increasing the amount of inventory which must be stored and financed.* Likewise in a company one often finds low profitability coupled with inadequate capacity to meet demand. Both problems are solved by raising price sufficiently to improve profitability and permit expansion. In a city the changes in legal and tax structures to initiate spontaneous internal renewal will be more effective and less expensive than renewal by governmental redevelopment programs.

The expectation that systems can be improved in some of their characteristics without paying a price in other characteristics has important political implications. Many governmental programs

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* See Chapters 17 and 18 of Industrial Dynamics by Jay W. Forrester (M.I.T. Press, 1961)

are now set up as "zero-sum games". In other words, the implication is that improving "A" will have a cost at "B". For example, if depressed areas in a city are to be renewed, the cost must be paid by taxpayers elsewhere. Or, if better control of our social system is to be obtained, individual freedoms must be curtailed. Or, if corporate efficiency is to be increased, it must be at the expense of human values. These prices may be extracted if changes are made in the wrong manner, but it appears that there is so much room for improvement in the performance of our social systems that changes can at first benefit both "A" and "B" without having to choose and compromise between the two.

The world is entering the transition from growth to equilibrium. The history of mankind has been a continual struggle for growth--growth in geographical areas, of living, in population, in urbanization, and in sizes of social units. This growth is now impinging on the population capacity of the world. There is much talk of the necessity to limit world population in the foreseeable future. But the proper time for stabilizing population may well have been in the past. Quite possibly the world ecology is not capable of providing for the present world population the standard of living which has been exhibited and publicized by the Western democracies. If so, a large fraction of the world's population has been led to expect an impossible future.

All models thus far examined which generate the life-cycle of a social system show tremendous shifts in internal

pressures as the system moves from the growth phase into equilibrium. Much of the stress which we see on the worldwide scene at the present time is probably coming from the forces which are beginning to depress growth in geographical areas, population, and standard of living. But the structure and rules under which a system operates determine the severity of the stresses that arise as equilibrium is entered. Various transitions between growth and equilibrium appear possible. One of the greatest forthcoming challenges to mankind is to enter a state of equilibrium by transitions that avoid catastrophe and still preserve individual values and purpose.

On this broader scale, many social subsystems need to be modeled to establish their structure, their theory, and their behavior. A few of these are identified in the following sections.

A. International Systems

International economic transactions interrelate the economy of a country with the outside world. The stresses that recur in the international monetary system and in international trade are manifestations of mismanaged complex systems. The structuring of a model of these processes would draw together the relevant theory. It would show which theories are compatible with observed behavior. It would point to regulations for managing imports and exports and foreign exchange which would insulate

a country from the mismanagement of others.

The policies of a social system may make that system relatively independent of or highly sensitive to the outside world. Certain policies can make a company vulnerable to small shifts in market behavior or competitor reactions. Other policies can be equally successful and at the same time reduce the vulnerability to outside events. In the same way we can expect that the foreign trade policies of a country can differ, not only in their long-term effect on the internal economy, but also can differ in their sensitivity to external influence. A single country, such as Canada, may not be able to force the adoption of sound policies by the world community. It does, however, have substantial choice in the extent to which its own policies make it dependent on outside actions.

Because of its close proximity to the United States, Canada is especially influenced by business and investment relationships from outside. A modeling of Canadian economic development could show how best to use outside investment. Some investment no doubt accelerates economic development, but too much may suppress internal entrepreneurship and longer-term strength and independence. By importing investment money and technical expertise, Canada may be reducing its own generation of investment funds and technical skills. If so, it becomes progressively more dependent on the outside support. All such relationships are subject to being

examined in search of improved national policies.

Canada, with its agricultural base, is interested in world commodity markets. Fluctuating price and production in such markets dislocate national economies. The general nature of a commodity market has been studied using industrial dynamics methods by Meadows*. Meadows shows how the managerial, economic, and biological aspects of a commodity interact to produce the various periodicities observed in commodity cycles. An extension of that work can be made into the design of price and production stabilization policies which should be far more effective than any yet employed for international commodity stabilization.

B. Economic Systems

The dynamics of economic systems are far from understood. Existing econometric models attempt to explain the present behavior but are not suitable for exploring governmental policy changes of the kind which might change the character of economic behavior.

The industrial dynamics type of model is an extension of verbal theory. The theories proposed by economists can be converted to dynamic model form to determine how adequately the theories represent observed behavior. There are no economic models in widespread use which can by themselves generate the kinds of behavior seen in actual systems. To construct models that would

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* Meadows, Dennis L., Dynamics of Commodity Production Cycles, (Wright-Allen Press, Inc., 238 Main Street, Cambridge, Mass., U.S.A., 1970).

capture the essence of economic behavior would be a task only a few times greater than the creation of the model of a city in Urban Dynamics.

