APR 15 1971

Massachusetts Institute of Technology
Alfred P. Sloan School of Management
50 Memorial Drive
Cambridge, Massachusetts, 02139

April 14, 1971

Mr. Kenneth H. Olsen, President
Digital Equipment Corporation
Maynard, Mass.

Dear Ken:

At Thursday's meeting of the Society for the Advancement of Management, I promised to replace the copy of Professor Forrester's House of Representatives testimony which you had given away. Here are two copies of a more extensive reprint; these are taken from the Government Printing Office transcript of the proceedings of the Urban Growth Sub-Committee. They include the committee's discussion as well as three appended papers. I thought you might want a copy available for circulation, as well as one to hold on to.

Dinner on Thursday was fun. You and Dick Morse could team up almost anywhere to take the prize for fascinating conversation. Thanks again for joining us.

I am passing on your regards to Jay.

Sincerely,

John A. Seeger
Administrative Officer
System Dynamics Group

JAS:ar

Enc: House of Representatives testimony

cc: J. W. Forrester

Testimony by

JAY W. FORRESTER

for the

HEARINGS

BEFORE THE

AD HOC SUBCOMMITTEE ON URBAN GROWTH

OF THE

COMMITTEE ON BANKING AND CURRENCY

HOUSE OF REPRESENTATIVES

NINETY-FIRST CONGRESS

SECOND SESSION

ON

INDUSTRIAL LOCATION POLICY

PART 3

JULY 23; SEPTEMBER 23, 24; OCTOBER 6, 7; NOVEMBER 18, 19;
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[1] Del Clawson, California, resigned from the committee, February 17, 1970.

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INDUSTRIAL LOCATION POLICY

WEDNESDAY, OCTOBER 7, 1970

HOUSE OF REPRESENTATIVES,
AD HOC SUBCOMMITTEE ON URBAN GROWTH OF THE
COMMITTEE ON BANKING AND CURRENCY,
Washington, D.C.

The subcommittee met, pursuant to recess, at 10:20 a.m., in room 2222, Rayburn House Office Building, Hon. Thomas L. Ashley (chairman of the subcommittee) presiding.

Present: Representative Ashley.

Also present: Laurance G. Henderson, and Casey Ireland, professional staff members.

Mr. ASHLEY. The subcommittee will come to order.

Our witness this morning is Dr. Jay W. Forrester, professor of management at Massachusetts Institute of Technology.

Professor Forrester is a member of the National Academy of Engineering, and a fellow of the Institute of Electrical and Electronics Engineers and the American Academy of Arts and Sciences. He is a director of the ALZA Corp. He received the B.S. degree from the University of Nebraska and the S.M. degree from MIT and has been awarded honorary doctorate degrees in engineering from the University of Nebraska and in science from Boston University. In 1968 he received the Inventor of the Year Award from George Washington University and in 1969 the Valdemar Poulsen Gold Medal from the Danish Academy of Technical Sciences. His book "Industrial Dynamics" received the Academy of Management Award in 1962 and his "Urban Dynamics" was chosen as best publication in 1969 by the Organization Development Council.

Dr. Forrester has written extensively and is the holder of a number of patents. He is an eminent witness and we certainly are pleased to have you with us this morning. I must say I remember reading the piece in the New York Times of a year or so ago which traced your very interesting course telling the reader of your change in what appeared to be essential interest from the more technical pursuits to that of urban problems. And so it is certainly a particular pleasure, Dr. Forrester, as I say, to have you here. Why don't you proceed in any way you wish.

STATEMENT OF DR. JAY W. FORRESTER, PROFESSOR OF MANAGEMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. FORRESTER. I have a prepared statement, reading of which will probably take about an hour. I would be happy to have interruptions. I think it would be a good background for any questions you may have later. Shall I proceed?

Mr. ASHLEY. By all means. Please.

Dr. FORRESTER. My comments address several issues of interest to this subcommittee:

1. Population trends in the United States.
2. Quality of urban life.
3. National policy for urban growth.
4. Unexpected, ineffective, or detrimental results often generated by Government programs.

The Nation exhibits a growing sense of futility as it repeatedly attacks deficiencies in our social system while the symptoms continue to worsen. Legislation is debated and passed with great promise and hope. But many programs prove to be ineffective. Results often seem unrelated to those expected when the programs were planned. At times programs cause exactly the reverse of desired results.

Today I hope to explain how such contrary results can happen. Until we come to a much better understanding of social systems, we should expect that attempts to develop corrective programs will continue to disappoint us. There are fundamental reasons why people misjudge the behavior of social systems. There are orderly processes at work in the creation of human judgment and intuition that frequently lead people to wrong decisions when faced with complex and highly interacting systems.

It is premature this morning to give answers to the major questions that face you. But I hope to show why some of these questions have been misjudged in the past. I hope to leave with you a sense of caution about continuing to depend on the same past approaches that have led to our present feeling of frustration. On the positive side, I will suggest an approach which can eventually lead to a better understanding of our social system and thereby to more effective policies for guiding the future.

A NEW APPROACH TO SOCIAL SYSTEMS

It is my basic theme that the human mind is not adapted to interpreting how social systems behave. Our social systems belong to the class called multiloop nonlinear feedback systems. In the long history of evolution it has not been necessary for man to understand these systems until very recent historical times. Evolutionary processes have not given us the mental skill needed to properly interpret the dynamic behavior of the systems of which we have now become a part.

In addition, the social sciences have fallen into some mistaken "scientific" practices which compound man's natural shortcomings. Computers are often being used for what the computer does poorly and the human mind does well. At the same time the human mind is being used for what the human mind does poorly and the computer does well. Even worse, impossible tasks are attempted while achievable and important goals are ignored.

Until recently there has been no way to estimate the behavior of social systems except by contemplation, discussion, argument, and guesswork. To point a way out of our present dilemma about social systems, I will sketch an approach that combines the strength of the human mind and the strength of today's computers. The approach is an outgrowth of developments over the last 40 years, in which much of the research has been at the Massachusetts Institute of Technology. The concepts of feedback system behavior apply sweepingly from physical systems through social systems. The ideas were first developed and applied to engineering systems. They have now reached practical usefulness in major aspects of our social systems.

I am speaking of what has come to be called "industrial dynamics." The name is a misnomer because the methods apply to complex systems regardless of the field in which they are located. A more appropriate name would be "system dynamics." In our own work, applications have been made to corporate policy, to the dynamics of diabetes as a medical system, to the growth and stagnation of an urban area, and most recently to world dynamics representing the interactions of population, pollution, industrialization, natural resources, and food. System dynamics, as an extension of the earlier design of physical systems, has been under development at MIT since 1956. The approach is easy to understand but difficult to practice. Few people have a high level of skill; but preliminary work is developing all over the world. Some European countries and especially Japan have begun centers of education and research.

COMPUTER MODELS OF SOCIAL SYSTEMS

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.

Our social systems are far more complex and harder to understand than our technological systems. Why, then, do we not use the same approach of making models of social systems and conducting laboratory experiments on those models before we try new laws and Government programs in real life? The answer is often stated that our knowledge of social systems is insufficient for constructing useful models. But 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 directly design new social systems by passing laws and starting new social programs? I am suggesting that we now do know enough to make useful models of social systems. Conversely, we do not know enough to design the most effective social systems directly without first going through a model-building experimental phase. But I am confident, and substantial supporting evidence is beginning to accumulate, that the proper use of models of social systems can lead to far better systems, and to laws and programs that are far more effective than those created in the past.

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 action.

Before going further, I should emphasize that there is nothing new in the use of models to represent social systems. Each of you uses models constantly. Every person in his private life and in his business life instinctively uses models for decisionmaking. The mental image of the world around you which you carry in your head is a model. One does not have a city or 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. All of our decisions are taken on the basis of models. All of our laws are passed on the basis of models. All executive actions are taken on the basis of models. The question is not to use or ignore models. The question is only a choice among alternative models.

The mental model is fuzzy. It is incomplete. It is imprecisely stated. Furthermore, within one individual, a mental model changes with time and even during the flow of a single conversation. The human mind assembles a few relationships to fit the context of a discussion. As the subject shifts so does the model. When only a single topic is being discussed, each participant in a conversation employs a different mental model to interpret the subject. Fundamental assumptions differ but are never brought into the open. Goals are different and are left unstated. It is little wonder that compromise takes so long. And it is not surprising that consensus leads to laws and programs that fail in their objectives or produce new difficutlies greater than those that have been relieved.

For these reasons we stress the importance of being explicit about assumptions and interrelating them in a computer model. Any concept or assumption that can be clearly described in words can be incorporated in a computer model. When done, the ideas become clear. Assumptions are exposed so they may be discussed and debated.

But the most important difference between the properly conceived computer model and the mental model is in the ability to determine the dynamic consequences of what will happen when the assumptions within the model interact with one another. The human mind is not adapted to sensing correctly the consequences of a mental model. The mental model may be correct in structure and assumptions but, even so, the human mind, either individually or as a group consensus, is most apt to draw the wrong conclusions. There is no doubt about the digital computer routinely and accurately tracing through the sequences of actions that result from following the statements of behavior for individual points in the model system. This inability of the human mind to use its own mental models is clearly shown when a computer model is constructed to reproduce the assumptions held by a single person. In other words, the model is refined until it is fully agreeable in all its assumptions to the perceptions and ideas of a particular person. Then, it usually happens that the system that has been described does not act the way the person anticipated. Usually there is an internal contradiction in mental models between the assumed structure and the assumed future consequences. Ordinarily the assumptions about structure and internal motivations are more nearly correct than are the assumptions about the implied behavior.

The kind of computer models that I am discussing are strikingly similar to mental models. They are derived from the same sources. They may be discussed in the same terms. But computer models differ from mental models in important ways. The computer models are stated explicitly. The "mathematical" notation that is used for describing the model is unambiguous. It is a language that is clearer and more precise than the spoken languages like English or French. Computer model language is a simpler language. Its advantage is in the clarity of meaning and the simplicity of the language syntax. The language of a computer model can be understood by almost anyone, regardless of educational background. Furthermore any concept and relationship that can be clearly stated in ordinary language can be translated into computer model language.

There are many approaches to computer models. Some are naive. Some are conceptually and structurally inconsistent with the nature of actual systems. Some are based on methodologies for obtaining input data that commit the models to omitting major concepts and relationships in the psychological and human reaction areas that we all know to be crucial. With so much activity in computer models and with the same terminology having different meanings in the different approaches, the situation must be confusing to the casual observer. The key to success is not in having a computer. The important thing is how the computer is used. With respect to models, the key is not to computerize a model, but instead to have a model structure and relationships which properly represent the system that is being considered.

I am speaking here of a kind of computer model that is very different from the models that are now most common in the social sciences. Such a computer model is not derived statistically from time-series data. Instead, the kind of computer model I am discussing is a statement of system structure. It contains the assumptions being made about the system. The model is only as good as the expertise which lies behind its formulation. Great and correct theories in physics or in economics are few and far between. A great computer model is distinguished from a poor one by the degree to which it captures more of the essence of the social system that it presumes to represent. Many mathematical models are limited because they are formulated by techniques and according to a conceptual structure that will not accept the multiple-feedback-loop and nonlinear nature of real systems. Other models are defective because of lack of knowledge or deficiencies of perception on the part of the persons who have formulated the model.

But a recently developed kind of computer modeling is now beginning to show the characteristics of behavior of actual systems. These models explain why we are having the present difficulties with our actual social systems and furthermore explain why so many efforts to improve social systems have failed. In spite of their shortcomings, models can now be constructed that are far superior to the intuitive models in our heads on which we are now basing national social programs.

We have not time this morning for details of methodology. I will leave with you a copy of my book "Industrial Dynamics" (published by the MIT Press, 1961) which discusses the general approach and

shows early applications to industrial situations. I am also leaving my book "Principles of Systems" (published in 1968 by the Wright-Allen Press, Cambridge, Mass.) which shows some of the concepts that we use to arrive at the underlying structure of social systems.

This approach to the dynamics of social systems differs in two important ways from common practice in social sciences and government. There seems to be a common attitude that the major difficulty is shortage of information and data. Once data is collected, people then feel confident in interpreting the implications. I differ on both of these attitudes. The problem is not shortage of data but rather our inability to perceive the consequences of the information we already possess. The system dynamics approach starts with the concepts and information on which people are already acting. Generally these are sufficient. The available perceptions are then assembled in a computer model which can show the consequences of the well-known and properly perceived parts of the system. Generally, the consequences are unexpected.

COUNTERINTUITIVE NATURE OF SOCIAL SYSTEMS

By converting mental models to explicit computer models, we have found a number of interesting characteristics in complex social systems. Initially these insights came from our corporate work. Time after time we have gone into a corporation which is having severe and well-known difficulties. The difficulties can be major and obvious like falling market share, or low profitability, or instability of employment. Such difficulties are known throughout the company and by anyone outside who reads the management press.

One can enter such a company and discuss with people in key decision points what they are doing to solve the problem. Generally speaking we find that people perceive correctly their immediate environment. They know what they are trying to accomplish. They know the crises which will force certain actions. They are sensitive to the power structure of the organization, to traditions, and to their own personal goals and welfare. In general, when circumstances are conducive to frank disclosure, people can state what they are doing and can give rational reasons for their actions. In a troubled company, people are usually trying in good conscience and to the best of their abilities to solve the major difficulties. From such an organization one can take the policies that are well known and are being followed at the various points in the organization. The policies are being followed on the presumption that they will alleviate the difficulties. One can then combine these policies into a computer model to show the consequences of how the policies interact with one another. In many instances it then emerges that the known policies describe a system which actually causes the troubles. In other words, the known and intended practices of the organization are fully sufficient to create the difficulty, regardless of what happens outside the company or in the marketplace. In fact, a downward spiral develops in which the presumed solution makes the difficulty worse and thereby causes redoubling of the presumed solution so that matters become still worse.

