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The Dynamics of Social Systems

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THE DYNAMICS OF SOCIAL SYSTEMS

a paper prepared as a
candidate for the designation:
"Research Honors in Sociology"
by

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Foreword

This paper has been written to fulfill requirements placed on me as a candidate for the designation "Research Honors in Sociology" in connection with my graduation from Illinois Wesleyan University in May of 1973.

My topic grew out of an interest in a subject which first came to my attention during the fall of my junior year in "Social Theory", a class taught by Dr. D. Paul Miller. At that time, I became aware of Professor Jay W. Forrester of the Massachusetts Institute of Technology, through an article that he had written entitled "Counterintuitive Behavior of Social Systmes." I read more of Forrester's writings and pursued my interest by writing a term paper required for the course mentioned above entitled "A Comparison of Traditional Reform Versus Forresterian Reform."

Thus, thought and study on this project has covered a span of time greater than the "short term and spring 1973" designation would infer, though the actual drafting and redrafting of this paper as it now stands, was done during that time span.

Short term was a time of intensive reading and studying, followed by a ten-day stint in Boston, where I attended the lectures of a seminar entitled "The Dynamics of Social Systems" at the Massachusetts Institute of Technology in Cambridge. This seminar was led by Professor Forrester and members of his staff, and was valuable even beyond what I had anticipated.

I was received graciously at MIT and was helped tremendously through individual discussions with staff members, additional literature given to me, and a tour of the Systems' Dynamics center and DYNAMO computer room.

My special thanks to the following people: Professor Jay W. Forrester and his staff, especially Dr. R. Greene, who handled the arrangements necessary for me to attend MIT on this temporary basis, Dr. D. Paul Miller who has acted as my committee chairman for this honors' project, and has been my constant encourager, and to the members of my committee:

Dr. David Braught
Mr. Ray Comeau
Dr. Wendell Hess
Dr. John Troyanovich

for their interest and participation.

Most sincerely,

Sue

Susan Jane Albery
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April 18, 1973

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Introduction

We often hear life in general described as "the system" when the speaker is expressing a feeling of futility. We feel that we can't understand why things go as they do, and very often we are correct in this frustration and lack of understanding. We can't understand "the system" or any other system of any magnitude. We often say that we must "get above" something before we can view it. Yet how can one "get above" all of the aspects of an industry as complex as Polaroid, or a city as large and multifaceted as Los Angeles?

What we have done in the past is to observe a portion (often we think a large portion) of our particular concern and draw conclusions based on our intuition and past experience. Yet things have not gotten better as the years have gone by and as industry and cities and the world have grown and issues have become more complicated and far-reaching. Our best efforts have been stopgap at best and detrimental at worst.

There is now a school of study called "Systems' Dynamics". The claim of this school of study is not one of total solution, but of offering a framework within which the systems of our lives can be seen in toto, within which the forces which affect those systems can be seen as their interrelations affect each other and the whole. For it is the effects of these interrelations which our intuitive solutions cannot fathom; the inferences that they have for our problem as a whole.

Thus, the term "systems' dynamics" labels a framework; an umbrella of method under which problems, and the systems of which they are a part, can be studied in the largest necessary context. These can be systems within economics, industry, or cities, as previously mentioned, or systems within concerns of ecology, or even interpersonal or interracial relationships.

This is the concept which must be grasped most firmly; systems' dynamics is not a subject unto itself, but a method for studying other subjects; a tool, an aid, a framework.

My intent is to explain the "how" of this framework, not in extensively difficult terms, but as I understand its application. Since I am blessed with very little mathematical bent, acceptance of the part of this which relies on a computer, was, for me, a leap of faith. This was not a major problem for me, as I am convinced of the feasability and applicability of this particular mode of sutdy. I ask you to appreciate this acceptance and proceed with me from this point, believing that understanding the innermost technical workings of this method is not integral to understanding its value and application.

The Elusive Principles of Systems

Man lives and works within social systems which include the interaction of people, technology, laws, natural forces, and ethical values that determine the evolution of a civilization.[1] His scientific research is exposing the structure of nature's systems and his technology has produced complex physical systems. But even so, the principles governing the behavior of systems are not widely understood. As used here "system" means a grouping of parts that operate together for a common purpose, and a system may include people as well as physical parts.

Forrester feels that there are several reasons why the concepts of the principles of systems do not appear more clearly in our literature and education. Often, people have felt no need for understanding the basic nature of systems since systems seem to possess no general theory and meaning. Often, the principles of systems, when sought after, have been so obscure that they seemingly could not be studied.

In primitive society, the existing systems were those arising in nature and their characteristics were accepted as divinely given and as being beyond mans' comprehension or control. Man simply adjusted himself to the natural systems around him and to the family and tribal social systems which were created by gradual evolution rather than by design. Man adapted to systems without feeling compelled to understand them.

As industrial societies emerged, systems began to dominate life

as they manifested themselves in economic cycles, political turmoil, recurring financial panics, fluctuating employment, and unstable prices. But these social systems suddenly became so complex and their behavior so confusing that no general theory seemed possible.

Gradually over the last hundred years, it has become clear that the barrier to understanding systems has been, not the absence of important general concepts, but only the difficulty in identifying and expressing the body of universal principles that explain the successes and failures of the systems of which we are a part. Economics has identified many of the basic relationships within our industrial system. Psychology and religion have described some of the interactions between systems of people. Medicine has treated biological systems. Political science has explored governmental and international systems. We have been overwhelmed by fragments of knowledge but we have had no way to structure this knowledge.

A structure is essential if we are to be effective in interrelating these fragments and interpreting our observations in any field of knowledge. Without an integrating structure, information remains a hodge-podge of fragments and knowl

tion of observations, practices and conflicting incidents. Without a structure to interrelate facts and observations, it is difficult to learn from experience, and it is difficult to use the past to educate for the future.[2] Jerome S. Bruner of Harvard argues the importance of structure when he says, "Grasping the structure of a subject is understanding it in a way that permits many other things to be related to it meaningfully. To learn structure in short, is to

learn how things are related."[3]

There are fundamental reasons why people misjudge the behavior of social systems. The most obvious of course, is the lack of knowledge we have about their basic structure. Also, there are orderly processes at work in the creation of human judgement and intuition that frequently lead people to wrong decisions when faced with complex and highly interacting systems. It is Forrester's basic theme that the human mind is not adapted to interpreting how social systems behave. Thus, his approach is one that combines the strength of the human mind and the strength of today's computers. The basis of the method is recognizing that the structure of <u>any</u> system---the many circular, interlocking, and sometimes time-delayed relationships among its components--is just as important in determining its behavior as the individual components themselves, thus mind and computer are both very much needed. The approach is an outgrowth of developments over the last forty years, in which much of the research has been done at the Massachusetts Institute of Technology. The concepts of this systems study apply from physical systems to social systems. The ideas were first developed and applied to engineering systems, and have now reached practical usefulness in major aspects of our social system.[4]

Any approach must be built on past strengths and improve on past weaknesses. The classical approach to solving problems that have arisen in complex systems is based on intuition. We think about how the parts of a system are related, and try to come to a decision based on our past experienc

study approach to counseling or education. A simple diagram expresses the separation of all of the information that we have availiable to use in this thought process. (See plate #1, next page.) Most of this information comes from direct observation, and remains in peoples' minds. This is a dynamic process which occurs as we think about how things change through time. A small part of the information which has been in peoples' minds through the ages has been written; included in this would be the classics. However, the written emphasizes the static aspects of information (dates, places, etc.) rather than the dynamic, with proportionately few exceptions. The most static of all information that we have availiable to us is that which has been preserved as numerical data. Historically then, our decisions and evaluations of systems and their probable behavior have been based on our intuitive use of all of the information that we have availiable to use for problem solving.[5]

Forrester believes that the intuitive method of problem solving in systems is unsatisfactory, and the basis for his alternative approach is a method called modelling. A model is a substitute for an object or system, and can be of many forms and serve many purposes. We are all familiar with physical models that represent objects. Any set of rules and relationships that describe something is a model of that thing. In a sense, all of our thinking depends on models.[6] Every person in his private life and in his community life uses models for decision making. The mental image of the world around one, carried in each individual's head, is a model.

DIRECT OBSERVATION-INFORMATION IN PEOPLES' MINDS

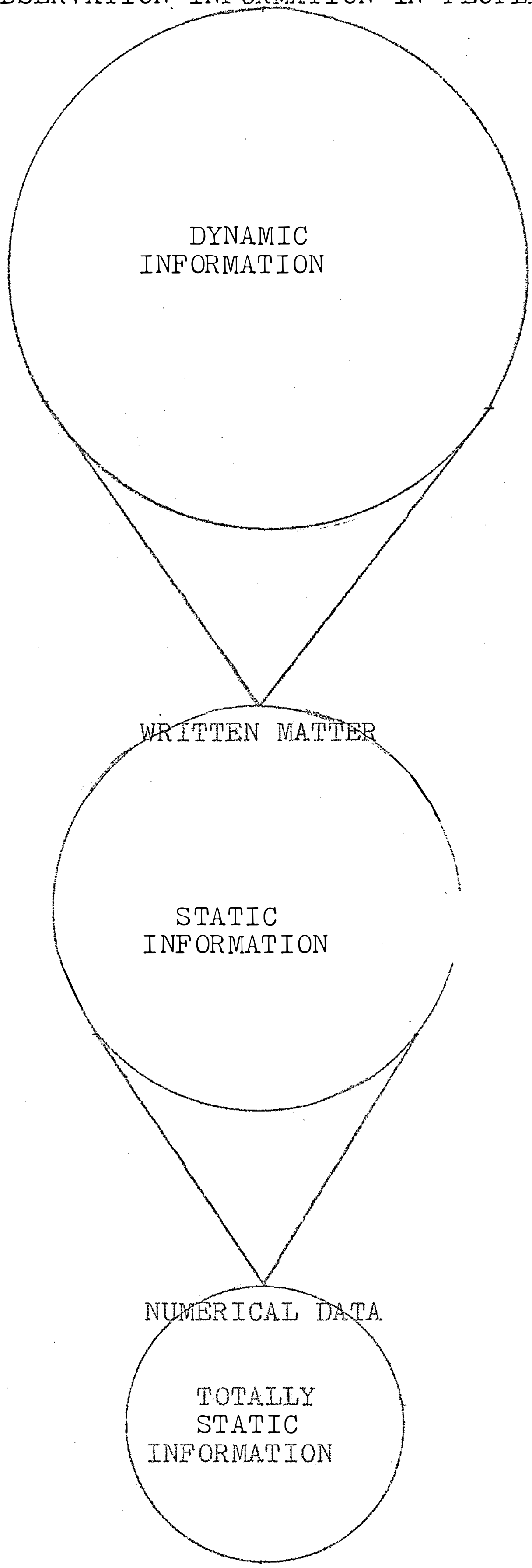


PLATE #1

One does not have a family, a business, a city, a government, or a country in his head. He has only selected concepts and relationships which he uses to represent the real system. A mental image is a model, and all of our decisions are made on the basis of models. All of our laws are passed, and all executive actions are taken on the basis of models as well. The question is not whether to use or ignore models. The question is only a choice between alternative models in an individual's mind.[7]