A theory of economic behavior needs to be developed and expressed as a dynamic model which will interrelate fiscal and monetary policy, inflation, economic growth, and unemployment. From a dynamic model of a national economy, we could expect surprising lessons just as the model in Urban Dynamics causes a reassessment of our concepts about the city. It may well be that existing theory about the control of inflation may be ineffective or actually a cause of inflation. Almost certainly the time response of the economic system is far slower than commonly supposed. The forces to produce inflation may be years or decades in forming, quick solutions are probably not possible.

Another task in the economic area will be to examine the dynamics of transition from economic growth to equilibrium. For a substantial percentage of the population in Canada and the United States, the standard of living is as high as necessary or desirable. Many of the present internal social stresses come from the collapse of time-honored, historical goals of striving for greater material well-being. What kind of economic system will one have when growth ceases? Will it be one of continous internal self-renewal or will it be one of declining standard of living and stagnation? Just as an urban area can exhibit various kinds of equilibrium, we can expect an economy to do likewise.

As with the city, each equilibrium will exhibit characteristic pressures that go with the particular equilibrium. Unless we understand those pressures and are willing to accept them the particular equilibrium mode cannot be sustained. Even in a country with the future development potential of Canada, parts of the system are already beginning to approach equilibrium. And the pressures that go with growth suppression should be under study.

As with other social systems, it is reasonable to assume that all of the necessary knowledge now exists for constructing an effective model of the system. We usually find that the behavior of the system is a natural consequence of interactions between components whose individual characteristics are well established. The pace of progress in this area will depend on the availability of people adequately trained in organizing existing information into an appropriate structure (that is, theory) of the economic system. Progress is not being delayed by the need for more data collection.

C. Population Systems

The present rules under which our social systems operate generate population, population growth, and population distribution. In the future, population must come more under control of the social system if tenable living conditions are to be maintained.

What forces will we use for limiting population? Will falling standard of living and starvation be the ultimate pressure, or will other social controls be used instead? Will population expand until forest and farmland have fallen too low to sustain a satisfactory human environment, or will the expansion of residential and industrial areas be sharply curtailed so that the resulting space pressures force a limitation of population before productive agricultural land is overrun?

Just as the policies of a city determine the distribution of people and activities within the city, so the policies of a country determine the distribution of population and the structure of its economic activity. Consider the distribution of population into four categories--agricultural, manufacturing, service, and information processing. The last category, information processing, is expanding rapidly. It includes all of those people whose essential function is the transmittal and conversion of information--lawyers, doctors, teachers, white collar workers, executives, and governmental employees. What happens to this group in an equilibrium economy? Fewer are probably needed than in a growing system or one struggling with the problems of transition from growth to equilibrium. Just as a city develops more skilled workers at the end of its growth phase than it can sustain in its stagnant equilibrium, so an economy can be expected to require a re-alignment between major population groups.

D. Ecological Systems

The reverse of urbanization is the protection of agricultural land and open space. As the standard of living rises, more of the national effort must be devoted to protecting the environment from population and industrialization. We are now at the point where population is encroaching rapidly on agricultural land. A precipitous transition can occur wherein expanding urban areas simultaneously require more food but cut the capacity for food production. The transition from apparently excess rural area to a deficiency can occur suddenly. Such transition must be foreseen. Pushing back urbanization and recovering farmland would be a traumatic, expensive undertaking.

The dynamics of change, in animal population, in the ecology of lakes, and even in changing climate need to be better understood with the development of sound theory.

E. Industrial Systems

In the broad sweep of social systems, the behavior of the business corporation must not be overlooked. It was first in connection with the industrial corporation that the present industrial dynamics approach to systems was developed. However industrial dynamics has not yet been widely enough understood to have major influence on the business world. Canada especially needs to examine the dynamics of its industrial enterprises. How

are they to be encouraged? What should be their relationship to other countries? How does local or foreign financing affect the development of entreprenuers and business leaders? To what extent does Canada depend on the import of industrial materials and components? How do tax laws direct the course of industrial development? How can business leaders be better trained to understand the growth and stability of the industrial corporation? All of these questions are capable of being explored in the context of relevant social systems.

F. Other Social Systems

Many other social systems are of growing significance. In parts of the industrial world communities are breaking down as the focal point of human endeavor. This breakdown of the community has been precipitated by the way corporations transfer personnel, and by growing strength of larger governmental units but are these trends good? Or, should the equilibrium society of the future have more of a local-community orientation? If there should be community orientation, how is this to be achieved?

Discussion of the community brings one to the psychological and psychiatric forces on the individual and the family. How are these forces conditioned by the broader economic and larger social systems? Should present trends in the community and work environment of the individual be allowed to continue or must an

equilibrium society be based on more local and individual freedom?