The same downward spiral frequently develops in government. Judgment and debate lead to a program that appears to be sound. Commitment increases to the apparent solution. If the presumed solution

actually makes matters worse, the process by which this happens is not evident. So, when the troubles increase, the efforts are intensified that are actually worsening the problem.

DYNAMICS OF URBAN SYSTEMS

Our first major excursion outside of corporate policy began in February 1968 when John F. Collins, former mayor of Boston, became professor of urban affairs at MIT. He and I discussed my work in industrial dynamics and his experience with urban difficulties. A close collaboration led to applying to the dynamics of the city the same methods that had been created for understanding the social and policy structure of the corporation. A model structure was developed to represent the fundamental urban processes. The proposed structure shows how industry, housing, and people interact with each other as a city grows and decays. The results are described here in my book "Urban Dynamics" (MIT Press, 1969).

I had not previously been involved with urban behavior or urban policies. But the emerging story was strikingly similar to what we had seen in the corporation. Actions taken to alleviate the difficulties of a city can actually make matters worse. The book examines four common programs for improving the depressed nature of the central city. One is the creation of jobs as by bussing the unemployed to the suburbs or through governmental jobs as employer of last resort. Second was a training program to increase the skills of the lowest income group. Third was financial aid to the depressed city as by Federal subsidy. Fourth was the construction of low-cost housing. All of these are shown to lie between neutral and detrimental almost irrespective of the criteria used for judgment. They range from ineffective to harmful judged either by their effect on the economic health of the city or by their long-range effect on the low-income population of the city.

The results both confirm and explain much of what has been happening over the last several decades in our cities.

In fact, it emerges that the fundamental cause of depressed areas in the cities comes from excess housing in the low-income category rather than the commonly presumed housing shortage. The legal and tax structure has combined to give incentives for keeping old buildings in place. As industrial buildings age, the employment opportunities decline.

Mr. ASHLEY. When you say excess housing, Professor, do you mean excess over needs, over requirements?

Dr. FORRESTER. I mean excess over needs. I mean excess over what the city is able to support. I mean excess over the income earning opportunuities of the area.

That is of course startling and it takes awhile to get accustomed to the idea. But the interesting thing is that even black leaders in the ghetto areas, given 6 hours of discussion, begin to realize that it is a correct statement.

One of the major problems of the old city is improper proportioning between the activities of the city. The city was in economic balance at the end of its growth phase. But as industrial buildings age 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, accommodates more people than can find jobs. I am speaking here of the low-income urban population. A social trap is created where excess low-cost housing beckons low-income people inward because of the available housing. They continue coming to the city until their numbers so far exceed the available income opportunities that the standard of living declines far enough to stop further inflow. Income to the area is too low to maintain all of the housing. Excess housing falls into disrepair and is abandoned. One can simultaneously have extreme crowding in those buildings that are occupied, while other buildings become excess and are abandoned because the economy of the area can not support all of the residential structures. But the excess residential buildings threaten the area in two ways—they occupy the land so that it can not be used for job-creating buildings, and they stand ready to accept a rise in population if the area should start to improve economically.

Any change which would otherwise raise the standard of living only takes off the economic pressure momentarily and causes the population to rise enough that the standard of living again falls to the barely tolerable level. A self-regulating system is thereby at work which drives the condition of the depressed area down far enough to stop the increase in people.

At any time, a near equilibrium exists affecting population mobility between the different areas of the country. To the extent that there is disequilibrium, it means that some area is slightly more attractive than others and population begins to move in the direction of the more attractive area. This movement continues until the rising population drives the more attractive area down in attractiveness until the area is again in equilibrium with its surroundings. Other things being equal, an increase in population of a city crowds housing, overloads job opportunities, causes congestion, increases pollution, encourages crime, and reduces almost every component of quality of life.

This powerful dynamic force to reestablish an equilibrium in total attractiveness means that any social program must take into account the eventual shifts that will occur in the many components of attractiveness. As used here, "attractiveness" is the composite effect of all factors that cause population movement toward or away from an area. Most areas in a country have nearly equal atttractiveness most of the time with only sufficient disequilibrium in attractiveness to account for the shifts in population. But areas can have the same composite attractiveness with different mixes in the components of attractiveness. In one area component A could be high and B low while the reverse could be true in another area that nevertheless had the same total composite attractiveness. If a program makes some aspect of an area more attractive than its neighbor's, and thereby makes total attractiveness higher momentarily, population of that area rises until other components of attractiveness are driven down far enough to again establish an equilibrium. This means that efforts to improve the condition of our cities will result primarily in increasing the population of the cities and causing the population of the country to concentrate in the cities. The overall condition of urban life, for any particular ecnomic class of population, cannot be appreciably better or worse than that of the remainder of the country to and from which people may come. Programs

aimed at improving the city can succeed only if they result in eventually raising the average quality of life for the country as a whole. But there is substantial doubt that our urban programs have been contributing to the national quality of life. By concentrating total population, and especially low-income population, in urban locations, undermining the strength and cohesiveness of the community, and making government and bureaucracy so big that the individual feels powerless to influence the system within which he is increasingly constrained, the quality of life is being reduced. In fact, if they have any effect, our efforts to improve our urban areas will in the long run tend to delay the concern about rising total population and thereby contribute directly to the eventual overcrowding of the country and the world.

Any proposed program must deal with both the quality of life and the factors affecting population. "Raising the quality of life" means releasing stress and pressures, reducing crowding, reducing pollution, alleviating hunger, and treating ill health. But these pressures are exactly the sources of concern and action aimed at controlling total population to keep it within the bounds of the fixed world within which we live. If the pressures are relaxed, so is the concern about how we impinge on the environment. Population will then rise further until the pressures reappear with an intensity that can no longer be relieved. To try to raise quality of life without intentionally creating compensating pressures to prevent a rise in population density will be self-defeating.

Consider the meaning of these interacting attractiveness components as they affect a depressed ghetto area of a city. First, we must be clear on the way population density is now being controlled. Population is, in fact, now being controlled. There is some set of forces determining that the density is not far higher or lower than it is. But there are many possible combinations of forces that an urban area can exert. The particular combination will determine the population mix of the area and the economic health of the city. I suggest that the depressed areas of most American cities are created by a combination of forces in which there is a job shortage and a housing excess. The availability of housing draws the lowest income group until they so far exceed the opportunities of the area that the low standard of living, the frustration, and the crime rate counterbalance the housing availability. Until the pool of excess housing is reduced, little can be done to improve the economic condition of the city. A low-cost housing program alone moves exactly in the wrong direction. It draws more low-income people. It makes the area differentially more attractive to the poor who need jobs and less attractive to those who create jobs. In the new population equilibrium that develops, some characteristics of the social system must compensate for the additional attractiveness created by the low-cost housing. The counterbalance is a further decline of the economic condition for the area. But as the area becomes more destitute, pressures rise for more low-cost housing. The consequence is a downward spiral that draws in the low-income population, depresses their condition, prevents escape, and reduces hope. All of this is done with the best of intentions. For a more complete explanation, I refer you to "Urban Dynamics."

A summary of urban dynamics is given in my paper "Systems Analysis as a Tool for Urban Planning" from a symposium in October 1969, at the National Academy of Engineering. I am asking that the

text be made a part of the record of this hearing. (The paper referred to by Dr. Forrester may be found on p. 239.) It suggests a reversal of present practice in order to simultaneously reduce the aging housing in our cities and allocate land to income-earning opportunities. The land shifted to industry permits the "balance of trade" of the area to be corrected by allowing labor to create and export a product to generate an income stream with which to buy the necessities of modern life from the outside. But the concurrent reduction of excess housing is absolutely essential. It supplies the land for new jobs. Equally important, the resulting housing shortage creates the population-stabilizing pressure that allows economic revival to proceed without being inundated by rising population. This can all be done without driving the present low-income residents out of the area. It can create upward economic mobility to convert the low-income population to a self-supporting basis.

The first reaction of many people to these ideas is to believe that they will never be accepted by elected officials or by residents of depressed urban areas. But some of our strongest support and encouragement is coming from those very groups who are closest to the problems, who see the symptoms first hand, who have lived through the failures of the past, and who must live with the present conditions until enduring solutions are found.

Over the last several decades the country has slipped into a set of attitudes about our cities that are leading to actions that have become an integral part of the system that is generating greater troubles. If we were malicious and wanted to create urban slums, trap low-income people in ghetto areas, and increase the number of people on welfare, we could do little better than follow the present policies. The trend toward stressing income and sales taxes and away from the real estate tax encourages old buildings to remain in place and block self-renewal. The concessions in the income tax laws to encourage low-income housing will in the long run actually increase the total low-income population of the country. The highway expenditures and the Government loans for suburban housing have made it easier for higher-income groups to abandon urban areas than to revive them. The pressures to expand the areas incorporated by urban government, in an effort to expand the revenue base, have been more than offset by lowered administrative efficiency, more citizen frustration, and the accelerated decline that is triggered in the annexed areas. The belief that more money will solve urban problems has taken attention away from correcting the underlying causes and has instead allowed the problems to grow to the limit of the available money, whatever that amount might be. Some of these points are discussed more fully in my unpublished paper "Toward a National Urban Consensus," dated March 6, 1970, which I ask be made a part of the record of the hearings.[1] (The paper referred to by Dr. Forrester may be found on p. 256.)

CHARACTERISTICS OF SOCIAL SYSTEMS

I turn now to some characteristics of social systems that mislead people. These have been identified in our work with corporate and urban systems and from more recent work that I will describe on the worldwide pressures that are now enveloping our planet.

[1] Our continuing examination of urban behavior has been made possible through a grant to MIT from the Independence Foundation of Philadelphia.

First, social systems are inherently insensitive to most policy changes that people select in an effort to alter the behavior of the system. In fact, a social system tends to draw our attention to the very points at which an attempt to intervene will fail. Our experience, which has been developed from contact with simple systems, leads us to look close to the symptoms of trouble for a cause. When we look, we discover that the social system presents us with an apparent cause that is plausible according to what we have learned from simple systems. But this apparent cause is usually a coincident occurrence that, like the trouble symptom itself, is being produced by the feedback-loop dynamics of a larger system. For example, as already discussed, we see human suffering in the cities; we observe that it is accompanied (some think caused) by inadequate housing. We increase the housing and the population rises to compensate for the effort. More people are drawn into and trapped in the depressed social system. As another example, the symptoms of excess population are beginning to overshadow the country. These symptoms appear as urban crowding and social pressure. Rather than face the population problem squarely we try to relieve the immediate pressure by planning industry in rural areas and by discussing new towns. If additional urban area is provided it will temporarily reduce the pressures and defer the need to face the underlying population question. The consequence, as it will be seen 25 years hence, will have been to contribute to increasing the population so much that even today's quality of life will be impossible.

As a second characteristic of social systems, it seems that all have a few sensitive influence points through which the behavior of the system can be changed. These influence points are not in the locations where most people expect. Furthermore, if one identifies in a model of a social system a sensitive point where influence can be exerted, the chances are still that a person guided by intuition and judgment will alter the system in the wrong direction. For example in the urban system, housing is a sensitive control point but, if one wishes to revive the economy of a city and make it a better place for low income as well as other people, it appears that the amount of low-income housing must be reduced rather than increased. Another example is the worldwide problem of rising population and the disparity between the standards of living in the developed and the underdeveloped countries. I will discuss that world system in a moment. But it is beginning to appear that a sensitive control point is the rate of generation of capital investment. And how should one change the rate of capital accumulation? The common answer has been to increase industrialization, but recent examination suggests that hope lies only in reducing the rate of industrialization. This may actually help raise quality of life and contribute to stabilizing population.

As a third characteristic of social systems, there is usually a fundamental conflict between the short-term and long-term consequences of a policy change. A policy 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. This is especially treacherous. The short run is more visible and more compelling. It speaks loudly for immediate attention. But a series of actions all aimed at short-run improvement

can eventually burden a system with long-run depressants so severe that even heroic short-run measures no longer suffice. Many of the problems which this committee faces today are the eventual result of short-run measures taken as long as two or three decades ago.

I call your attention to chapter 6 of the "Urban Dynamics" book which discusses more of the ways we are led into making incorrect decisions about social systems.

A GLOBAL PERSPECTIVE

I have mentioned social organizations at the corporate level and then touched on work which has been done on the dynamics of the city. Perhaps it will be helpful to examine a much broader scope that is closer to the national problems you face.

In July of this year we held a 2-week international conference on world dynamics. It was a meeting organized for the Club of Rome, a private group of about 50 individuals drawn from many countries who have joined together to attempt a better understanding of social systems at the world level. Their interest lies in the same problems of population, resources, industrialization, pollution, and worldwide disparities of standard of living on which many groups now focus. But the Club of Rome is devoted to taking actions that will lead to a better understanding of world trends and to influencing world leaders and governments. The July meeting at MIT was primarily for the executive committee of the Club of Rome so its members could judge the usefulness of the social system dynamics program at MIT and its applicability to the objectives of the club. Of the present executive committee, the group included Aurelio Peccei who is managing director of Italconsult in Rome and is on the boards of directors of Olivetti, Fiat, and Alitalia Airlines; Hugo Thiemann, director-general of the Battelle Institute in Geneva; and Eduard Pestel, president of the Technical Institute of Hannover in Germany.

The program included the general theory and behavior of complex systems and talks on the behavior of specific social systems ranging from corporations through commodity markets to biological systems, drug addiction in the community, and growth and decline of a city. Especially prepared for this conference was a dynamic model of the interactions between world population, industrialization, depletion of natural resources, agriculture, and pollution. A discussion of this world system will soon appear in my book "World Dynamics" (Wright-Allen Press, Cambridge, Mass.). A research project on world dynamics is now continuing under the guidance of Prof. Dennis Meadows, author of "Dynamics of Commodity Production Cycles" (also Wright-Allen Press, 1970). The "Project on the Predicament of Mankind" is being sponsored by the Club of Rome at MIT for a year with plans to develop a research group of men from many countries who will eventually base their continuing efforts in a neutral country such as Switzerland. The immediate project will reexamine, verify, alter, and extend the preliminary dynamic study of the world system and will relate it to the present worldwide concern about trends in civilization.