The human mind is well adapted to building and using models that relate to objects in space. Also the mind is excellent at manipulating models that associate words and ideas. But the unaided human mind, when confronted with modern social and technological systems, is not adequate for constructing and interpreting dynamic models that represent changes through time in complex systems.[8] Thus, the mental model is often fuzzy and incomplete, and is imprecisely stated. Within one individual, a mental model changes with time and even during the flow of a single conversation. The human mind assembles a few relations to fit the context of a discussion, but as the subject shifts, so does the model.[9] This is evident as we think how often we change our attitudes or conceptions of an issue in the course of a single discussion. As a result, we keep changing the content of a mental model, often without realizing that we have done so. We are continuously changing assumptions and interpreting real-life observations into model structure. Further, the mental model is not easy to communicate to others. The intuitive mental process is often hard to express,

and mental models of dynamic systems cannot be manipulated effectively. We often draw the wrong conclusion about system behavior, even if we start with a correct mental model of the separate system relationships. Our experience comes from observing the simplest systems. When the same expectations are applied to more extensive systems, the wrong results are often obtained. Because we cannot mentally manage all the facets of a complex system at one time, we tend to break the system into pieces and draw conclusions separately from the subsystems. Thus, we often hear someone say "Let's look at this problem one step at a time." By doing this, we may come to a conclusion about a small part of the system, but we fail to see how the subsystems within the larger system interact, and without understanding these relationships, we fail to be able to solve the overall problems of the system. This failure is something that we have all experienced at one time or another. We have gone at a problem, solving the issue which we perceive as being crucial, only to find later that because of the larger context of the problem, that we were dealing with, our efforts were in the wrong direction.[10]

People would never attempt to send a spaceship to the moon without first testing the equipment by constructing prototype models and by computer simulation of the anticipated space trajectories. No company would put a new kind of household appliance or electronic computer into production without first making laboratory tests. Such models and laboratory tests do not guarantee against failure, but they do identify many weaknesses which can then be corrected before

they cause full-scale disasters.[11]

Our social systems are far more complex and harder to understand than our technological systems, yet we try new laws and government programs in real life without ever having a chance to test them. Decisions are made and put into effect on the basis of mental models, even though the shor
acknowledged. "Why not use the same approach of making models of a social system and conducting laboratory experiments on those models?" says Forrester. A common answer to this is often that our knowledge of social systems is insufficient for constructing useful models. Yet what justification can there be for the apparent assumption that we do not know enough to construct models, but believe we do know enough to design new social systems by passing laws and starting new social programs? Using Forrester's methods, it is now possible to construct in the laboratory realistic models of social systems. Such models are simplifications of the actual social system, but can be far more comprehensive than the mental models that we otherwise use as the basis for debating governmental and other important action.[12]

A technical explanation of how such a model is made would be time-consuming and very difficult for me. Once again, as I did in the introduction, I ask you while reading and evaluating this paper, to accept what I have been able to accept. During the time that I have been working with this paper, and the studies which led to it, I have come to the point where I do have a better grasp of what the modelling process entails than I originally thought I ever could. However, it is a concept, that though I have a feel for it, I can't

explain in any great amount of technical detail. This partial lack of understanding bothered me a great deal until I spent some time with Forrester and his staff at MIT. In the time I spent there, talking with them and observing their methods in the Systems' Dynamics Laboratory and computer center, I lost my concern about not being able to grasp totally the intracacies of the modelling technique. These techniques, for some, are the major stumbling blocks to acceptance of systems' dynamics and its methods. Yet after observation and discussion, and realization of the progress made through the results obtained by using this method, I have no problem embracing it. Hopefully, the degree of explanation which I can provide for you will be sufficient to bring you to the point where you can at least tolerate my acceptance. An important factor to remember is that much of the quality of each model depends on the expertise which lies behind its formulation,[13] and that professional practice and training are necessary for modellers.[14] There are very few people trained to program excellent models, but some progress is being made in this area. Forrester and his team are men who have worked with this concept for years and years, and they are still constantly concerned with ways ~~to~~ of upgrading their modelling techniques. It is largely upon their expertise that my staunch support is based.

Briefly, the formation of a model consists of the modeller drawing information of the system to be studied from the availiable dynamic knowledge contained in peoples' minds. Thus, the systems' dynamicist starts most effectively from intensive discussions with a group of people who know the system first-hand. Such people should

be active participants in the social system and should speak from a variety of backgrounds and viewpoints.[15] Dynamic information, we must remember, is that knowledge which comes directly from observation. An example of such gathering of information is a situation in industry where something has gone awry in the larger system of that business, and a downward spiral has started. One finds that people can analyze the situation as to what the basic problems may be, yet the solution decided upon is often based on understanding of a small part of the total system. Thus, the solution is often at odds with the larger goal. The degree of complexity of the problem within the system is too great, and the partial solution worsens the situation. Yet human intuition leads those involved to feel that the problem is that they are not working hard enough at the solution. So, as the situation gets worse, they try harder and harder, making things worse yet, and on and on. A downward spiral has started because of the discrepency between the elementary assumptions and what we <u>think</u> they lead to.[16] The same downward spiral frequently develops in national government and at the level of world affairs. Judgement and debate lead to programs that appear to be sound. Committment increases to the apparent solution, but if the presumed solutions actually make matters worse, the process by which this happens is not evident. So, when the troubles increase, the efforts which are actually worsening the problems are intensified.[17]

It is into such a situation as the industrial example given above that the modeller comes, and begins to talk to people about

what they perceive the problem to be.[18] In their totality, the mental models which people hold contain far richer detail than has ever been reduced to writing, and in turn, our written literature is far richer in concepts than the quantitative and statistical literature, as was shown by the simple diagram of plate #1. All possible information sources are used in computer model construction, to the extent that the sources contain effective inputs. But individuals are usually the most complete, diverse, and sensitive to the localized causal forces in a society.[19] Thus, it is logical that the modeller goes to the people involved to get the dynamic information needed for modelling a given system. All possible opinions are obtained, and the entire situation is discussed. Each opinion must be stated as an assumption, and these assumptions are clarified time and time again to assure the accurate input of each person's conceptions.[20] In this way, the model comes out of the hazy realm of mental imagery into an unambiguous representation of statement to which all have access. Assumptions can then be checked against all availiable information and can be rapidly improved.[21] Obviously, at this point, the information gained is still based on the classical approach--peoples' intuition concerning a given situation. Yet this is precisely what is needed; as many opinions and insightful evaluations of a situation as can be gained. Forrester contends that in any situation, there <u>is</u> someone who <u>does</u> perceive the situation correctly, but without a model to test various assumptions, there would be no way of knowing whose assumption is right. Thus, each statement is gone over until

its proponent is satisfied that he is being represented completely explicitly in our written language.[22] The next step is to clarify the verbal statement by translating it into a less ambiguous form and into a form that will allow experimentation with the implications of the statement already made. Any truly complete and unambiguous statement can be cast into mathematical notation. The job is essentially no different from the translation from one verbal language to another, for mathematics is merely another language form, one with even more rigid rules than English for controlling its definitions, syntax, and logic. This model will constitute a straightforward, understandable description of a situation, as perceived by all of the minds involved.[23] Thus, a computer model, because it must be stated explicitly, makes theory unambiguous. The assumptions can then be criticized and revised. They can be compared with the assumptions in alternative proposed theories. Data and observation can be used to improve the assumptions. A theory expressed as a computer model can be checked and verified in more ways than a verbal theory. Because the component assumptions are stated more clearly, they can be compared more easily with all availiable information. Any given theory can be determined by computer simulation, and the model system can be compared with the behavior of the actual system.[24]

Models make possible the generation of a specific time history of behavior which would result if the system were started with a specified initial state and with any specified behavior of the external environment. The model takes the place of the real system

and simulates its operations under circumstances that are as realistic as was the original description of the system. This is the counterpart of trying a new policy or organizational structure in a real system, but here cost is insignificant compared with the cost in time <u>and</u> money of a real-life experiment. Furthermore, a great deal more is learned because the experimental conditions are fully known, controllable and reproducable, so that changes in system behavior can be traced directly to their causes.[25] Such models have further value in that they can unify diverse disciplines by integrating ethical, psychological, legal, geographical, technical, sociological, and economic aspects of a social system. Thus, the modelling system can deal with human and moral assertions, if precisely stated, as well as with the physical aspects of our existence.[26]

Obviously, the computer can choose a logical course of action only from among the input it has received. This is true of any computer. Yet this fact should not diminish the value of systems' dynamics modelling. The validity and usefulness of dynamic models should be judged, not against imaginary perfection, but in comparison with the mental and descriptive models which we would otherwise use. We should judge the formal models by their clarity of structure and compare this clarity to the confusion and incompleteness so often found in a verbal description. We should judge the models by whether or not the underlying assumptions are more clearly exposed than in the confusion of our thought processes, and by the

certainty with which they show the correct time-varying consequences of the statements made in the models compared to the unreliable conclusions we often reach in extending our mental image of system structure to its behavioral implications. We should judge the models by the ease of communicating their structure compared to the difficulty in conveying a verbal description.

By constructing a formal model, our mental image of the system is clearly exposed. General statements of size, magnitude, and influence are given numerical values. As soon as the model is so precisely stated, one is usually asked how he knows that the model is "right." A controversy often develops over whether or not reality is exactly as presented in the model. But such questions miss the first purpose of a model which is to be clear and to provide concrete statements that can be easily communicated.

There is nothing in either the physical or social sciences about which we have perfect information. We can never prove that any model is an exact representation of "reality." Conversely, among those things of which we are aware, there is nothing of which we know absolutely nothing. So we always deal with information which is of intermediate quality; it is better than nothing and short of perfection. Models are then to be judged, not on an absolute scale that condemns them for failure to be perfect, but on a relative scale that approves them if they succeed in clarifying our knowledge and our insights into systems.