The psychological foundation of all of our social systems, whatever their size, needs to be better understood. How are goals and traditions generated? How are goals sustained? What keeps goals from collapsing under stress? Dynamic models of goal generation and of the effect of traditions on decision making have been constructed and should be further explored.

In dealing with social systems the concepts of "human values" need to be identified and clarified. We need to understand better the criteria for a successful social system. How is a good system to be judged? In what way should social systems serve the individual? How is the social system to be kept from encroaching upon individual freedom? Philosophy, history, and human aspirations must be made an integral part of social dynamics.

CHAPTER V

THE DEVELOPMENT OF A CAPABILITY IN SOCIAL SYSTEM ANALYSIS

In discussing the future of social system analysis, comparisons with technology and medicine may help to clarify the magnitude and nature of the future.

Understanding the behavior of our social systems is the next great intellectual frontier. The last several decades have been devoted to the exploration and utilization of physical science. The next several decades will focus in a similar way on a science of social systems. Just as physical science in the last fifty years has moved from the research laboratory into general education, so an understanding of the dynamics of social systems will progress from the research laboratory to school at all levels.

A full professional competence in analyzing the dynamics of social systems will require a background of training comparable to that required to produce a medical surgeon capable of making human-organ transplants. Such an investment in time and effort may at first seem forbidding but its importance to the human race is even greater. The stages in training of a social dynamicist will be somewhat similar to those experienced by a medical doctor. There is theory to be learned, lecture material to be transmitted, cases to be studied, laboratory experience to be acquired, and an internship to be served. Then experience and

practice are required to develop skills. But, like medicine, there is the opposite end of the spectrum. Just as first aid can be learned quickly and usefully by the individual, so some knowledge of social dynamics can temper the attitudes and judgment of every individual. Just as physical science should be part of the background of the well-educated individual, so will social dynamics be a part of the perspective of the future well-educated man.

But the field is still embryonic. Education and applications are in an early stage. The development of theory and the application of theory will go hand-in-hand. Practice depends on theory but theory can only be developed out of practical experience. Where then is the starting point in Canada?

The first step should be creation of several small groups, each developing its capability in structuring and analyzing complex systems. One of these groups should probably be within the Canadian government. Perhaps three others should be established in universities where research and education can proceed together.

The groups can draw on work which has been pioneered at the Massachusetts Institute of Technology. Some text material and many professional papers exist. The published material is probably no more than 10% of the material that exists in the experience and practical background of faculty members at M.I.T.

In turn, the material being taught at M.I.T. is probably no more than 30% of that required for full professional training in social dynamics. Canada will need to learn from the published material and from personal contact with those having greater experience. Any group intending to start in this field would be well advised to send its members for a year of study at the Massachusetts Institute of Technology. If this cannot be done, arrangements should be made for individual coaching by someone who has a good grasp of the work being done in Cambridge.

Beyond this, any group embarking on social dynamics at the present time must pioneer, must carry on a research program, and must help develop the field. Each of the groups should start with five or more people. A smaller number can make substantial progress but a smaller group is apt to disband and lose momentum if one or two of its members choose to leave.

If the groups are to be most effective, careful selection of the initial members is crucial. In our experience, the best prospects are men who have an engineering background in feedback dynamics (servomechanisms), and who have already gone on into positions of management or politics. The background in engineering dynamics is far more important than one in statistics and matrix operations as common in the fields of social science. The best existing training is at present given in departments of electrical engineering which specialize in feedback-control

systems. But a word of caution should be heeded. Much of present day research in control systems stresses highly mathematical theory and can produce the wrong attitudes and frame of reference. The practical engineer who has designed physical systems and the feedback-control engineer who has advanced into management are better prospects. They combine theory with practice. They have managerial experience and a background in practical psychology and organization.

On the average it appears that mathematicians, computer specialists, mathematical social scientists, and mathematical economists are less likely to succeed in developing the field of social dynamics. These individuals are apt to be too immersed in theory and too isolated from personal contact with the forces, pressures, and motivations within our social systems.

It would be a mistake to start a new group working on specific social tasks of immediate importance. The group should first develop fundamental competence in the theory of structure and dynamic behavior. It should retrace, as case studies, the modeling of systems which has already been done. It should gain experience with relatively simple systems. This can well be done by taking verbal theories of structure and behavior which already exists in the literature of every field and converting these to precise models. Doing so will organize the existing theories about system structure and will expose whether or not the

propositions about structure lead to the assumed behavior.

The cost required to develop a competence in social dynamics is open-ended. Again, the analogy is to the development of the fields of science or medicine. Small steps are taken at the beginning. If there is progress, further steps are justified. An initial commitment which would support four groups of five people each for about five years would make a significant start. Five years should be the minimum commitment to any initial group. Even with an excellent choice of candidates, two years will be required to master the available material of the field and to gain elementary experience in system modeling and computer simulation. Two or three more years would then be required to demonstrate independent progress in new areas.