TRANSITION FROM GROWTH TO EQUILIBRIUM

The simple model of world interactions as thus far developed shows several different alternative futures depending on whether population growth is eventually suppressed by shortage of natural resources, by pollution, by crowding and consequent social strife, or by insufficient food. Malthus dealt only with the latter but it is possible for civilization to encounter other controlling pressures before a food shortage occurs.

It is certain that resource shortage, pollution, crowding, food failure, or some other equally powerful force will limit population and industrialization if persuasion and psychological factors do not. Exponential growth cannot continue forever. 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 to choose, the social system by its internal processes will choose for us. The "natural" mechanisms for terminating exponential growth appear to be the least desirable. Unless we understand and begin to act soon, we may be overwhelmed by a social and economic system we have created but can't control.

Figure 1 [1] shows the structure that has been assumed. It interrelates the mutual effects of population, capital investment, natural resources, pollution, and the fraction of capital devoted to agriculture. These five system "levels" are shown in the rectangles. Each level is caused to change by the rates of flow in and out, such as the birth rate and death rate that increase and decrease population. As shown by the dotted lines, the five system levels, through intermediate concepts shown at the circles, control the rates of flow. As an example, the death rate at symbol 10 depends on population P and the "normal" lifetime as stated by death rate normal DRN. But death rate depends also on conditions in other parts of the system. From circle 12 comes the influence of pollution that here assumes death rate to double if pollution becomes 20 times as severe as in 1970; and, progressively, that death rate would increase by a factor of 10 if pollution became 60 times as much as now. Likewise from circle 13 the effect of food per capita is to increase death rate as food becomes less available. The detailed definition of the model states how each rate of flow is assumed to depend on the levels of population, natural resources, capital investment, capital devoted to food, and pollution.

[1] All figures are taken from the manuscript for "World Dynamics" by Jay W. Forrester, Wright-Allen Press, Cambridge, Mass., available about February 1971.

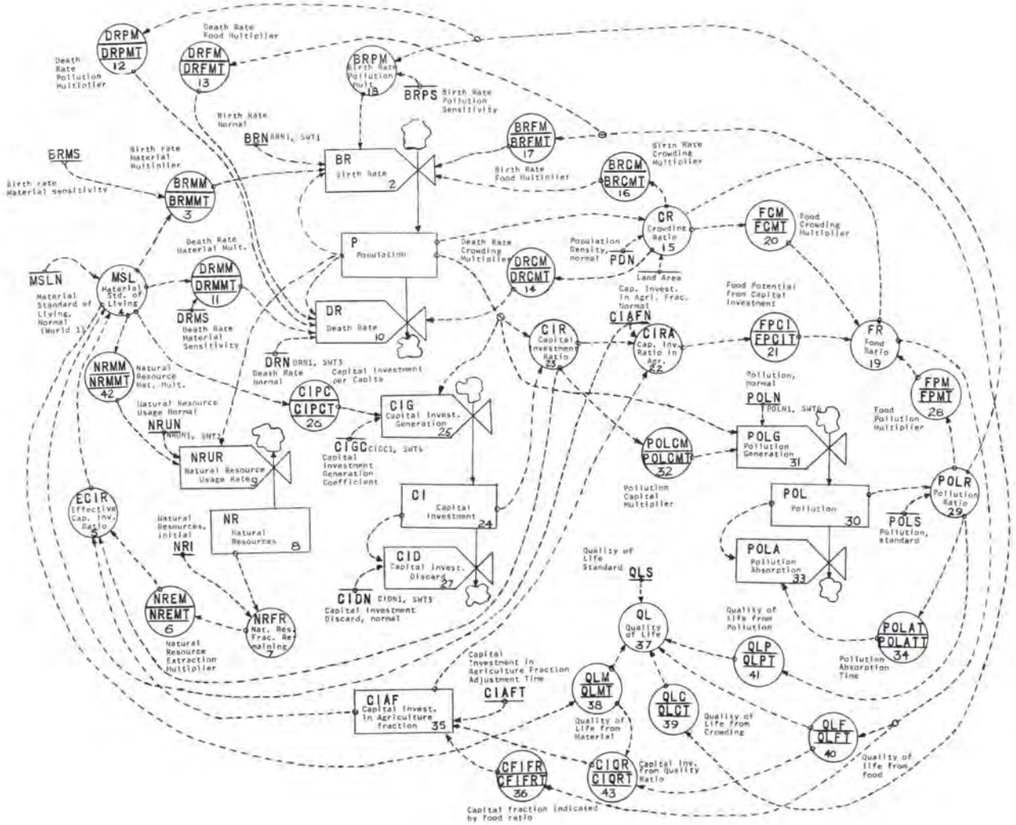

FIGURE 1

Individually the assumptions in the model are plausible, create little disagreement, and reflect common discussions and assertions about the individual responses within the world system. But each is explicit and can be subjected to scrutiny. From one viewpoint, the system of figure 1 is very simplified. It focuses on a few major factors and omits most of the substructure of world social and economic activity. But from another viewpoint, figure 1 is comprehensive and complex. The system is far more complete and the theory described by the accompanying computer model is much more explicit than the mental models that are new being used as a basis for world and governmental planning. It incorporates dozens of nonlinear relationships. The world system shown here exhibits provocative and even frightening possibilities.

With the model specified, a computer can be used to show how the system, as described for each of its parts, would behave. Given a set of beginning conditions the computer can calculate and plot the results that unfold through time.

Figure 2 shows the mode of behavior of this world system wherein population reaches a peak and then declines because industralization is suppressed by falling natural resources. The world today seems to be entering a condition in which pressures are rising simultaneously from every one of the influences that can suppress growth—depleted re-

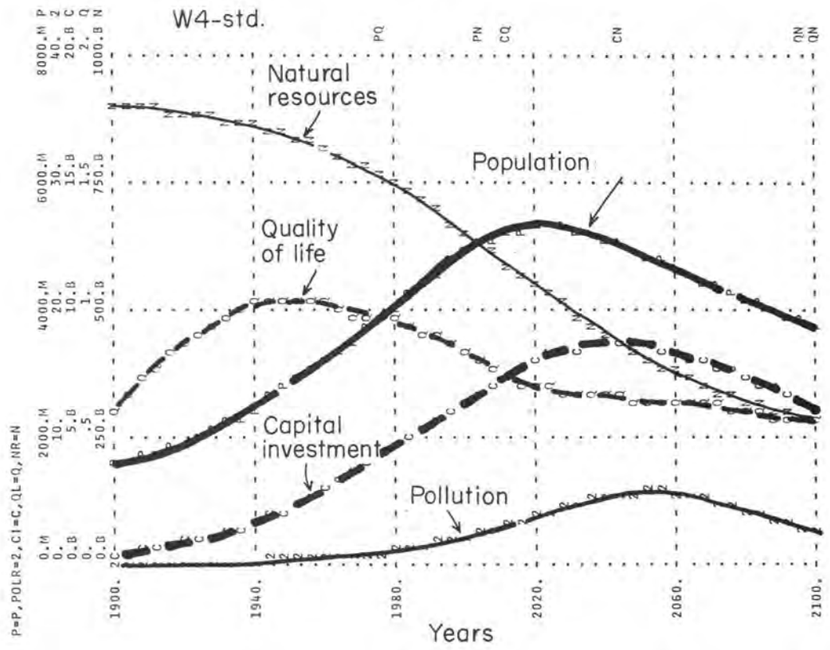

FIGURE 2.—Basic world model behavior showing the mode in which industrialization and population are suppressed by falling natural resources.

sources, pollution, crowding, and insufficient food. It is still unclear which will dominate if mankind continues along the present path. Figure 2 shows a period from year 1900 to 2100. The model system starts with estimates of conditions in 1900. Adjustments have been made so that the generated paths pass through the conditions of 1970.

In figure 2 the quality of life peaks in the 1950's and by 2020 has fallen far enough to halt further rise in population. Declining resources, and the consequent fall in capital investment then exert further pressure to gradually reduce world population.

But we may not be fortunate enough to run gradually out of natural resources. Science and technology may very well find ways to use the more plentiful metals and atomic energy so that resource depletion does not intervene. If so, the way then remains open for some other pressure to arise within the system. Figure 3 shows what happens within this system if the resource shortage is foreseen and avoided.

Here the only change from figure 2 is in the usage rate of natural resources after the year 1970. In figure 3 after 1970, resources are used at a rate 75 percent less than assumed in figure 2. In other words, the standard of living is sustained with a lower drain on the expendable and irreplaceable resources. But the picture is even less attractive. By not running out of resources, population and capital investment are allowed to rise until a pollution crisis is created. Pollution then acts directly to reduce birth rate, increase death rate, and to depress food production. Population which, according to this simple model, peaks

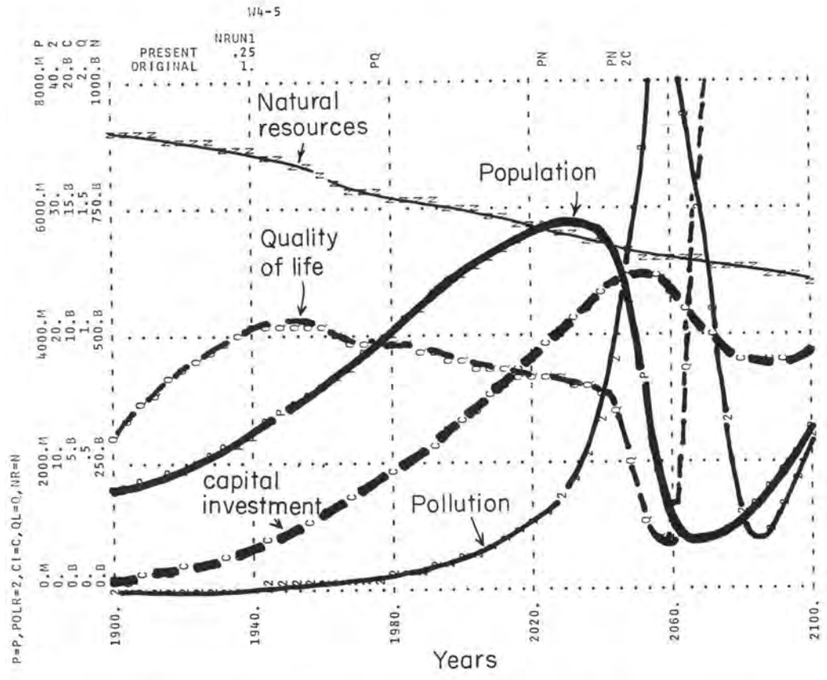

FIGURE 3.—Pollution crisis precipitated by lower usage rate of natural resources. In 1970 natural resource usage is reduced 75 percent by more effective technology without affecting material standard of living.

at the year 2030 has fallen to one-sixth of the peak population within an interval of 20 years. Such would be a worldwide catastrophe of a magnitude never before experienced. Should it occur, one can speculate on which sectors of the world population will suffer most. It is quite possible that the more industralized countries (which are the ones which have caused such a disaster) would be the least able to survive such a disruption to environment and food supply. They might be the ones to take the brunt of the collapse.

Figure 3 shows how a technological success (reducing our dependence on natural resources) can merely save us from one fate only to fall victim to something worse (a pollution catastrophe). There is now developing throughout the world a strong undercurrent of doubt about technology as the savior of mankind. There is a basis for such doubt. Of course, the source of trouble is not technology as such but is instead the management of the entire technological-human-political-economic-natural complex.

Figure 3 is a dramatic example of the general process discussed earlier wherein a program aimed at one trouble symptom results in creating a new set of troubles in some other part of the system. Here the success in alleviating a natural resource shortage throws the system over into the mode of stopping population growth by pollution caused by industralization which has been freed from natural resource restraint. This process of a solution creating a new problem has defeated

many of our past governmental programs and will continue to do so unless we devote more effort to understand the dynamic behavior of our social systems.

Suppose in the basic world system of figures 1 and 2 we ask how to sustain the quality of life which is beginning to decline after 1950. One way to attempt this, and it is the way the world is now choosing, might be to increase the rate of industrialization by raising the rate of capital investment. Models of the kind we are here using make such hypothetical questions answerable in a few minutes and at negligible cost. Figure 4 shows what happens if the "normal" rate of capital accumulation is increased by 20 percent in 1970. The pollution crisis reappears. This time the cause is not the more efficient use of natural resources but the upsurge of industrialization which overtaxes the environment before resource depletion has a chance to depress industralization. Again, an "obvious" desirable change in policy has caused troubles worse than the ones that were originally being corrected. This is important, not only for its own message, but because it demonstrates how an apparently desirable change in a social system can have unexpected and even disastrous results.