The representation need not be defended as perfect, but only

that it clarifies thought, captures and records what we do know, and allows us to see the consequences of our assumptions. A model is successful if it opens the road to improving the accuracy with which we can represent reality.

When a model is reduced to diagrams and equations, when its underlying assumptions can be examined, when it can be communicated to others, and when we can compute its time patterns to determine the behavior implied by the model, then we can reasonably hope to understand reality better. It is toward this goal of better understanding, easier communication, and improved management of social systems that Forrester and others who believe in systems' dynamics proceed.[27]

The Technical Aspects of Models

There are many terms used time and time again in describing and dealing with models. Deep technicality is not called for, but for a basic understanding, some explanation of terms is necessary. The general concept of models was described sufficiently in the last section, yet within the concept of systems, there are several descriptions of processes which can be helpful.

The behavior of a social system depends on its structure and on the policies that govern decision-making. By structure, we mean the interrelations between components of the system and the channels of information availiable at a decision-making point. By policy we mean the criteria that determine how the availiable information is converted into decisions and action. Policy includes all rationale that influences how decisions are reached; experience, prejudice, folklore, ethics, religious attitudes, self-interest, generosity, integrity and fear. Policy as used here includes all of the action-generating processes in science, biology and nature.[28]

Systems can be classified as "open" systems or feedback systems. An open system is one characterized by outputs that respond to inputs but where the outputs are isolated from and have no influence on the inputs. An open system is not aware of its own performance, and past action does not control future action. An example of an open system is a car, which by itself is not governed by where it has gone in the past, nor does it have a goal of where to go in the future.

In systems' dynamics, however, the concern is with feedback systems, which are sometimes called closed systems. In a closed system, past behavior influences future behavior.[29] The most important concept in establishing the structure of a system is the idea that all actions take place within "feedback loops." The feedback loop is the closed path that connects an action to its effect on the surrounding conditions, and these resulting conditions in turn come back as "information" to influence further action. We often erroneously think of cause and effect as flowing in only one direction. We speak of action A causing result B. But such a perception is incomplete. Result B represents a new condition of the system that changes the future influences that affect action A. Feedback loops govern action and change systems from the simplest to most complex.[30]

Within the concept of feedback loops, there are two types. There are negative feedback loops, and positive feedback loops. A negative feedback loop is a loop in which the control decision attempts to adjust some system level to a value given by a goal introduced from outside the loop. A negative feedback loop tends to hold a system in some stable state. It behaves much as a thermostat does in controlling the temperature of a room. If the temperature in the room falls, the thermostat activates the heating system which causes the temperature to rise again. When the temperature reaches its limit, the thermostat cuts off the heating system, and the temperature begins to fall again. In a negative feedback loop, a change in one element is propagated around the circle until

it comes back to change that element in a direct opposition to the initial change.[31] A positive feedback loop does not seek an externally determined goal as does the negative feedback loop. Instead, the positive loop diverges or moves away from the "goal." The positive loop does not have the reversal of sign in traversing the loop that is found in the negative loop. Action within the positive loop increases the discrepency between the system level (the condition of the system) and a "goal" or reference point.[32] To clarify this, we can view a positive feedback loop as what is sometimes called a vicious circle. An example is the familiar wage-price spiral; wages increase, which causes prices to increase, which leads to demands for higher wages, and so forth. In a positive feedback loop a chain of cause and effect relations closes on itself, so that increasing any one element in the loop will start a sequence of changes that will result in the original changed element being increased even more. Thus, where positive feedback loops generate runaway growth, negative feedback loops tend to regulate and hold a system in some stable state.[33]

A system may be a single feedback loop or interlocking feedback loops. Each loop contains one or more decision points that control action and one or more system levels that result from the action. A system can be so simple that it has only a single system level, or more complex. Thus, the feedback loop is the basic structural element in systems. Dynamic behavior is generated by feedback. The more complex systems are assemblies of interacting feedback loops.[34]

A visual aid can help in clarifying the definitions given.

6

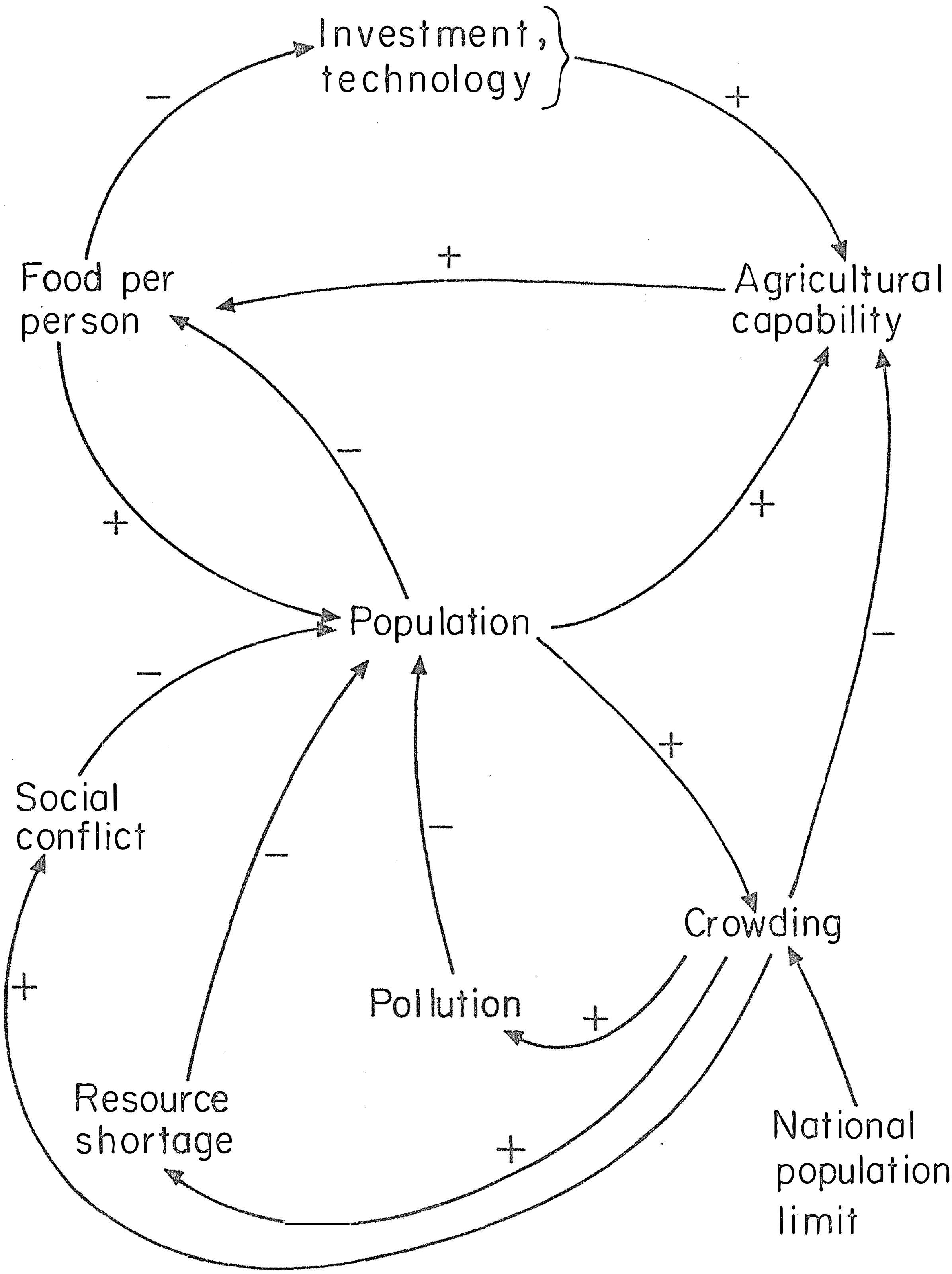

Investment, technology
Food per person
Agricultural capability
Population
Social conflict
Crowding
Pollution
Resource shortage
National population limit
+
−

PLATE 2 | 35

(See plate #2, preceeding page.)[35] Plate #2 shows a set of feedback loops that produce growth, cause growth to impinge on a fixed space limit, and then shift dominant control to an equilibrium-seeking set of relationships. The figure is simple and illustrative and does not include the multiplicity of factors in an actual social system. In the figure, the upper loops produce growth. In an area with some fertile land, the population rises, people till the land and their labor increases the agricultural capability, the food per person increases, and the rising food supply supports further increase in population. This growth in population continues until the fertile land has been fully employed and the marginal productivity of an additional agricultural worker does not produce enough food to support the worker. The food per person falls until the population is held in equilibrium and stops growing. But the falling food per person produces distress and may trigger additional investment and more technology in agriculture. The investment and technology may come from within the system, or it may come in foreign aid from the outside. In either case, agricultural capability is pushed up further, food per person is again lifted above the subsistence level and population continues upward. All of this assumes that non-agricultural aspects of crowding are still well below the national population limit set by other factors that would eventually restrain population. If food production continues to support a growing population, the population approaches the national population limit, crowding rises, population occupies the best agricultural land and agricultural capability declines faster than it can be restored by investment and technology.

Also at the same time, crowding leads to other forces that limit population--pollution, resource shortage, and social conflict, as well as disease and others. The consequence of growth is to induce ever-rising growth-restraining forces in the lower loops. In time the forces of growth and restraint come into balance and growth gives way to equilibrium. During the transition, the suppressive forces must and will rise as far as necessary to produce ultimate equilibrium. The greater the growth forces that society sustains in the upper loops, the greater must and will become the restraining forces that develop in the lower loops.[36]

The tool by which feedback loops are charted is the computer. The computer which Forrester and others working with systems' dynamics use is the DYNAMO compiler, a computer program which accepts the equations for a model of a dynamic feedback system and produces the requested simulation results as numerical tables and graphical plots. DYNAMO, which stands for DYNamic MOdels, was designed to execute models that follow the structure and equation conventions used in systems' dynamics. The DYNAMO compiler accepts a model written in the language of the equations which the modeller has translated from verbal input. It programs the model by converting the equations from their algebraic notation into detailed computer operating instructions. It executes the step-by-step computation, based on the control instructions that give solution interval and run length, and produces simulated results of the system represented by the model.[37] The simulation step requires a vast amount of arithmetical drudgery, and here the electronic computer comes into its own. The computer can take the mathematical

statements from the preceeding step, automatically do the detailed computer programming, generate a time history showing the input conditions as specified, and prepare the requested tabular and graphical curve.[38]

DYNAMO has evolved out of the electronic digital computer that became generally availiable between 1955 and 1960. Without it, the vast amount of work to obtain specific solutions to the characteristics of complex systems would be prohibitively expensive. In the last 15 years, the cost of arithemetic computation has fallen by a factor of 10,000 or more in those areas where digital computers can be used in their most efficient modes of operation.[39] Throughout the development of science up until 1955, the cost of computation was so great that most effort was applied to finding analytical solutions to simple systems and the more complex systems were ignored. Before 1940, the cost of simulation confined attention to the analytical solutions but these solutions could be obtained only to naively simple systems.[40] After World War II, the advent of computing machines brought the feasibility of dealing with more complex systems. Analog-type computers, as used in electrical-power-system network analyzers and in differential equation analyses, had been developed from 1930-1950.[41] Now the cost of computation has fallen to the point where repeated simulations of complex systems can be obtained inexpensively and quickly. The cost barrier was not alone in the past in discouraging the study of larger systems. Even where the cost might have been justified, the time required to carry out computation was so long that people were unwilling to wait for the re-

sults. All is changed now that a lengthy simulation of a complex system can be obtained for a few cents in a few seconds.[42]

A total explanation of the technicalities of systems' dynamics gets into much deeper explanation than I've goven above, however, this is sufficient for understanding the methods in general, and basic enough to be widely understood.

Techniques and Programs of the Past

Before going further into Forrester's methods and proposals, it is important to look at methods and programs which have been followed in the past. Obviously a point by point comparison cannot be made, for Forrester's approach is different in that he is looking at society as a system. This has never been the case previously, and the information which follows can give only fragmentary views of programs and beliefs which have been followed in the past in order to relieve the problems and pressures that society has faced. Once read, this flashback can serve as a basis of comparison and reference for the material which will follow concerning the functional application of Forrester's methods of Systems' Dynamics and analysis.

Social reform cannot be viewed merely in the perspective of American history. American social reform reflects a compounding of ideologies, values and traditions that must be understood in light of their development.[43]

Our American methods of social reform can be traced back to English beginnings. The first major milestone in the area was the Elizabethan Poor Law of 1601 which was the first establishment of legal and secular responsibilities for the poor.[44] Before the passage of that law, the poor, disabled, and retarded had been shunned and spat upon, and left to suffer and die.[45] However, major provisions of the Elizabethan Poor Law reflected a new spirit of wanting to do something more than inflict "cruel and unusual" pun-

ishment on vagrants and mendicants.[46]

The French Revolution did much to change family, church, employment and property institutions. New laws of the time reflect shifts from rural and feudal values to contractual relationships. The most far reaching effect was the transfer of education from home and church to the state.[47]

The Industrial Revolution was also a major step in the history of social reform. Social research on it has centered mainly on the condition of the working class as labor became degraded under industrialization.[48]

The concepts of public responsibility for deprived persons in the American colonies were similar to those in England. Our first charity organizations and Poor Laws date from the time of the Industrial Revolution. In 1880, there was a trend to consolidate the charities then in operation. There was an awakening to social needs and ways of ameliorating social problems.[49]

Later, the upheaval of the depression revealed many disparities in the American reform laws. New programs were implemented to aid America's floundering economy and to help the increasing numbers of poor. Such programs as the Works Progress Administration, the Federal Emergency Relief Administration, the Civilian Conservation Corps, the National Youth Administration, the Public Works Administration, and others helped alleviate the condition of many in need.[50]

A new idea in assistance came about in 1935 in the form of the Social Security Act which included Federal grants to states. In 1950, further amendments under public assistance titles of the Social Secur-

ity Act reflected growing recognition of the need in this area.[51]

The above historical sketch represents the practical aspects and growth of social reform. Social reform has been known by a variety of names over the centuries. Although precepts and ideologies about the poor and needy have changed, there has been an underlying belief by most that human beings should help one another. Humanitarianism was perhaps the basic impetus for the evolution of American social reform as we know it today.[52]

Social welfare institutions themselves have developed in response to human needs in society,[53] and this leads us to social reform in our own time, and its problems. Public welfare is the only government program operating in the U.S. today which has as its assigned task the provision of the ultimate guarantee against poverty and social deprivation. Its role in society is to assure to individuals, families, and communities the recognized basic essentials of living within a framework of related government and voluntary measures.[54].

In a summary of recommendations to the Secretary of Health, Education and Welfare by the Council on Public Welfare, the statement was made that "All societies in order to survive must make provision for their needy within the limits of their resources and social pattern."[55]

There are large numbers of voluntary organizations on the local and national level which also operate in many general and specific fields of community organization. Sometimes there are efforts in

cooperation with local authorities, and sometimes there aren't.[56]

The whole welfare debate is a curious mixture of humanitarianism, egalitarianism, productivity and old-fashioned imperialism.[57] As previously

"cruel and unusual" punishment to the poor and disabled was the Elizabethan Poor Law of 1601.[58] This attitude has been carried into the present. One fundamental historical reason for adoption of certain principles of social reform was the aim of making services availiable and accessable to the whole population in such ways as would not involve users in any humiliating loss of status, dignity, or self-respect. The conviction evolved that there should be no sense of inferiority, pauperism, shame or stigma in the use of publicly provided services; no attributation that one was becoming a "public burden."[59] Of course, this opinion can only be presented as a dominant one. There have also been conceptions of social welfare and reform as a burden and a waste of resources in the provision of benefits for those who do not need them. The general solution given by the critics is to abolish all of the welfare complexity and concentrate help on the few they consider to have the greatest need.[60]

An aim of such a program would be to deter people from using or abusing a service by inducing a sense of inferiority among those using public services, thus going against historical tradition on this point.[61]

Even in those programs which tried to avoid any embarassment,

what was insufficiently recognized was the extent to which many of these programs would require the poor to define themselves; to stand up and declare themselves poor people.[62]

A deep sense of unease about such reform problems has been developing over the last decade especially. Although a middle class standard of living is being attained by an increasing proportion of the population, there is still widespread social dissatisfaction. Many observers feel that the improvement in living standards during the past fifteen years has been bought at a heavy social cost. Even more disconcertingly, our successes have only revealed new difficulties.[63].

Thus, the time seems ripe for a new approach and a presentation of Forrester's methods can give us insight into one of the most comprehensive frameworks suggested.

Urban Dynamics

Some of Forrester's strongest efforts and most effective work have been done in the area of urban problems and concerns. It has been his contention that actions taken to alleviate the difficulties of a city can actually make matters worse. He believes that this is true because complex systems are counterintuitive, a concept that was discussed earlier in this paper. That is to say, systems behave in ways that are opposite to what most people expect. Experience and intuition have been developed almost entirely from contact with simple systems. However, in many ways, simple systems behave exactly the opposite from complex systems. Therefore, our experience misleads us into drawing the wrong conclusions about complex social systems. Further, complex systems are strongly resistant to most policy changes, thus there are inherent reasons within compl systems why so many of our attempts at correcting a city, for example, are destined to fail. In complex systems, the short term response to a policy change is apt to be in the opposite direction from the long term effect. This is especially treacherous. A policy change which improves matters in the short run lays a foundation for degradation in the long run. The short tenure of men in political office favors decisions which produce results quickly. These are very often the actions that eventually drive the system to ever-worsening performance.[64] Thus, in our modern economy there has been an essential change. Often a man does not

stay more than a few years in one position nor reap the long-range successes and failures that follow his decisions. Emphasis is on short-term results and even his own personal future is assured by retirement plans. His position is not his to be left to his children. As our economy has evolved, the personal-interest time horizon has shrunk from a lifetime to a few years.

This modern discrepancy between the distant consequences of required decisions and the brief tenure of men in the positions where the decisions are made unavoidably reduces responsibility and morale. The man is judged on results determined by his predesessors and makes decisions that will affect primarily his successors.[65]

In general, our social systems have evolved to a very stable configuration. If the system is troublesome, we should expect that the causes of the trouble are deeply embedded. We can expend all of our energy to no avail in trying to compensate for the troubles unless we discover the basic causes and redesign the system so that it moves to a new mode of behavior.[66]

Public works administrators are concerned primarily with the technology of urban living. For more than a hundred years, the improvement of technology has been the route to improvement in urban living. Public confidence in technology is deeply ingrained. When there is a problem, we begin by seeking a technical solution. Technological approaches in the past seem to have succeeded, and are easier to visualize, organize, and execute than are changes and improvements in the psychological, social, economic, and ethical as-

pects of our existence.

Recently though, faith in technology is being clouded by doubt. Technology has been improving while at the same time, many aspects of our social conditions have been worsening. It's beginning to seem that there may be a connection between the two.[67]

In the past, population pressures and economic forces of a city have been relieved by the escape of people to new land areas. But that escape is becoming less possible. Up until now we have had, in effect, an inexhaustalbe supply of farm land and food-growth potential. But now we are reaching the critical point where, all at the same time, population is overrunning producing land, agrucultural land is almost fully employed for the first time, the rise in population is putting more demand on the food supplies, and urbanization is pushing agriculture out of the fertile areas into the marginal lands.[68]

With all of these problems, however, no achievable goals are guiding our urban planning. Without clear goals of what a city is to be thirty to fifty years hence, there is no basis for choosing between present alternatives. Most cities avoid explicit goals because goals imply commitments and, even more important, any clear goal favors one group over another. Most city planning groups refuse to take sides; they want to be all things to all people; they suscribe to all conceivable goals. Many of the "master plans" and "goals for the city" amount to more and better of everything for everyone. As such they set impossible goals. A city cannot be bet-

ter than its environment in every respect.[69]

One of the most clear-cut examples of the problems which are now facing the cities in this country is the issue of housing. It is Forrester's contention that the fundamental cause of depressed areas in the cities comes from excess housing in the low-income catagory rather than the commonly presumed housing shortage. The legal and tax structure has combined to give incentives for keeping old building in place. As industrial buildings age, the employment opportunities decline, thus employment falls. On the other hand, as residential buildings age, they are used by lower income groups who are forced to use them at a higher population density. Therefore, jobs decline and population rises while buildings age. Housing, at the higher population densities, accomodates more people than can find jobs. A social trap is created where excess low-cost housing beckons low-income people inward because of the availiability of housing. They continue to come to the city until their numbers far exceed the availiable income opportunities and the standard of living declines far enough to stop further inflow. Income to the area is too low to maintain all of the houses. Excess housing falls into disrepair and is abandoned. Thus, cities simultaneously have extreme crowding in those buildings that are occupied, while other buildings become excess and are abandoned because the economy of the area cannot support all of the residential structures. But the excess residential buildings threaten the area in two ways; they occupy the land so that it cannot be used for job-creating buildings, and they stand ready to accept a rise in population if the area should start to improve economically.[70]