Figure 4 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 social systems. First, the programs are apt to address symptoms rather than causes and attempt

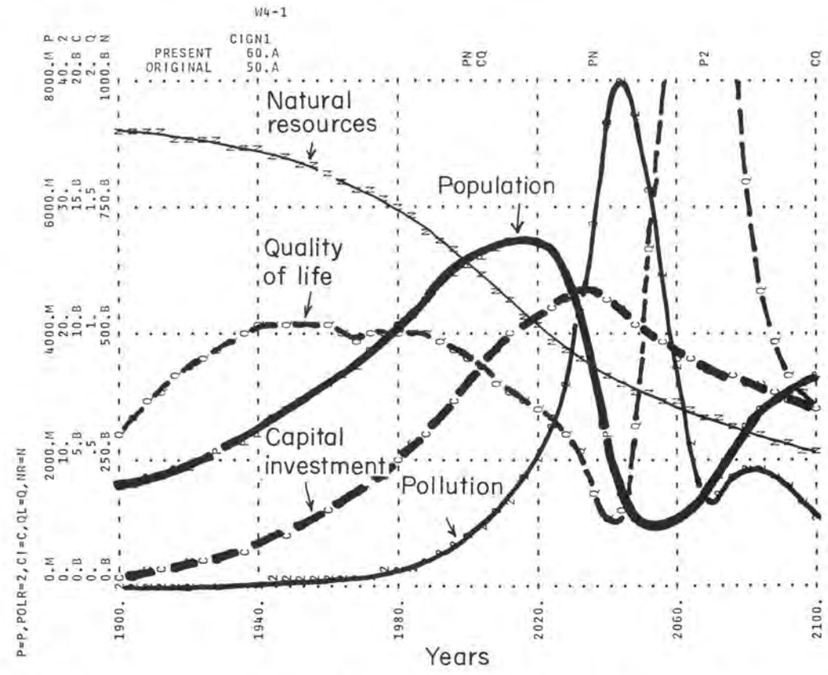

FIGURE 4.—In 1970 the rate of capital accumulation is increased 20 percent in an effort to reverse the beginning decline in quality of life. The pollution crisis occurs before natural resources are depleted.

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 effect of a program can be along an entirely different direction than was originally expected; suppressing one symptom only causes trouble to burst forth at another point.

Figure 5 retains the 20-percent additional capital investment rate after 1970 from figure 4 but in addition explores birth reduction as a way of avoiding crisis. Here the "normal" birth rate has been cut in half in 1970. (Changes in normal rates refer to coefficients which have the specified effect if all other things remain the same. But other things in the system change and also exert their effect on the actual system rates.) The result shows interesting behavior. Quality of life surges upward for 30 years for the reasons that are customarily asserted. Food-per-capita grows, material standard of living rises, and crowding does not become as great. But the more affluent world population continues to use natural resources and to accumulate capital plant at about the same rate as in figure 4. Load on the environment is more closely related to industrialization than to population and the pollution crisis occurs at about the same point in time as in figure 4.

Figure 5 shows that the 50-percent reduction in normal birth rate in 1970 was sufficient to start a decline in total population. But the ris-

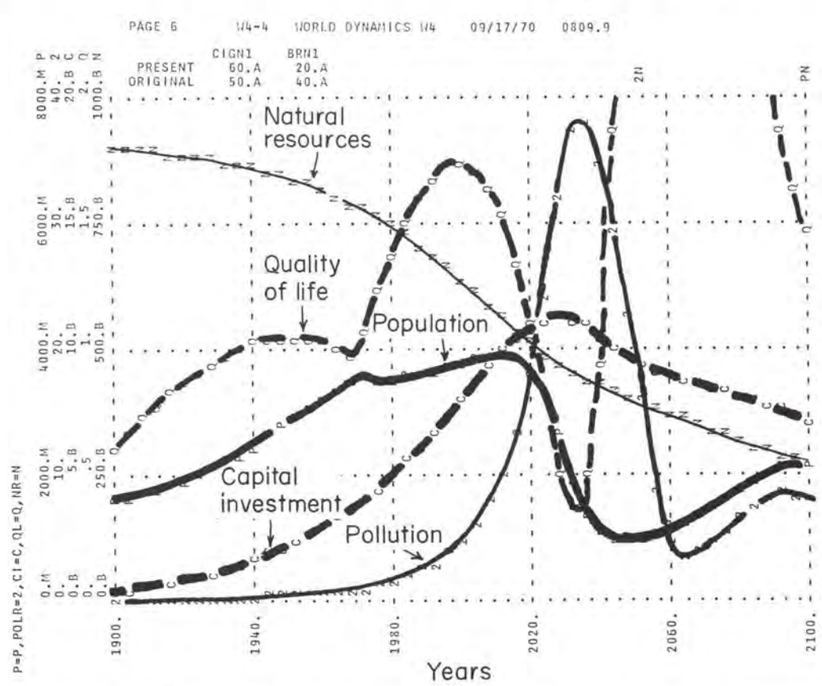

FIGURE 5.—In 1970 the 20 percent increase in capital accumulation of figure 4 is retained and "normal" birth rate is reduced 50 percent. Capital investment continues to grow until the pollution crisis develops. After an initial decline, population is again pushed up by the rapid rise in quality of life that precedes the collapse.

ing quality of life and the reduction of pressures act to start the population curve upward again. This is especially evident in other computer runs where the reduction in normal birth rate is not so drastic. Serious questions are raised by this investigation about the effectiveness of birth control as a means of controlling population. The secondary consequence of starting a birth control program will be to increase the influences that raise birth rate and reduce the apparent pressures that require population control. A birth control program which would be effective, all other things being equal, may largely fail because other things will not remain equal. Its very incipient success can set in motion forces to defeat the program.

Figure 6 combines the reduced resource usage rate and the increased capital investment rate of figures 3 and 4. The result is to make the population collapse occur slightly sooner and more severely. To the modified system of figure 6, figure 7 then examines the result if technol-

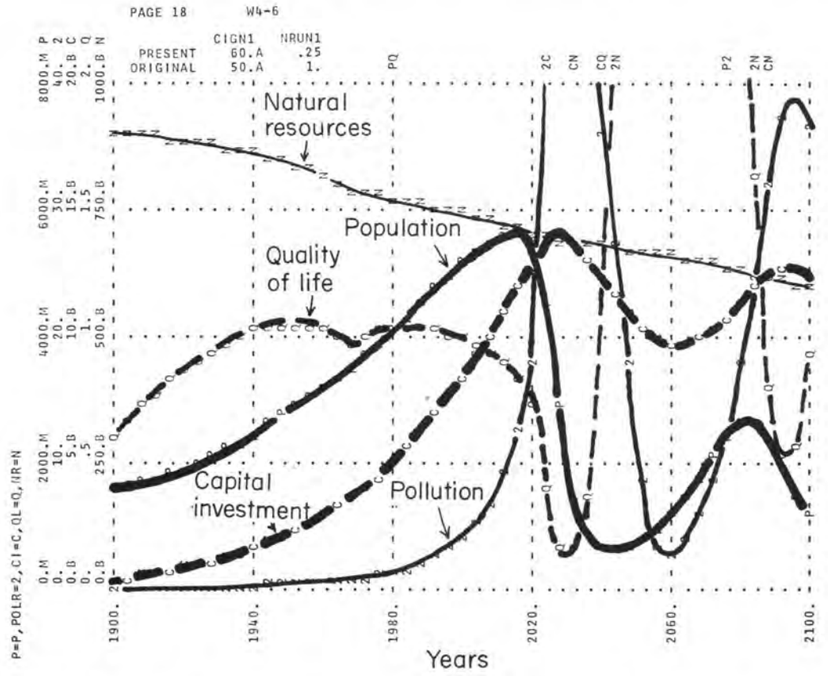

FIGURE 6.—The 20-percent increase of capital investment from figure 4 and the 75-percent reduction of natural resource usage from figure 3 are combined.

ogy finds ways to reduce the pollution generated by a given degree of industrialization. Here in figure 7, the pollution rate, other things being the same, is reduced by 50 percent from that in figure 6. The result is to postpone the day of reckoning by 20 years and to allow the world population to grow 25 percent greater before the population collapse occurs. The solution of reduced pollution has, in effect, caused more people to suffer the eventual consequences. Again we see the dangers of partial

solutions. Actions at one point in a system that attempt to relieve one kind of distress produce an unexpected result in some other part of the system. If the interactions are not sufficiently understood, the consequences can be as bad or worse than those that led to the initial action.

In our social systems, there are no utopias. There appear to be no sustainable modes of behavior that are free of pressures and stresses.

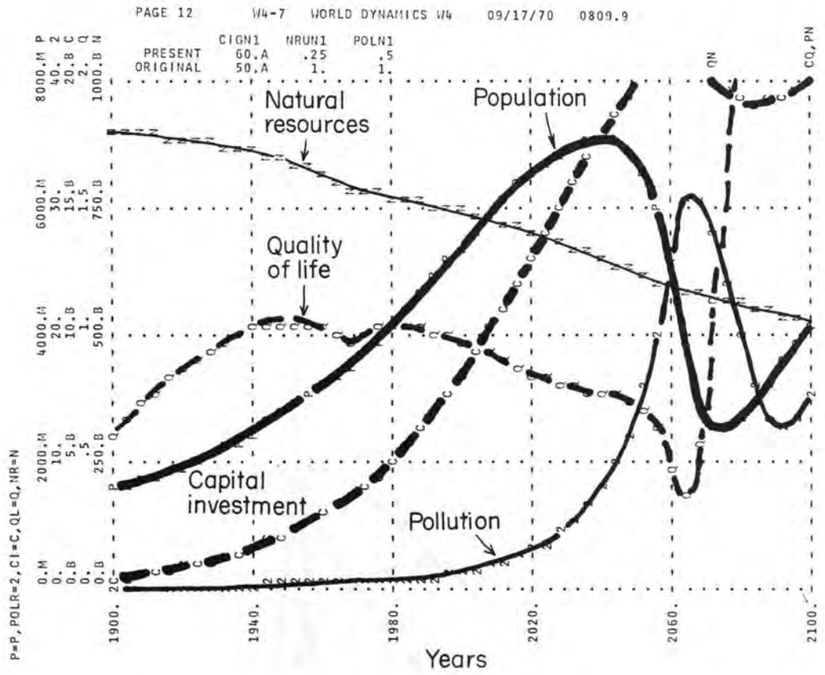

FIGURE 7.—Increased capital investment rate and reduced natural resource usage from figure 6 are retained. In addition in 1970 the normal rate of pollution generation is reduced 50 percent. The effect of pollution control is to allow population to grow 25 percent further and to delay the pollution crisis by 20 years.

But there are many possible modes and some are more desirable than others. Usually, the more attractive kinds of behavior in our social systems seem to be possible only if we have a good understanding of the system dynamics and are willing to endure the self-discipline and pressures that must accompany the desirable mode. The world system of figure 1 can exhibit modes that are more hopeful than the crises of the earlier figures. But to develop the more promising modes will require restraint and dedication to a long-range future that man may not be capable of sustaining.

Figure 8 shows the world system if several policy changes are adopted together in the year 1970. Population is stabilized. Quality of life rises about 50 percent. Pollution remains at about the 1970 level. Would such a world be accepted? It implies an end to population and economic growth.

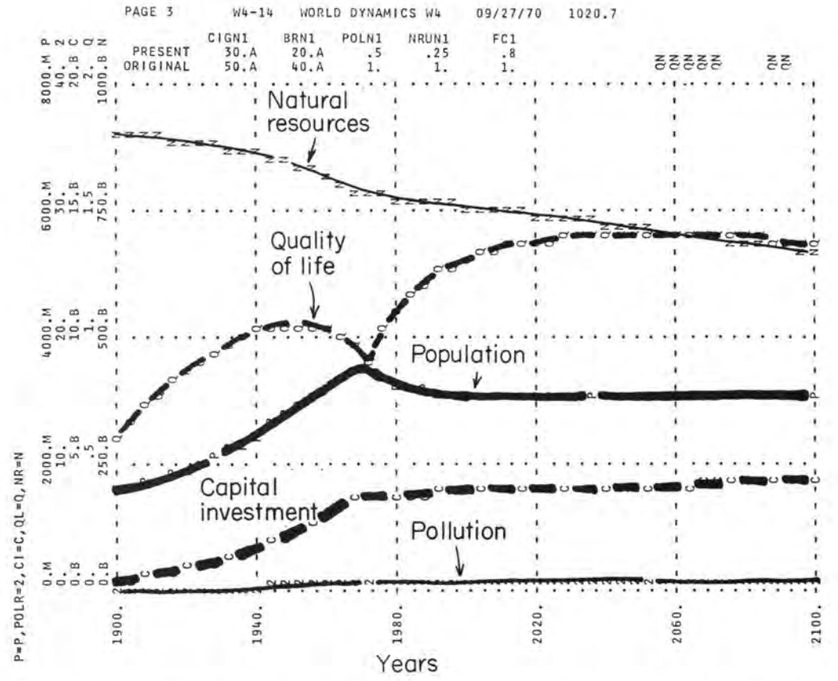

FIGURE 8.—One set of conditions that establishes a world equilibrium. In 1970 capital investment rate is reduced 40 percent, birth rate is reduced 50 percent, pollution generation is reduced 50 percent, natural resource usage rate is reduced 75 percent, and food production is reduced 20 percent.

In figure 8 the normal rate of capital accumulation is reduced 40 percent from its previous value. The normal birth rate is reduced 50 percent from its earlier value. The normal pollution generation is reduced 50 percent from the value before 1970. The normal rate of food production is reduced 20 percent from its previous value. (These changes in normal values are the changes for a specific set of system conditions. Actual system rates continue to be affected by the varying conditions of the system.) But reduction in investment rate and reduction in agricultural emphasis are counterintuitive and not likely to be discovered or accepted without extensive system studies and years of argument—perhaps more years than are available. The changes in pollution generation and natural resource usage may be easier to understand and to achieve. The severe reduction in worldwide birth rate is the most doubtful. Even if technical and biological methods existed, the improved condition of the world might remove the incentive for sustaining the birth reduction emphasis and discipline.

FUTURE POLICY ISSUES

The dynamics of world behavior bear directly on the future of the United States and the present work of this committee. American urbanization and industralization are a major part of the world scene. The United States is setting a pattern that other parts of the world are

trying to follow. That pattern is not sustainable. Our foreign policy and our overseas commercial activity seem to be running contrary to overwhelming forces that are developing in the world system. The following issues are raised by the preliminary investigations to date. They must, of course, be examined more deeply and confirmed by more thorough research into the assumptions about structure and detail of the world system.

1. Industrialization may be a more fundamental disturbing force in world ecology than is population. In fact, the population explosion is perhaps best viewed as a result of technology and industrialization. I include medicine and public health as a part of industrialization.