Thus, the basic elements in urban dynamics are that there is a finite supply of land in a city, all things age, and that people move in and out and thus the population changes. Further, the process of a structure aging is a dynamic trait of structures, and it is clear that a structure employs more people when it is new. This can be attributed to financial interests; new buildings are made for maximum efficiency. However, the longer the structure is there, the more its efficiency declines (due to improvements in building processes and technology) and the fewer opportunities for jobs exist there. Residential structures function under similar rules of dynamism, but their use is the opposite. As a residential structure ages, it houses more people, since poor people can pay less, and live more in a smaller area. So; with residential structures aging, more housing is created, and with industrial aging, fewer jobs are availiable. This leads to rising rates of unemployment in the city, and this basic phenomenon can explain many of the major problems in cities.[71]

Urban renewal in the form of building low-cost housing has been suggested and tried in many cities. However, it should be obvious from the information above that this is a detrimental step. The housing occupies land that should have been allocated to job-creating activities and, as a consequence, jobs become more scarce. But the new housing attracts more of the poor and unskilled. The unemployed population rises, jobs decline, income per capita remains low and destitution continues, with all of its related problems.[72]

A very important consideration in the study of cities is the aspect of relative attractiveness. According to Forrester, "attrac-

tiveness is the composite effect of all factors that cause population movement toward or away from an area."[73] His "attractiveness principle" states that, to any particular population class, all geographical areas tend to become equally attractive because people move from unattractive areas to areas of greater attractiveness. Population movement is an equalizing process. As people move toward a more attractive area, they drive up prices and overload job opportunities, the environmental capacity, the availiable housing, and the governmental services. In other words, rising population drives down all of the characteristics of an area that made it initially attractive.[74]

Thus, the concept of attractiveness is fundamental to the population flows. All of the characteristics of an area that make it attractive combine to influence migration. An attractive area draws people, but almost every component of attractiveness is driven down by an increase in population.[75]

From a brief discussion of attractiveness, as the one given above, it becomes evident that this is a major consideration in alleviating the problems of cities, and that it must be considered an integral component in any model of cities. When modelling in relation to the urban situation, the general model is simpler and more informative than a model of a specific city. This model can be, with proper changes of its parameters, appropriate for New York, Calcutta, a gold rush camp, or West Berlin. These all seem to have very different characteristics but they have certain elements in common which describe the urban processes. The general

model can strip away the multitude of detail which confuses any one specific situation. The general model identifies the central processes and is a statement of theory for the entire class of systems; in this case, cities.[76]

Attractiveness then, in a cursory overview, starts looking like an undesirable attribute for a city. To some degree, this is true, as unappealing as such a statement is for us to accept. In our social systems, there are no utopias. There appear to be no sustainable modes of behavior that are free of pressures and stresses. But, there is hope in the fact that there are many possible modes and some are more desirable to one situation, or in this case, city, and some are more desirable to another.[77] The fact that we must accept is that it is simply not possible to increase all of the attractiveness components of an area simultaneously without detrimental reactions through in-migration or other factors which affect the level of attractiveness.

Thus, several aspects of relative attractiveness must be faced, and accepted before further problems can be tackled;

a. Most components of attractiveness are reduced as the total population and the population density increase above some favorable range of human aggregation.

b. It is not possible to maintain high values for all components of urban attractiveness. Any area with a high composite attractiveness draws people until the composite attractiveness is driven down to equilibrium with other areas.

c. If any aspect of an urban area is improved, some other aspect must and will show in time a corresponding decline.

d. Urban planning that fails to choose the negative factors that are to be used to limit population and population den-

> sity will encounter unexpected negative factors being created by the dynamics of the system in response to population movement.[78]

Point d. is especially important for us to note. In effect, it says that unless we place priorities on the things which are most important to us in the area of attractiveness, the system will place the priorities for us, and probably not in the order we would have chosen. To me, such logic makes a good deal of sense. In our individual lives, most of us do not expect to be able to have <u>all</u> of the things we want, simply because of time conflicts, lack of money, or any one of a thousand reasons. Yet within our cities, we have tried to avoid placing such priorities, and the result is chaos and deterioration of those cities.

We must realize that what we do today fundamentally affects the future. If we follow intuition, the trends of the past will continue into deepening difficulty. If we will use the knowledge which we have, and the programs which men such as Forrester are offering, we can expect a sounder basis for action.

Within social systems, and cities are no excpetion, there is usually a fundamental conflict between the short-term and long-term consequences of a policy change. A policy change which produces improvement in the short run; within 5 to 10 years, is usually one which degrades the system in the long run; beyond 10 years. Likewise, those policies and programs which produce long-run improvement may initially depress the behavior of the system. Obviously, the short run is more visible and more compelling, and argues loudly for

immediate attention. But a series of actions all aimed at short-run improvement can eventually burden a system with long-run de-depressants so severe that even heroic short-run measures no longer suffice. Many of the problems which we face today are the eventual result of short-run measures taken as long as two or three decades ago.[79]

It is important to look at the underlying causes with respect to deterioration of a city. They lie largely in our tax laws and our zoning laws, and most of the changes we are talking about in those particular areas are moving in the wrong direction. Instead of a property tax that declines with declining value of the property, we perhaps should have a property tax that is fixed; a certain number of dollars on the basis of square feet of floor space regardless of age. This would help make the aging property economically untenable before it hastens the blight of an area. Another suggestion is that each building have a mandatory trust fund into which the owner must pay a levy each year. At any time, whoever owns the building can draw out the money in the trust fund if he demolishes the building and clears the land. This would create an earlier incentive for replacement. Property tax levies and income tax accounting could both be changed to produce pressures in the same direction.[80] However, as things presently stand, our urban areas have had most of the forces of internal self-renewal removed. We are left with economic, legal, zoning, and tax policies which practically guarantee that we generate slums.[81]

So what can a city do? Forrester explains some of the options as they have been realized through the work done with models. A city can influence its future by choosing among the components of attractiveness. The attractiveness components of a city fall into two categories according to whether they operate more forcefully on quality of life in the city or on inward migration and growth. These two categories are the "diffuse" and the "compartmentalized" characteristics of a city. The objective should be to maximize those diffuse characteristics of a city that improve quality of life while controlling the compartmentalized characteristics that can prevent expanded population and population density that would defeat the improvement for present residents.

The diffuse characteristics, such as public safety and clean air, are shared equally by all; their effect is not limited to particular individuals, and they apply alike to present residents and those who might move in. The compartmentalized characteristics of a city, like jobs and housing, are identified with particular individuals; they can be possessed by present residents but are not necessarily availiable to others from the outside.

Every diffuse characteristic of a city that makes it more attractive for the present residents will also make it more attractive for those who might move in and who would increase the population and density. Therefore, every improvement in the diffuse categories of attractiveness must be accompanied by some worsening in

the compartmentalized categories of attractiveness to prevent self-defeating growth. The attractiveness characteristics of a city should be categorized in terms of whether they affect all residents or primarily potential newcomers. For example, the vitality of industry, a balanced socio-economic mix of population, the quality of schools, the freedom from pollution, low crime rates, public parks, and cultural facilities are all desirable to present residents. If there is no counterbalance to restrain an expanding population, such attractive features tend to be self-defeating by causing inward migration. But the compartmentalized characteristics of a city primarily affect growth without necessarily reducing quality of life for present residents. The number of housing units and the number of jobs tend to be compartments in the sense that they have a one-to-one correspondence with individuals rather than each being shared by all. The absence of an unoccupied house and/or job can be a strong deterrant to in-migration, without necessarily driving down the internal quality of life.

Forrester sees no solution for urban problems until cities develop the courage to plan in terms of a maximum population, a maximum number of housing units, a maximum permissible building height, a maximum number of jobs. A city must also choose the type of city it wants to be. To become and remain a city that is all things to all people is impossible. There can be many uniquely different kinds of cities, each with its special mix of advantages and disadvantages. However, the policies that create one type of city may

destroy another type. A choice of city type must be made, and corresponding policies chosen to create the required combination of advantages <u>and disadvantages</u> that are characteristic of that type. One might have an industrial city, a commercial city, a resort city, a retirement city, or a city that attracts and traps without opportunity a disproportionate number of unemployed and welfare residents, as some cities are now doing. But there are severe limits on how many types of cities can be created simultaneously in one place. When the choices have been made, and when effort is no longer dissipated in growth, there will be an opportunity to come to grips with social and economic decay.

It seems perhaps, that planning and controlling the size and composition of a city and the migration to it are undemocratic or immoral. It may even seem that Forrester is suggesting control where there has not been control before. Neither is true. Every city has arrived at its present size, characteristics and composition because of the actions that have controlled the city's evolution of the past...by adding to the water system, sewers, and streets, a city has, in effect, decided to increase its size. By building a rapid transit system, a city is often, in effect, deciding to change the composition of its population by encouraging new construction in outlying areas, allowing inner areas to decay, and attracting low-income and unskilled persons to the inner ring at the same time that job opportunities decline. In other words, control of growth and migration has often been guided by short-term considerations, with un-

desirable long-term results. The issue is not one of control or no control. The issue is the kind of control and toward what end.

If people are to i fluence the policies most affecting them, it follows that policies will be different in different places and the resulting choices between growth and quality of life will be different.

If some cities and states take effective steps to establish an equilibrium with their natural surroundings, and to maintain a viable and proper internal balance of population and industry, then the remaining growth in the country will quickly descend on those communities and states that have taken no such action. A national consensus to establish a viable balance with the capacity of the environment will quickly develop out of the contrasts between those who have and those who have not dealt with the basic issues, Forrester feels. Local action can set a precedent for the country as a whole.[82]

Problems Facing Us, and the World Model

By far the most extensive and impressive of all of the models that Forrester has conceived and programmed is the world model; a formal written model of the world. It constitutes a preliminary attempt to improve our mental models of long-term global problems by combining the large amount of information that is already in human minds and in written records with the new information-processing tools that mankind's increased knowledge has produced; the scientific method, systems analysis, and the modern computer.

The world model was built specifically to investigate five major trends of global concern:

accelerating industrialization
rapid population growth
widespread malnutrition
depletion of nonrenewable resources
and a deteriorating environment.

These trends are all interconnected in many ways, and their development is measured in decades or centuries, rather than in months or years. With the model, Forrester is seeking to understand the causes of these trends, their interrelations, and their implications as much as one hundred years in the future.[83] This computer model interconnects concepts from demography, economics, agriculture and technology. The model describes a world system that shows a variety of alternative behaviors. Within this model the world system can exhibits many alternative modes of behavior in response to different policies that man might follow in guiding population growth, capital

investment generation, natural resource usage, pollution control and agricultural output.[84]

The model that has been constructed is, like every other model, imperfect, oversimplified, and unfinished. Its creators are well aware of its shortcomings, but believe that it is the most useful model now availiable for dealing with problems far out on the time-space graph. To their knowledge, it is the only formal model in existence that is truly global in scope, that has a time horizon that is longer than 30 years, and that includes important variables such as population, food production, and pollution, not as independent entities, but as dynamically interacting elements, as they are in the real world.

Since it is a formal, or mathematical model, it also has two important advantages over mental models. First, every assumption made is written in a precise form so that it is open to inspection and criticism by all. Second, after the assumptions have been scrutinized, discussed, and revised to agree with the best current knowledge, their implications for the future behavior of the world system can be traced without error by a computer, no matter how complicated they become.[85]

A major purpose in constructing a world model has been to determine which, if any, of these behavior modes will be most characteristic of the world system as it reaches the limits to growth. This process of determining behavior modes is "prediction" only in the most limited sense of the word. These models are not exact predictions of the values of the variables at any particular year in the future. They are

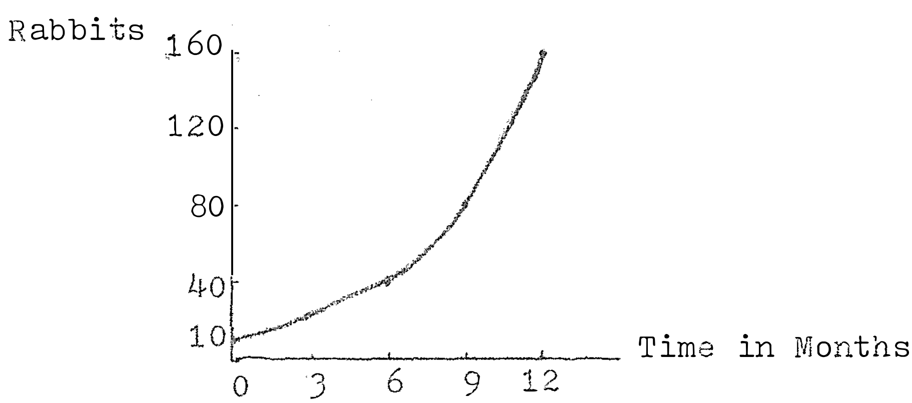
indicators of the system's behavioral tendencies.[86] One should not expect models of the kind discussed here to predict the exact form and timing of future events. Instead, the model should be used to indicate the direction in which the behavior would alter if certain changes were made in the sustaining structures and policies.[87]

The major conclusion reached through the use of the world model thus far is that if the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity.[88]

As a discussion of the world model progresses, it becomes evident that a crucial element in it is the concept of growth. In our society, the word growth has been closely connected with good and positive things. Our background has been that expansion is desirable, and that if big is good, bigger is better. Our society has behind it a thousand years of tradition that has encouraged and rewarded growth. The folklore and the success stories praise growth and expansion.[89] We have been rewarded for increasing our output, and in America, growth and progress have become synonymous. Yet there is a problem inherant in such thinking, and we are beginning to be forced to see what it is. The clichés, the folklore, and the Horatio Alger stories of the past must be shaken off as we face the fact that continuing growth, far from solving our problems, is the primary generator of our growing social distress.[90]

All five elements basic to the study reported here: population, food production, industrialization, pollution, and consumption of nonrenewable resources, are increasing. The amount of their increase each year follows a pattern that mathematicians call exponential growth. A quantity exhibits exponential growth when it increases by a constant percentage of the shole in a constant time period. Exponential increase is deceptive becahse it generated immense numbers very quickly.[91]

Forrester gave us a very graphic example of exponential growth in a lecture given January 16, 1973 at MIT. He stated that he was starting with a field which had a capacity of 160 rabbits, and that it had 10 rabbits in it at the time it was fenced off. Thus, three rabbits are added per ten per month, according to average reporduction rates and gestation periods of rabbits. The following is a simple graph of the two elements; rabbits (increase) and time.



Obviously, it takes only one year to reach capacity of the field. Someone suggested that adding a second floor would relieve the pressure greatly. Forrester then showed us the rate at which floors

would need to be added.

At the end of those 12 months, 2 floors would be needed.
At the end of 15 months, 4 floors would be needed.
At the end of 18 months, 8 floors would be needed.
At the end of 21 months, 16 floors would be needed.
At the end of 24 months, 32 floors would be needed.
At the end of 27 months, 64 floors would be needed.
At the end of 31 months, 128 floors would be needed.
At the end of 34 months, 240 floors would be needed!!!

Yes, skyscrapers can be built, but obviously, exponential growth cannot go on forever.

A French riddle for children illustrates another aspect of exponential growth; the apparent suddenness with which it approaches a fixed limit. Suppose you own a pond on which a water lily is growing. The lily plant doubles in size each day. If the lily were allowed to grow unchecked it would completely cover the pond in 30 days, choking off all of the other forms of life in the water. For a long time the lily plant seems small, and so you decide not to worry about cutting it back until it covers half of the pond. On what day will that be? On the 29th day of course. You have one day left to save your pond.[92] Exponential growth is a characteristic of every one of the five trends of concern.

Discussions of the world system often rely on comparing present conditions with ultimate limits. By such comparison present world demand usually seems well below the capacity of the environment. But an important factor is usually overlooked; demand is rising with a doubling time of only a few decades.[93] The world population grew from one to two billion in a period of more than 100 years. The third billion was added in 30 years and the world's population has had less

than 20 years to prepare for its fourth billion. The fifth, sixth, and perhaps seventh billions may arrive before the year 2000, less than 30 years from now.[94].

It is no accident or coincidence that throughout history, a substantial fraction of the world population has been undernourished and on the verge of starvation. Population is regulated to the food supply. But this far, man has caused population to continue to increase by being able to push up the food supply. Increasing the total amount of food has done little in the long run to reduce the percentage of undernourished people. Instead, the larger the population generated by increased food supply, the greater the total number of people who live under the threat of starvation.[95]

Much concern is expressed about the importance of limiting population. However, we need have no fear that population will continue to rise forever. Exponential growth rates do not continue forever. Growth of population and industrialization will stop. If man does not take conscious action to limit population, the forces inherent in the natural and social system will rise high enough to limit growth. The question is only a matter of when and how growth will cease, not whether it will cease.[96]

The history of economic development in Western countries is not directly applicable as a guide for today's new societies. In the economic development of the United States and Europe, the pace was gradual; education, capital accumulation, and technological change advanced together. Other parts of the world are developing in a different environment. Their elemental economies exist in the presence of nations

with a high standard of living. Their people are impatient to reach the the economic level of more advanced countries. Capital formation, education, and the aspirations of the people must grow in synchronism if revolution and war are not to overtake economic development.[97] Thus, many industrial nations are now growing rapidly and are placing great demands on world resources. Many of those resources come from the presently underdeveloped countries. What will happen when the resource-supplying countries begin to withhold resources because they foresee the day when their own demand will require the availiable supplies? Pressures from impending shortages are already appearing. Will the developing nations stand by and let their economies decline while resources still exist in other parts of the world, or will a new era of international conflict grow out of pressure from resource shortage?[98]

Thus, there may be no realistic hope of the present underdeveloped countries reaching the standard of living demonstrated by the present industrialized nations. The pollution and natural-resource load placed on the world environmental system by each person in advanced countries is probably 20-50 times greater than the load now generated by a person in underdeveloped countries. With four times as many people living in underdeveloped countries as in developed countries, their rising to the economic level that has been set as a standard by the industrialized nations could mean an increase of ten times in the natural resource and pollution load on the world environment. Noting the destruction that has already occured on land, in the air, and especially in the oceans, capability appears not to exist for hand-

ling such a rise in the standard of living. In fact, the present disparity between the developed and underdeveloped nations may be equalized as much by a decline in the developed countries as by an improvement in the underdeveloped countries. This means that a society with a high level of industrialization may be nonsustainable. It may be self-extinguishing if it exhausts the natural resources on which it depends. Or, if unending substitution for declining natural resources were possible, new international strife over pollution and environmental rights might pull the average world-wide standard of living back to the level of a century ago.

From the long view of a hundred years hence, the present efforts of underdeveloped countries may be unwise. They may now be closer to an ultimate equilibrium with the environment than are the industrialized nations. The present underdeveloped countries may be in a better condition for surviving the forthcoming world-wide environmental and economic pressures than are the advanced countries. If one of the several forces strong enough to cause a collapse in world population does arise, the underdeveloped countries might suffer far less than their share of the decline because economies with far less organization, integration and specialization are far less vulnerable to disruption.[99]

Pollution is a factor in the world model which calls for much serious consideration. Man's concern for the effect of his activities on the natural environment is only very recent. Scientific attempts to measure this effect are even more recent and still are very

incomplete. We are certainly not able to come to any final conclusion about earth's capacity to absorb pollution at this time. We can, however, make some basic points which illustrate, from a dynamic, global perspective, how difficult it will be to understand and control the future state of our ecological systems. These points are:

1. The few types of pollution that actually have been measured over time seem to be increasing exponentially.
2. We have almost no knowledge about where the upper limits to these pollution curves might be.
3. Many pollutants are globally distributed; their harmful effects appear long distanced from their points of generation.[100]

This ignorance about the limits of the earth's ability to absorb pollutants, as mentioned in point #2 above, should be reason enough for caution in the release of polluting substances. The danger of reaching those limits is especially great because there is typically a long delay between the release of a pollutant into the environment and the appearance of its negative effect on the ecosystem.

Whenever there is a long delay from the time of the release of a pollutant to the time of its appearance in a harmful form, we know that there will be an equally long delay from the time of control of that pollutant to the time when its harmful effect finally decreases. In other words, any pollutant control system based on instituting controls only when some harm is already detected will probably guarantee that the problem will get much worse before it gets better. Systems of this sort are exceedingly difficult to control, because they require that present actions be based on results expected far in the future.

At the present time, only the developed nations of the world are

seriously concerned about pollution. It is an unfortunate characteristic of many types of pollution however, that eventually, they become widely distributed around the world.