2. Within the next century, man may be facing choices from a four-pronged dilemma—suppression of modern industrial society by a natural resource shortage, collapse of world population from changes wrought by pollution, population limitation by food shortage, or population control by war, disease, and social stresses caused by physical and psychological crowding.

3. We may now be living in a "golden age" where, in spite of the worldwide feeling of malaise, the quality of life is, on the average, higher than ever before in history and higher now than the future offers.

4. Efforts for direct population control may be inherently self-defeating. If population control begins to result as hoped in higher per capita food supply and material standard of living, these very improvements can generate forces to trigger a resurgence of population growth.

5. The high standard of living of modern industrial societies seems to result from a production of food and material goods that has been able to outrun the rising population. But, as agriculture reaches a space limit, as industrialization reaches a natural-resource limit, and as both reach a pollution limit, population tends to catch up. Population then grows until the quality of life falls far enough to generate sufficiently large pressures to stabilize population.

6. There may be no realistic hope for 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 an advanced country is probably 20 to 50 times greater than the load now generated by a person in an underdeveloped country. With four times as much population in underdeveloped countries as in the present developed countries, their rising to the economic level of the United States could mean an increase of 200 times in the natural resource and pollution load on the world environment. Noting the destruction that has already occurred on land, in the air, and especially in the oceans, no capability appears to exist for handling such a rise in standard of living for the present total population of the world.*

7. 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 is possible, the international strife over "pollution and environmental rights" may pull the average worldwide standard of living back to the level of a century ago.

*See the correction at the end of this reprint.

8. From the long view of a hundred years hence, the present efforts of underdeveloped countries to industrialize along Western patterns may be unwise. They may now be closer to the ultimate equilibrium with the environment than are the industrialized nations. The present underdeveloped countries may be in a better condition for surviving the forthcoming worldwide environmental and economic pressures than are the advanced countries. When one of the several forces materializes that is strong enough to cause a collapse in world population, the advanced countries may suffer far more than their share of the decline.

A NEW FRONTIER

It is now possible to take hypotheses about the separate parts of a social system, to combine them in a computer model, and to learn the consequences. The hypotheses may at first be no more correct than the ones we are using in our intuitive thinking. But the process of computer modeling and model testing requires these hypotheses to be stated more explicitly. The model comes out of the hazy realm of the mental model into an unambiguous model or statement to which all have access. Assumptions can then be checked against all available information and can be rapidly improved. The great uncertainty with mental models is the inability to anticipate the consequences of interactions between the parts of a system. This uncertainty is totally eliminated in computer models. Given a stated set of assumptions, the computer traces the resulting consequences without doubt or error. This is a powerful procedure for clarifying issues. It is not easy. Results will not be immediate.

We are on the threshold of a great new era in human pioneering. In the past there have been periods characterized by geographical exploration. Other periods have dealt with the formation of national governments. At other times the focus was on the creation of great literature. Most recently we have been through the pioneering frontier of science and technology. But science and technology are now a routine part of our life. Science is no longer a frontier. The process of scientific discovery is orderly and organized.

I suggest that the next frontier for human endeavor is to pioneer a better understanding of the nature of our social systems. The means are visible. The task will be no easier than the development of science and technology. For the next 30 years we can expect rapid advance in understanding the complex dynamics of our social systems. To do so will require research, the development of teaching methods and materials, and the creation of appropriate educational programs. The research results of today will in one or two decades find their way into the secondary schools just as concepts of basic physics moved from research to general education over the past three decades.

If this committee looks out two or three decades hence, it will see that what we do today fundamentally affects that future. If we follow intuition, the trends of the past will continue into deepening difficulty. If we set up research and educational programs which are now possible but which have not yet been developed, we can expect a far sounder basis for action.

I hope that Members of Congress will take time to understand the nature of the dynamics of our social systems and that governmental programs can begin to recognize the fundamental forces that have defeated so many past efforts. Our 2-week conference with the Club of Rome in July was most successful in conveying the possibilities to those who attended. I am hereby offering a similar invitation to the House of Representatives and the Senate to take part in a 1-week examination of where we now are in understanding the dynamics of social systems. The 1 week to make such a study may be hard to allocate, but surely we agree that comparable amounts of time are devoted to hearings and investigations of less importance. In fact, many hearings are made necessary because past programs have been initiated without sufficient awareness of the full consequences. I hope that some 25 Members, jointly from the House and the Senate, could be assembled to engage in the kind of discussion which we had in July. I can refer you to a list of witnesses who can support the importance and justification for such an investment of time.

THE COMMITTEE'S ALTERNATIVES

Let me close by discussing several matters now facing this committee.

The record of the hearings to date imply that the committee accepts the future growth of U.S. population as preordained, beyond the purview and influence of the committee, and as a ground rule which determines the committee's task as finding cities in which the future population can live. But I have been describing the circular processes of our social systems in which there is no unidirectional cause and effect but instead a ring of actions and consequences that close back on themselves. One could say, incompletely, that the population will grow and that cities, space, and food must be provided. But one can likewise say, also incompletely, that the provisions of cities, space, and food will cause the population to grow. Population generates pressure for urban growth, but urban pressures help to limit population.

Population grows until stresses rise far enough, which is to say that the quality of life falls far enough, to stop further increase. Everything we do to reduce those pressures causes the population to rise further and faster and hastens the day when expediencies will no longer suffice. This committee is in the position of a wild animal running from its pursuers. We still have some space, natural resources, and agricultural land left. We can avoid the question of rising population as long as we can flee into this bountiful reservoir that nature provided. But it is obvious that the reservoirs are limited. As Dr. Moran stated on page 68, in "Population Trends," volume 1 of your printed hearings, "There has to be a point at which this exponential growth in population is slowed down, brought to a halt." The wild animal usually flees until he is cornered, until he has no more space. Then he turns to fight but he no longer has room to maneuver. He is less able to forestall disaster than if he had fought in the open while there was still room to yield and to dodge. The United States 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 space to flee.

What does this mean? Instead of automatically accepting the need for new towns and the desirability of locating industry in rural areas, we should consider confining our cities. If it were possible to prohibit the encroachment by housing and industry onto even a single additional acre of farm and forest, the resulting social pressures would hasten the day when we stabilize population. Some European countries are closer to realizing the necessity of curtailing urban growth than are we. As I understand it, farmland surrounding Copenhagen cannot be used for either residence or industry until the severest of pressures forces the Government to rezone small additional parcels. When land is rezoned the corresponding rise in land price is heavily taxed to remove the incentive for land speculation. The waiting time for an empty apartment in Copenhagen may be years. Such pressures certainly cause them to face the population problem more squarely than do we.

This subcommittee is the Subcommittee on Urban Growth. But should it not be the Subcommittee on National Equilibrium? Our greatest challenge now is how to handle the transition from growth into equilibrium. 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. But that is not the path of the future. Many of the present stresses in our society are from the pressures that always accompany the conversion from growth into equilibrium.

In our studies of social systems, we have made a number of investigations of life cycles that start with growth and merge into equilibrium. There are always severe stresses in the transition. Pressures must rise far enough to suppress the forces that produced growth. Not only do we face the pressures that will stop population growth. We also are encountering the pressures that will stop the rise of industrialization and standard of living. The social stresses will rise. The economic forces will be ones for which we have no precedent. The psychlogical forces will be beyond those for which we are prepared. Figure 3–1 in my "Urban Dynamics" book shows how the pressures from shortage of land and rising unemployment accompany the usual transition from urban growth to equilibrium. But the pressures we have seen in our cities are minor compared to those which the Nation is approaching. The population pressures and the economic forces in a city that was reaching equilibrium have in the past been able to escape to new land areas. But that escape is becoming less possible. Until now we have had, in effect, an inexhaustible supply of farmland and food-growing potential. But now we are reaching the critical point where, all at the same time, population is overrunning productive land, agricultural 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. For the first time demand is rising into a condition where supply will begin to fall while need increases. The crossover from plenty to shortage can occur abruptly.

This is a subcommittee of the Banking and Currency Committee. The fiscal and monetary system of the country is a complex social-

economic-financial system of the kind we have been discussing. It is clear the country is not agreed on behavior of the interactions between government policy, growth, unemployment, and inflation. An article by a writer for Finance magazine in July 1970 suggests that the approach I have been discussing with you be applied in fiscal and monetary policy and their relationships to the economy. I am leaving a copy for the record of this hearing. (The article referred to, "A New Approach to Economic Analysis," may be found on p. 266.) I estimate that such a task would be only a few times more difficult than was the investigation of urban growth and stagnation. The need to do so becomes more urgent as the economy begins to move for the first time from a history of growth into the turbulent pressures that will accompany the transition from growth to one of the many possible kinds of equilibrium. We need to choose the kind of equilibrium before we arrive.

In a hierarchy of systems, there is usually a conflict between the goals of a subsystem and the welfare of the broader system. We see this in the urban system which is the responsibility of this committee. The goal of the city is to expand and to raise its quality of life. But this increases population, industralization, pollution, and demands on food supply. The broader social system of the country and the world requires that the goals of the urban areas be curtailed and that the pressures of such curtailment become high enough to keep the urban areas and population within the bounds that are satisfactory to the larger system of which the city is a part. If this committee chooses to work for some of the urban goals that have been suggested in the testimony to date, and if the committee succeeds, as it may well do, the result will be to deepen the distress of the country as a whole and eventually to deepen the crisis in the cities themselves. We may be at the point where higher pressures in the present are necessary if insurmountable pressures are to be avoided in the future.

I have tried to give you a glimpse of the nature of multiloop feedback systems, a class to which our social systems belong. I have attempted to indicate how these systems mislead us because our intuition and judgment have been formed to expect behavior different from that actually possessed by such systems. I believe that we are still pursuing national programs that will be at least as frustrating and futile as many of the past. But there is hope. I have given you no specific recommendations for national policy but have suggested that we can now begin to understand the dynamic behavior of our social systems. Progress will be slow. There are many crosscurrents in the social sciences which will cause confusion and delay. The approach that I have been describing is very different from the emphasis on data gathering and statistical analysis that occupies much of the time of social research. But there have been breakthroughs in several areas. I have extended an invitation for some 25 Members of Congress to devote a week to carefully considering these issues. If we proceed expeditiously but thoughtfully, there is a basis for optimism.

Mr. ASHLEY. That is an illuminating presentation, and I might say that it is quite disturbing.

It is disturbing in part because your thesis includes the predicate, it seems to me, that efforts to improve our living environment will have

reverse consequences that are undesirable, and yet from the standpoint of public policy the conviction that we do need to improve our living environment is rather fundamental. You might be right, to say the least, you may be right that with greater understanding there will come an ability to shape public policy in a different way. I don't think that we are very far advanced in that understanding at the present time, to say the least.

Part of the purpose of this subcommittee has been to try to shape some kind of strategy with respect to growth and the components of growth. We haven't sought to define the components of a growth policy or growth strategy. So that to some extent there is a degree of flexibility that is available.

I think that it is quite clear now that legislation will be passed that you are familiar with that will make provisions for the first time formally, officially, legislatively mandated for an evolving growth, national growth policy.

Do you regard this kind of an effort as being helpful in any respect? My question is simply this: That in the past we have operated as a nation on an extremely ad hoc basis with respect to how we have handled growth. I understand that growth may be something that we don't want to be faced with, but that would not obviate the necessity for some kind of strategy as distinct from a totally unplanned type of operation that the Nation is engaged in.

Dr. FORRESTER. We must have a growth policy. The question is, growth under what circumstances. To what extent and by what process do we now begin to see our way to a future equilibrium. Growth in the raw 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.

A growth policy, therefore, is absolutely essential. But I interpret the phrase to mean a policy to extract ourselves from the trends of the past and gradually to move into an equilibrium that would be sustainable in the future. This means a transition—a transition policy from growth to equilibrium. The policy should cover the questions of when and how.

Mr. ASHLEY. Yes, precisely. At its best that could precisely be said as to what we hope will evolve from the form, from the mechanism that is being established.

I think that it is interesting that the responsibility for the evolving of the specific components of the strategy have been placed with the executive branch of the Government and not the legislative. Your invitation, which I must say I hope to respond to, might at some point include the members of the Urban and Growth Council, if that is the mechanism, or the members of the subcommittee of the White House Domestic Council that will have this responsibility.

The second part of the legislation may not be so easily reconciled with your thesis. It does well for a better delivery system to produce not just housing but the living environment in which future generations will find themselves. How does that compare with what you have been saying? Is that really as self-defeating as would seem to be the case based on your statement? Is it really impossible to markedly im-

prove a pretty shabby living environment without increasing capital investment, without making it attractive for people to have more children? How certain are we of that, professor?

Dr. FORRESTER. Figure 8 in my statement suggested that in fact quality of life might rise on the average by doing some things opposite to the obvious.

Now, I don't propose that I believe all of the illustrations 100 percent at this point or that you should. But I believe them to the extent that I think they must be taken seriously and explored. I do believe them to that extent. We will probably learn vastly more as others join the investigation and the argument. I am, of course, under no illusion that these results will affect things in the next 1, 2, 3 years. The proposed changes are very fundamental. They strike deeply at a whole set of ideas that have built up over many decades. They would probably have no chance except for the frustration that has been developing as a result of past practices. We are not markedly more happy this year than 10 or 25 years ago. There must be underlying reasons for failures in past social programs and we think we begin to see these reasons in the system dynamics studies. If the conclusions come out to be radical and different perhaps that is necessary, because if conditions are to be different in the future from the past it means we must act differently. There will be many crosscurrents when the changes for the future are fully identified. My colleagues, Gordon Brown, former dean of engineering at MIT and John F. Collins, and I are patient and willing to develop the necessary supporting arguments. I am convinced that the reasoning I have given you will prevail. We have an obligation to keep it before people long enough that they can understand and evaluate.

Mr. ASHLEY. Well, I admire your intellect and I admire your courage, and I must say that I am not disposed to argue with you very much because I have a sense of what you are saying. There would be nothing the matter with public policy that seeks to improve the living environment if that public policy is only one component of a much broader policy. If we are willing to do other things that will forestall the interaction consequences that an effort simply to improve the living environment would result in, then I take it that this would be in accord with your basic thesis.

Dr. FORRESTER. Yes. But there is a point I did not take time for in the presentation. It should be stressed.

In our national and State legislative processes we try to correct the symptoms of a problem rather than asking what is causing the problem. It would often be simpler and less expensive to remove the underlying causes.

It is clear from our examination of social systems that most processes of active intervention will fail. Much of the effort will be negated by the system ceasing to do what it was already doing for itself. The load is thrown more and more on the outside program. That is one process. In addition, a set of internal pressures against the outside program are generated. Many mechanisms make an outside direct intervention unlikely to succeed.

Mr. ASHLEY. Well, you lose me a little bit there when you admit that it is necessary for the improvement of society to remove underlying causes of despair and frustration, poverty——

Dr. FORRESTER. Let's look at the underlying causes with respect to 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. 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. And the changes in laws commonly suggested to help are the ones that will, in the long run, deepen the difficulties. The processes controlling our social systems are so fundamental and powerful that it is difficult for outside intervention to succeed unless it acts on causes instead of symptoms.

If we change the laws that are producing the underlying economic and social causes we could have a set of policies that would lead to automatic internal self renewal in an urban area. Renewal would happen as a matter of course without anybody forcing the issue. Government can cause the problems it is trying to alleviate in the same way that corporations often actively cause their trouble. Both do so because few people realize how the actions distributed through the entire organization interact to produce the difficulty. Every piece of the system seems sensible and logical. Each policy has been established in good faith. The composite can be a near disaster. This counterintuitive character of systems is only beginning to be appreciated. It is important to see if we are moving in the right or the wrong directions. Generally speaking, I think we are moving in the wrong directions. The countywide social stress supports that. I believe the ghetto strife, the university student unrest, and the divisions in the country can be traced to the same set of common causes. Such pressures arise as a system begins to enter a new phase of behavior. The growth tradition of the past can no longer continue.

All the great problems discussed in the newspapers are closely interlinked. They are not isolated. They are related to each other and all are manifestations of the onset of a rising set of pressures being created as growth gives way to equilibrium. The social, geographical, and economic system is now just beginning to assert the pressures to stop growth. If we remain unaware of the oncoming pressures, we will be in trouble. We don't have a choice of avoiding the pressures. We only have a choice of what blend of pressures we would like to live under. And I say there is no utopia. There will be a set of pressures but there may be a choice before us as to which kind.

Mr. ASHLEY. The body politic is in very much the same situation as the corporation you described.

Dr. FORRESTER. Very similar.

Mr. ASHLEY. Just as it is prevalent for corporate officers to continue to make decisions which are certainly meant to be productive, to be profitable, but which in fact are the contrary, so it seems to me we find the body politic more able, more inclined to respond to pressures by the kind of overt action that you describe rather than the removal of

underlying forces which almost presupposes a perfect perception of what you have given us this morning, or something close to it.

Dr. FORRESTER. These ideas can be conveyed to a wide audience. I would not hesitate to teach the concepts of complex feedback systems to students in junior high school. I could take them through the entire structure of this world dynamics model and they would understand it.

Mr. ASHLEY. You say that having somewhat convinced me this morning. Is that what has given you this sudden confidence in your ability to reach the junior high school level of intelligence?

Dr. FORRESTER. No, no, such implication. We have found a high degree of understanding and receptiveness in almost everyone in the political area we have talked to. I suppose I came to the urban dynamics work with some of the same folklore and prejudices about men in public life that are found throughout the population and particularly in the universities. Often the popular image is not flattering. But every mayor and elected official I have met has shown a sincere interest in his problems and seems to be doing the best he is able. Furthermore, when the system analysis we are discussing is brought to his attention, he wants to understand.

Mr. ASHLEY. But in many respects we are all the product of the myths that are prevalent.

Dr. FORRESTER. That is right.

Mr. ASHLEY. Are you familiar with the work of the Committee on Intergovernmental Relations?

Dr. FORRESTER. No. My own diversification from corporate interests to social ones is rather recent.

Mr. ASHLEY. This is a group that has done some conceptual thinking in areas in which you are interested, particularly, as the name of the organization would suggest, with respect to governmental and intergovernmental relations, the need, for example, for a very, very different view of property taxation, but going far beyond that into the necessity for governmental structures and relationships that are responsive to the 1970's. I would commend their work which would be contained in——

Mr. HENDERSON. They have a number of reports.

Mr. ASHLEY (continuing). Various reports that I will furnish you citations of.

Dr. FORRESTER. I wish you would.

Mr. HENDERSON. Just one brief question. That is, earlier in your testimony you said that our approach has been intuitive in dealing with these problems in the past. The difference in your capability, is that based largely on the—you mentioned, for instance, the speed with which you could analyze problems with computers and so forth. Is it that you can analzye data much quicker to make judgments than you could by the intuitive approach we have used in the past, or how much of that is a basis for your analytical system?

Dr. FORRESTER. The key to what we are doing should not be considered the computer. The computer is a necessary tool. But the key is the concepts about the nature of systems and the theory of dynamic behavior. This is a difficult professional field which is fully equal to, let us say, the field of medicine when it comes to the difficulty and nature of training. We don't have the equivalent of the medical schools yet. We have perhaps 25 or 30 percent of what I would call an appropriate, necessary education, but it is going to be a professional field in its own right dealing with the dynamic behavior of social systems.

The only place this is usually taught in our educational system at present is in some engineering departments as applied to physical control systems. The field originally started in electrical engineering, especially in electrical engineering in MIT. It is now taught in mechanical engineering and aeronautical engineering in many universities. I am speaking of the dynamics of feedback systems or what in engineering are called servomechanisms.

It is a much broader field than the engineers realize. It is much more fundamental than has been acknowledged until recently.

The kinds of systems we are dealing with in social systems are 10 to a hundred times more complex than those which have been dealt with in engineering. So there is a great deal to be done in extending the approach. The really new thing here is that we are now across the threshold. For the first time the approach has become practical and powerful in suggesting answers with respect to social systems. But the field is only just across the threshold.

If I were to make any kind of an estimate, I would say that we're only 5 percent into the field. Comparatively, we are now about where science and technology were in 1930, and you see everything that has happened in science and technology since then.

Mr. HENDERSON. Most of the elements that go into your chart, for instance, if policy decisions could be made this year, the impact is going to fall 20, or 30 years out, isn't that—I mean you are talking a tremendous time lag. We are putting out today's fires here and you are talking about steps taken now that will have an impact in patterns 20 or 30 years out at the minimum.

Dr. FORRESTER. That is right. But the longrun good can win some support. The influence will first occur in those decisions that lie in the 40 to 60 percent probability of going either way. Then any additional argument or additional insight can tip the balance. Fundamental, deep-seated, sweeping changes cannot occur until there is a widespread public understanding and awareness, until some of the results of system research have been conveyed more widely, until there are textbooks within the reach of high school and secondary school students, and until there are professional programs in dynamics of social systems in universities. There still is not a good set of material for university use. Even so, at least 50 colleges and universities are starting programs in this area. They are making some progress. In another decade they will show substantial results. But they are still feeling their way at the present time.

I am talking about an approach to social systems that is very different from what has conventionally been taught in economics and in social science departments. It must win its reputation by what it accomplishes. This is beginning to happen. It is inevitable. I am presenting you something that is long run. It must have its influence from a wide base of support The executive department, in reply to a comment made earlier, can probably not use or introduce such radically different ideas about our social systems until there is a base of support in the country first.

Mr. ASHLEY. Very interesting comment, that the White House requires support rather than fulfilling a leadership role in a policy approach of this kind.

Dr. FORRESTER. I think the leadership role can come from anywhere. I call your attention to the Club of Rome. It has no official government status on the part of any member. This is, I think, the kind of a group that can have real influence. They are not bound to a system in which they must represent all interests. They can gather together because they see a need and address themselves to it, let the chips fall where they may. If they are right and persuasive, they will have accomplished something. If they are not, it is just as well. And in this country I would visualize the most rapid influence occurring through private individuals, not as any kind of hidden or withdrawn group but simply a community of people who begin to understand, who begin to write articles, who begin to talk to large numbers of people, and who begin to start a ground swell and momentum. Government then reaches a point where any action to the contrary must be explained. The ideas need to be introduced wherever possible, in Congress, in the executive department, but also outside Government in a variety of places.

Mr. ASHLEY. Well, you would be pleased to know that the reports of this subcommittee have been very well received; thousands and thousands of copies have been issued to universities, upon request.

Dr. FORRESTER. That is tremendously important. The group that will take an interest in these issues is very difficult to reach. It is not identified. It is not cohesive. But your hearings can help to reach them.

Mr. ASHLEY. Is there any way of estimating based on your experience and background how long it might take for a new approach of this kind, assuming its validity, to gain broad credence in the academic community and therefore among the general public?

Dr. FORRESTER. Well, it is more like 10 to 20 years than it is one or two, and partly it is set by the education and training problem. If turning out a person with professional skill is like turning out a medical student, or perhaps even a skillful surgeon, which means practice beyond school, you are talking about 5 to 6 years or more.

Mr. ASHLEY. Yes.

Dr. FORRESTER. There are probably not more than a dozen people in this country now committed to going that far with their education. We teach 150 students a year an introduction to social system dynamics, but it is a cultural treatment. It is one term. It is a new perspective. But they don't see themselves as going on into a professional field. A much smaller number take intensive study. We get most of our interested students by happenstance contact in the MIT student body. Most transfer from study in an engineering department. The process of training enough men will be slow. It will take time for many of the traditions in the social sciences to change.

But any new area takes a long time to introduce. Let me go to technology for an analogy.

It took almost 10 years from invention of the transistor until it was generally being used in products. The transistor is a straightforward job of manufacture, keeping out the contamination, and design of new circuits. It is elementary and trivial compared to making sweeping change in people's ideas, their self-perception, and their willingness to abandon old modes of thought. We do not have examples anywhere of major change being rapid. The only reason that change

in this area will be substantial within 10 or 20 years is the desperate need.

New ideas about social systems will be accelerated because people cannot afford to ignore them. The ideas have been around for 15 years and we could have accelerated them much sooner. But there wasn't enough need. I think that now we will have help, and substantial help.

Mr. ASHLEY. Mr. Ireland.

Mr. IRELAND. Thank you. I owe you an apology, sir. I said before the hearing that my son would understand this better than I would. I am afraid that I have to withdraw that. That is probably the most lucid statement I have heard, and I could have made that statement a number of times in one brilliant paper. I was in my time a history major. I was just wondering on the pressure of 2,000 years, I remember being over in Israel one time and learning that at the time of Christ over there it was a really teeming area.

Dr. FORRESTER. Which area?

Mr. IRELAND. Israel. Just north of the Sea of Galilee and in there where we have an encroaching desert, and so forth. Were some of these population and pollution pressures responsible for that transition would you say?

Dr. FORRESTER. I believe so. I have not studied the area. But I was told yesterday by Professor Meadows who is directing our world dynamics work that there is now a high rate of loss of farmland to desert. I understand Israel and the Middle East was forested at one time where it is now barren. That results from the pressures of overuse and the pressures to extract more from the environment than one can. We will see such pressure on a much wider scale. Pressure to irrigate lands leads to poisoning of land very often.

Mr. IRELAND. This happenstance would not be of course attributable to technologies. They had other pressures, possibly being the cockpit of wars over there for a long time. And overuse of the productive capacities of the time. I did a review of the population of Rome itself once and found out there was about 2 million, I think, at the time of Augustus, and about 200 years later, possibly a little more than that but before the coming of the barbarians it was down to 400,000. And Rome was still at the apex of its powers. Some of these pressures could have been existing at that time. And, of course, Rome finally fell down to—the lowest population it ever got was 20,000. It is now back up to 4 million, which is probably rehastening an evil day on them.

Mr. ASHLEY. Of course, what you are saying is that these interrelations have been going on for a long, long time.

Dr. FORRESTER. They have been going on for a long time. They have been modified by the appearance of new technology. Things happen to cause the rise and fall. When the social health of a society declines, a replacement will form in another place with new goals and policies. But we are talking about the dynamics of societies through a broad sweep of history.

Mr. IRELAND. Long range and otherwise.

Dr. FORRESTER. The kind of problem you spoke of in Israel could come from crowding or could be an outgrowth of technology. The technology of more intensive farming, even though it is very crude and primitive is nevertheless a demand on the environment that the

environment cannot support. It is like the demand on the air over New York City, more than can be supported.

Mr. ASHLEY. Unfortunately, there is a call to the floor of the House which will be far less interesting than what we are discussing here, but I do want to tell you, Professor Forrester, that this has been certainly the most illuminating and challenging presentation that we have had before this subcommittee. You have contributed greatly to our thinking in this area.

Dr. FORRESTER. Thank you.

Mr. ASHLEY. Thank you very much indeed for coming to Washington and being with us this morning.

The subcommittee will stand adojurned until further call of the Chair.

(The papers and article referred to by Dr. Forrester in his statement follow:)

SYSTEMS ANALYSIS AS A TOOL FOR URBAN PLANNING

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For the Symposium

THE ENGINEER AND THE CITY

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New ways are becoming available for analyzing our social systems. These permit the design of revised policies to improve the behavior of the systems within which we live. Many of the ideas discussed here are treated more fully in my book Urban Dynamics* which shows the city as an interacting system of industry, housing, and people. The book presents a theory, in the form of a computer model, that interrelates the components of a city. It shows how the interacting processes produce urban growth; and cause growth to give way to stagnation. Various changes in policies are examined with the laboratory model to show their effect on an urban area. A number of presently popular proposals are tested—a job training program, job creation by bussing to suburban industries or by the government as employer of last resort, financial subsidies to the city, and low-cost-housing programs. These all are shown to lie between neutral and detrimental in their effect on a depressed urban area. The evolution of an urban area from growth into stagnation creates a condition of excess housing. Housing is excess compared to the population and compared to the availability of income earning opportunities. To reestablish a healthy economic balance and a continuous process of internal renewal, it appears necessary to reduce the inherent excess housing of depressed areas and to encourage the conversion of part of the land to industrial use. By so doing, a large enough wage and salary stream can be brought from the outside economy to make the area self sustaining.