We do not know the precise upper limit of the earth's ability to absorb any single one kind of pollution, much less its ability to absorb the combinations of all kinds of pollution. We do know however, that there is an upper limit. It has already been surpassed in many local environments.[101]

When many such different quantities, as mentioned above, are growing simultaneously in a system, and when all of the quantities are interrelated in a complicated way, analysis of the causes of growth and of the future behavior of the system becomes very difficult. Does population growth cause industrialization, for example, or does industrialization cause population growth? The answer to such questions are being sought through the use of the world model, which can give us a better understanding of the entire complex system that unites all of these important elements.[102]

Technology; a Mixed Blessing

Although the history of human effort contains numerous incidents of mankind's failure to live within physical limits, it is success in overcoming limits that forms the cultural tradition of many dominant peoples in today's world. Over the past 300 years, mankind has compiled an impressive record of pushing back the apparent limits to population and economic growth by a series of spectacular technological advances.[103] Applying technology to the natural pressures that the environment exerts against any growth process has been so successful in the past that whole cultures have evolved around the principles of fighting against limits rather than learning to live with them. This culture has been reinforced by the apparent immensity of the earth and its resources and by the relative smallness of man and his activities.[104] Since the recent history of a large part of human society has been so continually successful, it is quite natural that many people expect technological breakthroughs to go on raising physical ceilings indefinitely. These people speak about the future with resounding technological optimism.[105] The hopes of the technological optimists center on the ability of technology to remove or extend the limits to growth of population and capital. Yet such blatant optimism is totally unrealistic. It is folly to argue that growth can go on forever. Growth in the raw sense of more of everything forever is impossible.[106] Our resources are finite, our world's ability to absorb pollutants is finite, and the number of people which our earth can support is finite. The relationship between the earth's limits and mankind's activities is changing. The exponential growth curves are adding

millions of people and billions of tons of pollutants to the eco-system each year. Even the ocean, which once appeared virtually inexhaustable, is losing species after species of its commercially useful animals. Thus, a technological solution may be defined as "one that requires a change only in the techniques of the natural sciences, demanding little or nothing in the way of change in human values of ideas or morality." Numerous problems today have no technological solutions. Examples are the nuclear arms race, racial tensions, and unemployment. Even if society's technological progress fulfills all expectations, it may very well be a problem with a technical solution, or the interaction of several such problems that finally brings an end to population and capital growth.[107]

Professor Forrester has shown that in the world model, the application of technology to apparent problems of resource depletion or pollution or food shortage has no impact on the essential problem which is exponential growth in a finite and complex system. Forrester's attempts to use even the most optimistic estimates of the benefits of technology in the model did not prevent the ultimate decline of population and industry, and in fact did not in any case postpone the collapse beyond the year 2100.[108]

It may be seen then, that technological optimism is the most common and the most dangerous reaction to Forrester's findings from the world model. Technology can relieve the symptoms of a problem without affecting the underlying causes. Faith in technology as the ultimate solution to all problems can thus divert our attention from the most

fundamental problem--the problem of growth in a finite system--and prevent us from taking effective action to solve it. Forrester's intent is certainly not to brand technology as evil or futile or unnecessary. He and his Systems' Dynamics team see themselves as technologists, working in a technological institution. They believe strongly that many of the technological devekionebts sycg as recycling, pollution control devices, contraceptives, etc., will be absolutely vital to the future of human society if they are combined with deliberate checks on growth.[109]

Solutions Within Systems' Dynamics

Our dependence on technological solutions has led us to a process which those working with systems' dynamics call suboptimising. This means the meeting of a local goal without attention to consequences in other parts of the system.[110] Forrester feels that this is the method we presently employ in solving social problems. Our efforts are directed toward improving each part of the system individually. We have done this; and in this country in the past, it has been fairly effective. We have had the space that we've needed geographically, with space to move to, and administratively, with much less red tape in our business dealings than now exists. The problem now is that we're still practicing this method on the premises that we started with. We solve our problems one piece at a time, and this leads to a sense of frustration because now, every time we improve part of the system, it is at the expense of another part of the system. None of our problems will go away, so we juggle alternatives, and end up trying to face all of our problems at the same time. If we work on one, the balloon of problems bulges out somewhere else.[111] The models within systems' dynamics can show us the effects of our efforts and help us understand them so that we don't pursue futile, frustrating, and/or detrimental courses on these problems.

What will be needed to sustain the world economy and population growth until, and perhaps even beyond, the year 2000? The list of necessary ingredients is long, but it can be divided roughly into two main categories. The first category includes the <u>physical</u> neces-

sities that support all physiological and industrial activity; food, raw materials, fossil and nuclear fuels, and the ecological systems of the planet which absorb wastes and recycle important basic chemical substances. These ingredients are in principle tangible, countable items, such as arable land, fresh water, metals, forests, and oceans. The second category of necessary ingredients for growth consists of the *social* necessities. Even if the earth's physical systems are capable of supporting a much larger, more economically developed population, the actual growth of the economy and of the population will depend on such factors as peace and social stability, education and employment, and steady technological progress. These factors are much more difficult to assess or predict.[112]

The world is running away from its long-term threats by trying to relieve social pressures as they arise. But if we persist in treating only the symptoms and not the causes, the result will be to increase the magnitude of the ultimate threat and reduce our capability to respond when we no longer have more space and resources to invade.[113]

Trade-offs

Obviously then, continued suboptimising is impossible. Future problems will be decided by choice between alternatives. Such alternatives are called "trade-offs" in the vernacular of Forresterian terminology.

All trade-offs arise from one simple fact; the earth is finite. The closer any human activity comes to the limit of the earth's ability to support that activity, the more apparent and unresolvable the trade-offs become. When there is plenty of unused arable, land, there can be more people and more food per person, for example. But when all of the land is already used, the trade-offs between more people or more food per person become choices between absolutes.

In general, modern society has not learned to recognize and deal with these trade-offs. The apparent goal of the present world system is to produce more people with more (food, material goods, clean air and water) for each person. It is not possible to foretell exactly which limitation will occur first, or what the consequences will be, because there are many conceivable, unpredictable human responses to such a situation.[114]

How many people can be fed on this earth? There is, of course, no simple answer to this question. The answer depends on the choices society makes among various availiable alternatives. There is a direct trade-off between production of more food and production of other goods and services needed or desired by mankind. The demand for these other goods and services is also increased as population grows and therefore

the trade-offs become continuously more apparent and more difficult to resolve. Even if the choice were consistently made to produce food as the first priority, continued population growth and the law of increasing costs could rapidly drive the system to the point where all availiable resources were devoted to producing food, leaving no further possibility of expansion.

Expansion of food production in the future is very much dependent on the availiability of nonrenewable resources. Given the present resource consumption rates and the projected increase in these rates, the great majority of the currently important nonrenewable resources will be extremely costly 100 years from now. This statement remains true regardless of the most optimistic assumptions about undiscovered reserves, technological advances, substitution, or recycling, as long as the demand for resources continues to grow exponentially. The prices of those resources with the shortest static reserve indices have already begun to increase. The price of mercury, for example, has gone up 500% in the last 20 years, the price of lead has increased 300% in the last 30 years.

The simple conclusions drawn by considering total world reserves of resources are further complicated by the fact that neither resource reserves nor resource consumption are distributed evenly around the globe.[115]

Added to the difficult economic question of the fate of various industries as resource after resource become prohibitively expensive is the imponderable political question of the relationships between producer and consumer nations as the remaining resources become con-

centrated in more limited geographical areas.

Are there anough resources to allow the economic development of the seven billion people expected by the year 2000 to a reasonably high standard of living? Once again, the answer must be a conditional one. It depends upon how the major resource-consumption societies handle some important trade-offs and decisions which are ahead. They might continue to increase resource consumption according to the present pattern. They might learn to reclaim and recycle discarded materials. They might develop new designs to increase the durability of products made from scarce resources. They might encourage social and economic patterns that would satisfy the needs of a person while minimizing the irreplacable substances he possesses and disperses.

All of these possible courses involve trade-offs. The trade-offs are particularly difficult in this case because they involve choosing between present benefits and future benefits. In order to guarantee availiability of adequate resources in the future, policies must be adopted that will decrease resource use in the present.[116]

Thus, some of the most pressing examples of trade-offs have been discussed above. It is no longer a question of whether or not we will make trade-offs, it is a matter of which trade-offs we will choose. The very fact that trade-offs are now an issue brings up a concept that is very important to understand. As mentioned before, the underlying cause of today's social pressures is growth.[117] Yet we know that growth in the sense of more of everything forever is impossible. No one can argue that growth will continue at the past and present rates. It simply cannot be done, unless we are willing to face complete collapse

very soon. A growth policy, therefore, is absolutely essential. We must follow a policy which will extract ourselves from the trends of the past and move us into an equilibrium that would be sustainable into the future. This means a transition; a transition policy from growth to equilibrium.[118] It is this growth to transition period to equilibrium period that calls for our understanding and effort. As Professor Forrester sees it, trade-offs depend a great deal on whether we are in a period of growth, transition, or equilibrium. During growth, trade-offs are made in terms of time; we have the option to enhance conditions now at the expense of the future. We can improve the quality of life by doing things which complicate matters in the future, and this process can go on until we encroach upon what we are drawing on. In the transition period, things set in motion "back when" become liabilities, and our raised standard of living begins to produce problems. Before, our trade-offs in time were always "out" in time, but eventually the price must be paid; we have approached the day of reckoning as we've moved through history on our growth curve. This price is paid in the transition region, and the nature of trade-offs changes. These are issues which need to be the focus of social research as far as Forrester is concerned, for in transition, one finds that he can no longer enhance "now" at the expense of future. The time comes when if you enhance one part of the system, the price must be paid immediately; trade-offs become choices between other sectors of life, not in other times somewhere in the future. Instead of being able to lower the pressure by pushing the limits out, we're working with pressures which lie on the same plane.

This is the situation we now find ourselves in. Our greatest immediate challenge is how we guide the transition from growth to equilibrium. There are many possible mechanisms of growth suppression. That some one or combination will occur is inevitable. Unless we come to understand and choose, the social system by its internal processes will choose for us.[119] Civilization then, is in a transition zone between past exponential growth and some future form of equilibrium.[120]

The tendency is to relieve all pressures until none can be suppressed. As a result, we will not have a long period of partial shortages to slow growth gradually. No areas of the world will encounter limits to growth much ahead of any other areas, so, as a result, mankind will not have the opportunity to learn on a small scale how to navigate the transition from growth to equilibrium. All will face the transition at about the same time and without the benefit of a guiding precedent.[121]

The transition period we now find ourselves in is a traumatic region. The dynamic mode is different from the period of growth mode.[122] As the world moves during the next several decades from exponential growth of population and industrialization into some form of equilibrium, we can expect rapidly growing social stresses of a magnitude, a distribution, and a diversity that have never before been encountered.[123] We tend to feel a sense of loss and disenchantment as we go into a region which is dynamically different from the past. Our stability for the future is affected; by increased popula-

tion, etc., and we feel our lack of freedom, which leads to increased pscyhological stress. It is a combination of many pressures that takes a system from growth through transition. How we evaluate these pressures expresses how we view the "quality of life." Thus, we face qualitative trade-offs in a transitional state rather than the time trade-offs of the growth period.[124]

Thus, during the transitional period which we are now experiencing, models are a way in which we can project our ideas of the quality of life, and the dimensions of the upcoming period of equilibrium, and see what our priorities should be, before we must face such decisions in actuality. Modelling is a method by which we can gain insight by trying many, many courses of action, and evaluating the consequences of each one before the decisions which will shape our futures must be made once and for all, so that we can reach a state of equilibrium. In such a state, there must be a condition of constant population, constant use of resources, and constant generation of pollution, all limited so that the equilibrium condition can be sustained indefinitely into the future.[125]

The minimum set of requirements for the state of global equilibrium are:

1. The capital plant and the population are constant in size; the birth rate equals the death rate and the capital investment rate equals the depreciation rate.
2. All input and output rates--births, deaths, investment, and depreciation--are kept to a minimum.
3. The levels of capital and population and the ratio of the two are set in accord with the values of the society.

An equilibrium defined in this way does not mean stagnation. The three points above define a dynamic equilibrium state, which need not and probably would not "freeze" the world into the population-capital configuration that happens to exist at the present time. The object in accepting the three above statements is to create freedoms for society, not to impose a strait-jacket.

What would life be like in such an equilibrium state? No one can predict what sort of institutions mankind might develop under these new conditions. There is, of course, no guarantee that the new society would be much better, or even much different from what exists today. It seems possible, however, that a society released from struggling with the many problems created by growth may have more energy and ingenuity availiable for solving other problems.

Population and capital are the only quantities that need to be constant in the equilibrium state. Any human activity that doesn't require a large flow of irreplacable resources that produce severe environmental degradation might continue to grow indefinately. In particular, those pursuits that many people would list as most desirable and satisfying for man--education, art, music, religion, basic scientific research, athletics, and social interactions--could flourish.[126]

Technological advance would be both necessary and welcome in the equilibrium state. A few obvious examples of the kinds of practical discoveries that would enhance the workings of a stady state society include:

--new methods of waste collection, to decrease pollution and make discarded materials availiable for recycling;

--more efficient techniques of recycling, to reduce rates of resource depletion;

--better product design to increase product lifetime and promote easy repair, so that the capital depreciation rate would be minimized;

--harnessing of incident solar energy, the most pollution-free power source;

--methods of natural pest control, based on more complete understanding of ecological interrelationships;

--medical advances that would decrease the death rate;

--contraceptive advances that would facilitate the equalization of the birth rate with the decreasing death rate.

Historically, mankind's long record of new inventions has resulted in crowding, deterioration of the environment, and greater social inequality because greater productivity has been absorbed by population and capital growth. There is no reason why higher productivity could not be translated into a higher standard of living or more leisure or more pleasant surroundings for everyone, if these goals replace growth as the primary value of society.[127]

The Question of Feasability

Many people feel that the programs that Forrester and other Systems' Dynamicists have introduced to avoid the growth and collapse mode are not only impossible, but unpleasant, dangerous, and even disastrous in themselves. Such policies as reducing the birth rate and diverting capital from production of material goods, by whatever means they might be implemented, seem unnatural and unimaginable, becuase they have not, in most people's experience, been tried, or even seriously suggested. There would be little point in even discussing such fundamental changes in the functioning of modern society if those who have studied such things felt that the present pattern of unrestricted growth were sustainable into the future. All of the evidence availiable, however, suggests that of the three alternatives--unrestricted growth, a self imposed limitation to growth, or a nature-imposed limitation to growth--only the last two are actually possible.

Accepting the nature-imposed limits to growth requires no more effort than letting things take their course and waiting to see what will happen. The most probable result of that decision will be uncontrollable decrease in population and capital. The real meaning of such a collapse is difficult to imagine because it might take so many different forms. Certainly whatever fraction of the human population remained at the end of the process would have very little left with which to build a new society in any form we can now envision.

Acheiving a self-imposed limitation to growth would require much effort. It would involve learning to do many things in new ways. It would tax the ingenuity, the flex, and the self-discipline of the human race. Bringing a deliberate, controlled end to growth is a tre-

mendous challenge, not easily met.[128]

Taking no action to solve these problems is equivalent to taking strong action. As mentioned before, it is suspected on the basis of present knowledge of the physical constraints of the planet that the growth phase cannot continue for another 100 years. Again, because of the delays in the system, if the global society waits until these constraints are unmistakably apparent, it will have waited too long.

Deliberate limiting of growth would be difficult, but not impossible. The way to proceed is clear, and the necessary steps, although they are new ones for human society, are well within human capabilities. Man possesses, at this time in his history, the most powerful combination of knowledge, tools, and resources the world has ever known. He has all that is physically necessary to create a totally new form of human society; one that would be built to last for generations. The two missing ingredients are a realistic, long-term goal that can guide mankind to the equilibrium society and the human will to acheive that goal. With that goal and that commitment, mankind would be ready to begin a controlled, orderly transition from growth to global equilibrium.[129]

The most elusive and most important information needed deals with human values. As soon as society recognizes that it cannot maximize everything for everyone, it must begin to make logical trade-offs. Should there be more people or more wealth, more wilderness or more automobiles, more food for the poor or more services for the rich?

Establishing the societal answers to questions like these and translating those answers into policy is the essence of the political process. Yet few people in any society even realize that such choices are being made every day, much less ask themselves what their own choices would be. The equilibrium society will have to fight the trade-offs engendered by a finite earth not only with a consideration of present human values but also with consideration of future generations. To do that, society will need better means than exist today for clarifying the realistic alternatives availiable, for establishing societal goals, and for achieving the alternatives th that are most consistent with those goals. Most important of all, long term goals must be specified and short-term goals made consistent with them.[130]

Obviously, feasability is a problem in the instigation of such steps. Such feasibility is always in question. Our perception of feasibility is affected by what each individual sees as alternatives. As more people get the feeling and knowledge of trade-offs this question changes, thus, information must be dispersed, and such questions must be discussed in educational surroundings, in political circles, in homes. Perhpas as conditions worsen, candidates for political office will give up their incessant promises, promises, as people begin to realize that such talk acnnot be backed up, and politicians in turn realize that honesty will get them further with their constituents. In such a case, candidates could be more candid about trade-offs, and we would perhaps end up voting for the man we believed to

offer the best combination of trade-offs.

Many decisions are made within political circles, and some of the most important are made at very high levels, as in senate, etc. Many, many issues are decided by a close vote; the difference of 10% of those voting in some cases. In such cases, even on major issues, influencing even a small number of senators and educating them to the methods and beliefs of Forresterian scholars could make a great difference in national policy, which would cause an immediate reaction in many programs. Obviously, feasability is a major problem, but through communication and continued study, much progress can be made.[131]

There are groups already whose purpose it is to foster understanding of the varied but interdependent components--economic, political, national and social--that make up the global system in which we all live; to bring that new understanding to the attention of policy makers and the public worldwide, and in this way to promote new policy initiatives and action. The Club of Rome is such a group. None of its members holds public office nor does the group seek to express any single ideological, political or national point of view. All involved are united by the conviction that the major problems facing mankind are of such complexity and are so interrelated that traditional institutions and policies are no longer able to cope with them, or even come to grips with their full content. Such groups are most probably the forerunners of a great number of such organizations.[132]

Humanitarianism in the Equilibrium State

Humanitarian concern means help for one's less fortunate fellow man. At times such action is based on a much too simplistic view of the situation. Such help is usually aimed at immediate goals. Long-term and short-term goals may be in conflict. Consider a country that is overpopulated. Its standard of living is low, food is insufficient, health is poor, and misery abounds. Such a country is especially vulnerable to any natural adversity. There are no reserves of food. Medical facilities are always overloaded, and there is no reserve to cope with any kind of misfortune. Floods make many homeless; but is that because of the flood or because overpopulation forced people to live in the flood region? Droughts bring starvation; but is that due to weather or to the overpopulation that made food reserves impossible? The country is operating in the overextended mode where all adversities are resolved by a rise in the death rate. The process is part of a natural mechanism for limiting further growth in population. But suppose that humanitarian impulses lead to massive relief efforts from the outside for each natural disaster. The long-term result seems to be that the people who are saved raise the population still higher. With increased population, vulnerability of the country is increased. Epidemics become more likely, and internal social strife more probable. A smaller adverse event can now trigger a crisis. Disasters occur oftener and relief is required more frequently. But relief leads to a net increase in population, to more people in crisis, to still

greater need for relief, and eventually to a situation taht even relief cannot handle.

Such situations should make us cautious about rushing into programs on the basis of short-term humanitarian impulses. The eventual result can be antihumanitarian. Emotionally inspired efforts often fall into one of three traps set for us by the nature of the social system. First, the programs are apt to address symptoms rather than causes and attempt to operate through points in the system that have little leverage for change. Second, the characteristic of systems whereby a policy change has the opposite effect in the short run from the effect in the long run can eventually cause deepening difficulties after a sequence of short-term actions. Third, the affect of a program can be along an entirely different direction than was originally expected; suppressing one symptom only cuases trouble to burst forth at another point.[133]

In trying to sort out issues involved in humanitarian treatment of today's social problems, the major responsibility must rest with the more developed nations, not because they have more vision or humanity, but because, having propagated the growth syndrome, they are still at the fountainhead of the progress that sustains it. As greater insights into the condition and workings of the world system are developed, these nations will come to realize that, in a world that fundamentally needs stability, their high plateaus of development can be justified or tolerated only if they serve not as springboards from which to organize more equitable distribution of wealth and income worldwide.[134]

Thus, Forrester's programs should not be viewed as anti-humanitarian. Conversely, they are aimed at preserving humanity. All that he asks is that we forsake intuition as our major tool in dealing with the problems of society and humanity. Yes, help must be given, and yes, humanitarian programs must be continued, but they must be based on logical dynamics, so that the outcome of our work with them is what we intend it to be. Then, in the long run, much more can be done for humanity than has ever been done before.

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