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

As you can see, these results are controversial. If they are right, it shows that most of the traditional steps taken to alleviate the conditions of our cities may actually be making matters worse. The book first appeared this last May; it is already in the second printing. Although it has so far received little public notice in this country, it has become the center of a political tempest in Canada. North of the border, newspaper headlines, editorials and radio and television panel discussions are debating its merits.

Urban Dynamics is based on methods for studying complex systems that form a bridge between engineering and the social sciences. Although I will present here some results from the book, my principal emphasis will be on the importance of the methods to all social systems.

Over a decade ago at MIT we began to examine the dynamic characteristics of managerial systems. The field known as "industrial dynamics" resulted.* Industrial dynamics belongs to the same general subject area as feedback systems, servomechanisms theory, and cybernetics. Industrial dynamics is the study of how the feedback loop structure of a system produces the dynamic behavior of that system. In managerial terms industrial dynamics makes possible the structuring of the components and policies of a system to show how the resulting dynamic behavior is produced. In terms of social systems it deals with the forces that arise within a system to cause changes through time.

A design study of a social system seeks changes in structure and policies that will improve the behavior of the system. Some people recoil at the thought of designing social systems. They feel that designing a society is immoral. But we have no choice about living in a system that has been designed. The laws, tax policies, and traditions of a society constitute the design of a social system. Our available choice is only between different designs. If we lament the functioning of our cities, or the persistence of inflation, or the changes in our environment, we mean that we prefer a social system of a different design.

The design process is first to observe the behavior modes of a system to identify the symptoms of trouble. Second, the system is searched for the feedback structures that might produce the observed behavior. Third, the level and rate variables making up that structure are identified and explicitly described in the equations of a computer simulation model. Fourth, the computer model is then used to simulate in the laboratory the

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*Forrester, Jay W., Industrial Dynamics, The M.I.T. Press, 1961.

dynamic behavior implicit in the identified structure. Fifth, the structure is modified until components of the structure and the resulting behavior agree with the observed conditions in the actual system. Sixth, modified policies can then be introduced into the simulation model in search of usable and acceptable policies that give improved behavior.

This design process brings the essential substance of a social system into the laboratory where the system can be studied. Laboratory representation of a social system can be far more effective than most people would expect. Anything that can be stated or described about a social system can be represented in such a laboratory model. The major difficulty is the rarity of skilled professional talent. There are very few men with a knowledge of the proper guiding principles and with experience in perceiving the pertinent feedback structure of complex, poorly defined systems. Whatever one may say about the shortcomings of the process, there is no comparably effective substitute.

Surprising discoveries come from this combination of theory and laboratory experimentation. We observe that relatively simple structures produce much of the complex behavior of real-life systems. We find that people's skills in perception are very different from those commonly supposed. It is often asserted in the social sciences that people are unreliable in analyzing their own actions, yet we find time and again that the policies and practices that people know they are following are the ones that interact to produce the most troublesome consequences. Conversely it can be clearly demonstrated that the vaunted powers of judgment and intuition usually deceive the person who tries to guess the time-varying consequences that follow even from a completely known system structure. We find that the modes of behavior which are most conspicuous in managerial, urban, and economic systems are produced by nonlinearities within those systems. The linearized models which have been used in much of engineering and the social sciences can not even approximate the important modes of behavior in our social systems. The most visible and troublesome modes are manifestations of nonlinear interactions. We find it relatively straight-forward to include the so-called intangible factors relating to psychological variables, attitudes, and human reactions. Again, if the influences can be discussed and described, they can be inserted in the policy structure of a model. Any person who discusses why people act the way they do, or explains a past decision, or anticipates a future action is relating the surrounding circumstances to the corresponding human response. Any such discussion is a description of decision-making policy. Any such policy statement can be put into a system model.

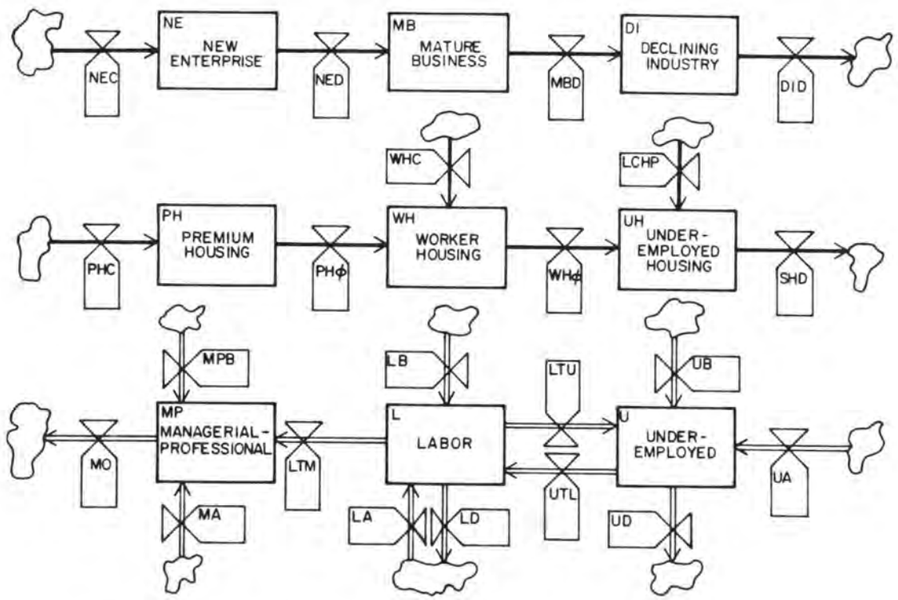

Figure 1. Urban structure.

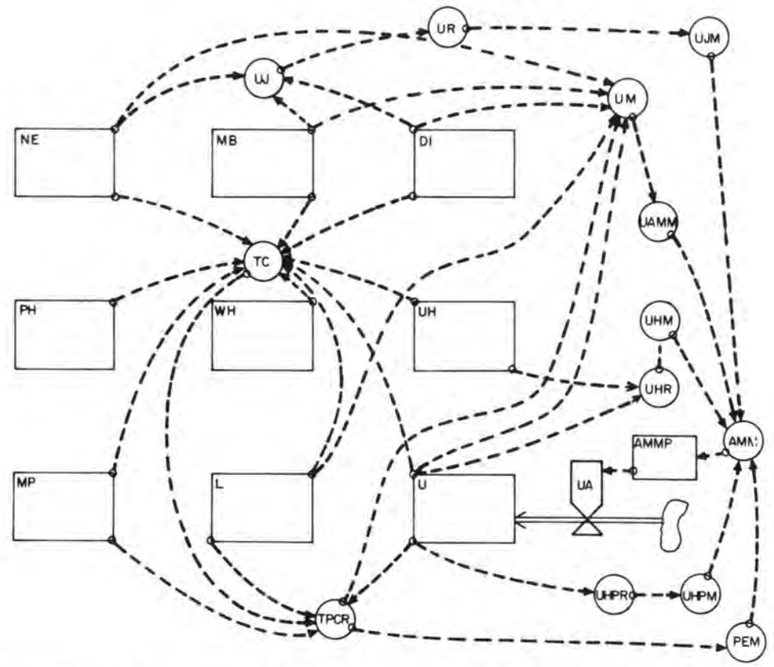

Figure 2. Information links to the underemployed-arrival rate.

A body of dynamic theory and principles of structure is emerging that allows us to organize and understand complex systems.* For example, the feedback loop becomes the basic building block of systems. Within the feedback loop there are two and only two kinds of variables. One is the level variable produced by integration, the other is the policy statement or rate variable which governs the changes in a system. The level variables are changed only by the rates of flow. The rate variables depend only on the levels. Any path through a system network encounters alternating level and rate variables. These and many other principles of structure are universal in the entire sweep of systems that change through time. Furthermore, the structure of a system determines its possible modes of behavior. Identical structures recur as one moves between apparently dissimilar fields. These identical structures behave in identical ways wherever they are found.

The same principles of structure and the same relationships between structure and behavior apply to a simple swinging pendulum, a chemical plant, the processes of management, internal medicine, economics, power politics, and psychiatry. A universal approach to time-varying systems is emerging which seems capable of dealing with systems of any complexity. We observe that students, as they master the principles and practice of dynamic analysis, develop a remarkable mobility between fields of endeavor. The same person can clarify the dynamics of how a transistor functions, organize the processes of a public health epidemic, design new management policies to avoid stagnation in product growth, discover the sensitive factors in ecological change, and show how government policies affect the growth and decline of a city.

Some diagrams showing urban behavior will illustrate these ideas. Figure 1 shows the central structure of an urban area. The nine rectangles represent the selected level variables. The 22 valve symbols represent the rates of flow that cause the nine system levels to change. Engineers often refer to these level variables as the state variables of a system. The distinction between level and rate variables is also familiar to anyone who examines financial statements. Balance sheet variables are always separated from variables on the profit-and-loss statement. They are separate because they are conceptually quite different. The balance sheet variables are system levels. They are created by accumulating financial flows. The profit-and-loss variables are system rates. This sharp distinction is found in all systems.

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*Forrester, Jay W., Principles of Systems, preliminary printing of first ten chapters, Wright-Allen Press, Inc., Room 516, 238 Main Street, Cambridge, Massachusetts 02142.

In the simplified urban system of Figure 1, nine levels are grouped into three subsystems. Across the top the industrial sector contains commercial buildings in three categories distinguished primarily by age. Across the center are residential buildings in three categories, also distinguished by age and condition. Across the bottom are three economic categories of population. Because of their complexity, the information linkages connecting the system levels to the system rates are not shown on this figure. In this figure one can begin to detect the reasons for urban decline. The age of a building tends to determine the character of its occupants. A new commercial building is occupied by a healthy, successful commercial organization that uses relatively more managers and skilled workers than those who are unskilled. As the building ages, it tends to house a progressively less successful enterprise with lower employment skills. In addition to the changing employment mix as the industrial building ages, there is a tendency for total employment per unit of floor space to decline. On the other hand, as residential buildings age there is a tendency for occupancy to increase as well as to shift to a lower economic category of population. One perceives then a condition where the aging of buildings in an urban area simultaneously reduces the opportunities for employment and increases the population. The average income and standard of living decline.

Figure 2 shows the same nine system levels and one of the 22 flow rates. The dotted lines are the information linkages from the system levels to control the one flow rate, here the arrival of underemployed population into the urban area. The various levels of the system combine to create a composite "attractiveness" which determines the inflow rate to the area. If the area is more attractive than those from which people might come, a net inward population flow occurs. If the area is less attractive, an outward flow dominates. Five components of attractiveness are shown in Figure 2. In the upper right corner UJM is the underemployed/job multiplier which relates the population to the available jobs and represents the income-earning attractiveness of the area. The circle UAMM generates the attractiveness created by upward economic mobility. In other words, an area with high upward economic mobility is more attractive than one offering no hope of advancement. The circle UHM relates the underemployed population to the available housing. The area becomes more attractive as housing becomes more available. UHPM represents the attractiveness of a low-cost-housing program if such exists. And in the lower right corner PEM is the influence on attractiveness of the public expenditure per capita. As per capita expenditure rises, it means better public services, better schools, and higher welfare budgets.

The concept of attractiveness is fundamental to the population flows. All of the characteristics of an area that make it attractive, these five and many more, combine to influence migration. An attractive area draws people. But almost every component of attractiveness is driven down by an increase in population. If there is an excess of housing, the area is attractive, but a rising population crowds the housing. If there is an excess of jobs, the area is attractive, but the incoming flow of people fills those jobs. In other words, migration continues until the attractiveness of the area falls and becomes equal to all other places from which people might come.

An important idea follows from examining these components of attractiveness. In a condition of population equilibrium, all areas must be equally attractive to any given population class, otherwise net migration would occur. If one component of attractiveness is increased in an area, other components must necessarily fall to establish a new equilibrium. Compensating changes in the components of attractiveness explain many past failures in our cities wherein we attempt to improve one aspect of the city only to discover that other aspects have become worse.

In making a laboratory model of a social system one should not attempt straightaway to solve a problem. Instead one should generate a model which will create the trouble symptoms. Only if one fully understands the processes whereby difficulties are created can he hope to correct the causes. This means that we want a model of an urban area which can start with empty land, grow a city, and show the processes whereby economic health falters into stagnation and decay.

As another guide to modeling, one should start, not by building a model of a particular situation, but instead should model the general class of systems under study. This may seem surprising, but the general model is simpler and initially is more informative than a model of a special case. Here we wish to model the general process of urban growth and stagnation. It should be a model which, with proper changes in parameters, is good 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 their urban processes. There are fewer concepts which are common to all than are to be found in any one. The general model can strip away the multitude of detail which confuses any one special situation. The general model identifies the central processes and is a statement of the theory for the entire class of systems.

Figure 3 shows the behavior of the laboratory model of an urban area. It presents the nine system level variables over 250 years. The first 100 years is a period of exponential growth but then the land area becomes filled, growth ceases, and the aging process begins. At year 100 near the end of the growth phase, the labor population is almost double the underemployed population. This is a healthy mix which is well matched to the job distribution in the area and which gives a high upward economic mobility to the underemployed population. But by year 150, the labor population has fallen and the underemployed population has risen until these two groups are almost equal. Business activity has declined and the area has taken on the characteristics of a depressed city. This has occurred because of the way that the industry, housing, and populations in Figure 1 have interacted with each other.

Figure 4 shows other variables during the same 250 years. Notice especially the underemployed/job ratio and the underemployed/housing ratio. During most of the first 100 years of growth these two ratios were almost constant. The underemployed/housing ratio was high (above the center of the figure) meaning that the population is large compared to the housing. In other words, during the first 100 years there was a housing shortage for the underemployed population. On the other hand, the underemployed/job ratio was low, meaning that the population was below the job opportunities, jobs were readily available, economic opportunity was good, and upward economic mobility was high. During this early period of growth and high economic activity, the underemployed population was being effectively adjusted in relation to other activity by balancing good economic opportunity against a housing shortage.

But between 90 and 140 years, notice the sharp reversal of the curves for underemployed/job ratio and underemployed/housing ratio. Within this 50-year span, the underemployed have increased while available jobs decreased; the result is a precipitous rise in unemployment. But in this same period, the housing that is aging and becoming available to the underemployed is rising even more rapidly than the underemployed population. Jobs have become scarce while housing has become surplus. The model is behaving the way our cities do.

Many people seem not to realize that the depressed areas of our cities are areas of excess housing. The economy of the area is not able to maintain all of the available housing. Because of low incomes, people crowd into some dwelling units while other buildings are abandoned, stand idle, and decay.

Recall the earlier comments about compensating movements in the components of attractiveness. Here, as housing becomes more available, jobs become more scarce. The stagnating urban area has become a social trap. Excess housing beckons people and causes inward migration until the rising population drives down the standard of living far enough to stop the population inflow. Anything which tends to raise the standard of living is defeated by a rise of population into the empty housing.

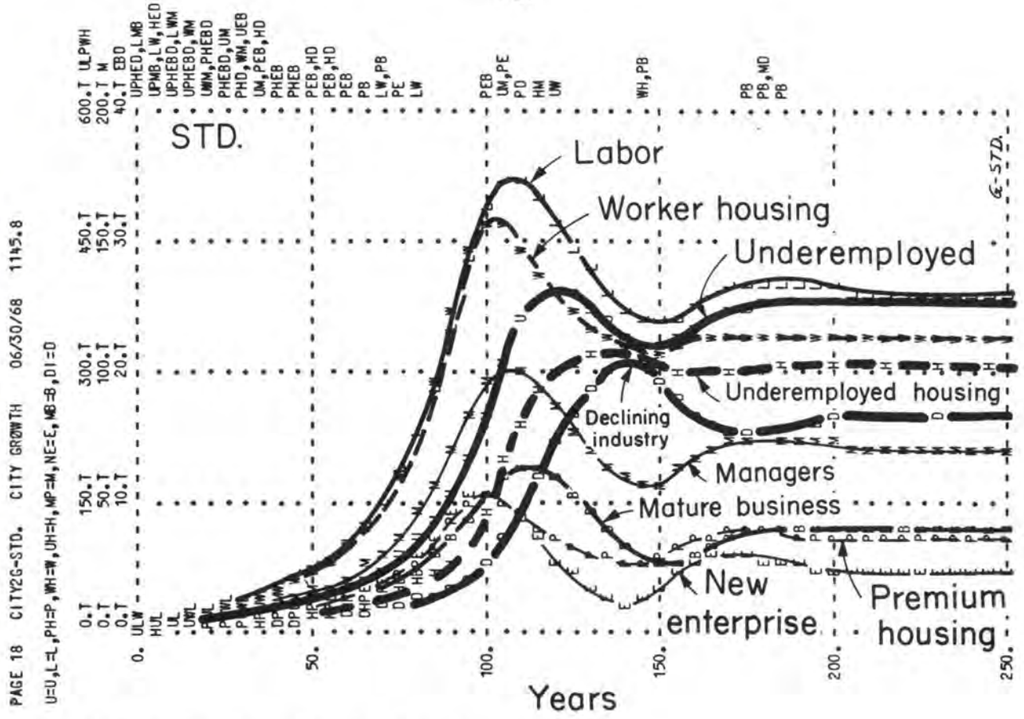

Figure 3. Growth and stagnation.

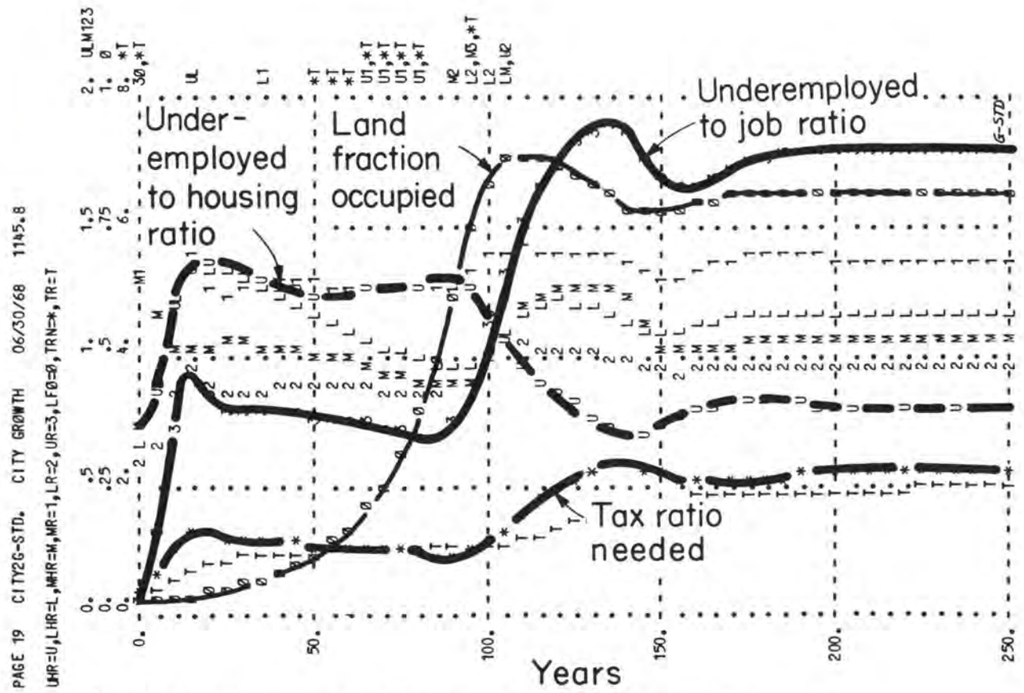

Figure 4. Compensating changes in housing and employment.

Figure 5 shows 50 years beginning with the conditions found at the end of Figure 3. At time 0, a low-cost-housing program is introduced which each year builds low-cost housing for 2.5% of the underemployed population. Observe what happens. Underemployed housing, which is being actively constructed, rises 45%, but premium housing falls 35%, and worker housing falls 30%. New enterprise declines 50% and mature business declines 45%, all in the 50-year period. Economic conditions become sufficiently worse that even the underemployed population, although it rises intially, eventually falls to slightly less than its beginning value. These changes are a result of the low-cost-housing program.

In Figure 6, the corresponding underemployed/job ratio has risen 30% indicating substantially higher unemployment while the underemployed/housing ratio has fallen 30% indicating a still higher excess of housing. Again, the two components of attractiveness compensate for one another with better housing and a falling standard of living. In the long run, the low-cost-housing program has not served the interests of the low-income residents. Instead, it has intensified the social trapping characteristic of the area. Over the period, the tax levies rise 35%. The area has become worse from almost all viewpoints.

In this same manner job training programs, job creation programs, and financial subsidies were examined. All lie between ineffective and harmful. The low-cost-housing program was the most powerful in depressing the condition of a stagnant urban area.

The depressed areas of our cities seem to be characterized by excess housing compared to jobs and by excessive concentration of low-income population. These conditions, created by aging industrial and dwelling buildings, interact to drive out the upper-income population and business activity, and to reduce the tax base. Once the decline starts, it tends to accelerate. Unless one can devise urban management policies that produce continuous renewal, difficulties are inherent.

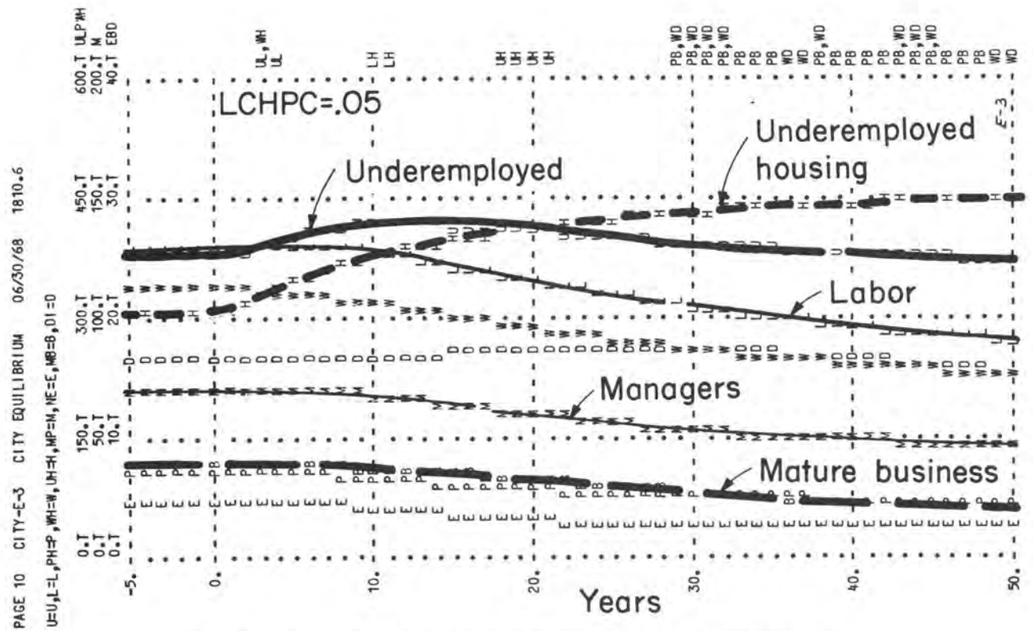

Figure 5. Decline of urban area caused by low-cost-housing construction each year for 2.5% of the underemployed.

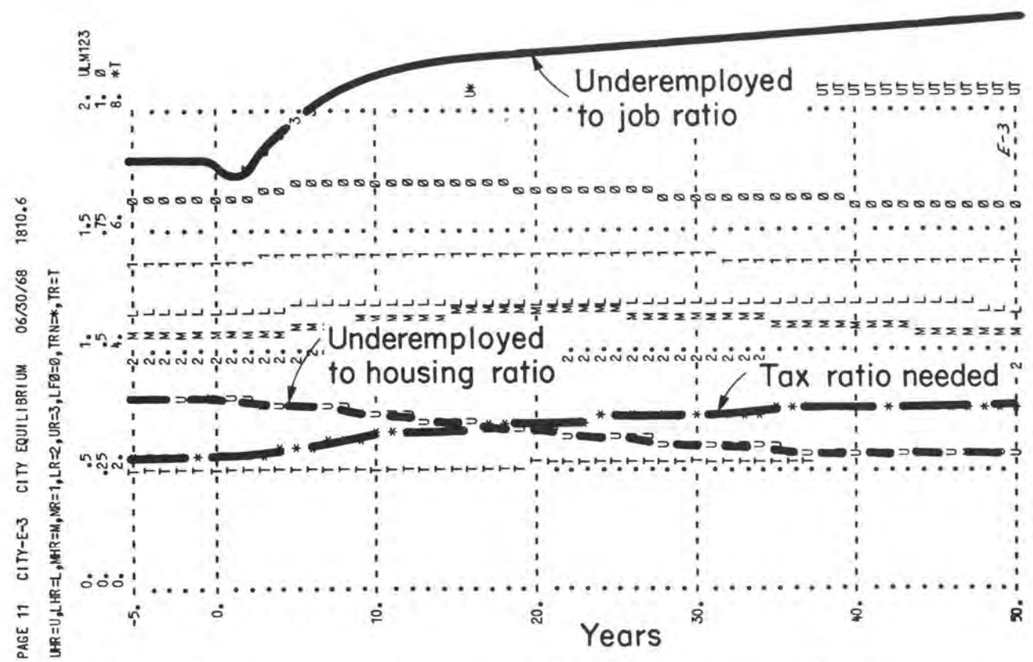

Figure 6. Rising unemployment and falling occupancy of housing.

Figure 7 shows an urban condition that begins with stagnation and then changes toward revival. Here 5% of the slum housing is removed each year and the incentives for new enterprise construction are increased somewhat. The result is a cascading of mutual interactions which raise the economic activity of the area, increase upward economic mobility for the underemployed population, and shift the population internally from the underemployed to the labor class. This is done without driving the existing low-income population out of the area. Underemployed housing is reduced. Initially this reduction comes largely from the empty housing. The resulting housing shortage restrains the population inflow which would otherwise defeat the revival of the area.

Figure 8 shows the same 50-year span as in the preceding figure. Here again, employment and housing move in opposite directions. The underemployed/job ratio falls which means more jobs and lower unemployment. On the other hand, the underemployed/housing ratio rises which means a tighter housing situation. If the economic circumstances are to be improved, we must accept some compensating change in other components of attractiveness. Here it is the increased tightness of housing which allows job opportunities to increase faster than population until a good economic balance is reached. I stress economic revival as the first stage of rebuilding a depressed area because it appears that an economic base must precede social and cultural development.

It is simply not possible to increase all of the attractiveness components of an area simultaneously. Attractiveness is here defined in a very broad sense. For example, legal restrictions like an immigration barrier into a country can produce enough "unattractiveness" to inward migration so that other components might be maintained at a high level. But wherever one component of attractiveness is high others will be found low.

Engineers, especially, should consider the compensating changes that will occur in the attractiveness components of an area because engineers tend to deal with economic considerations and technology. Economic and technical factors are more concrete than the intangible "quality of life" variables. The economic and technical aspects of a city are the ones we most easily see how to improve. Our technological society tends, therefore, to observe, react to, and improve the economic and technical aspects of a city. Such improvements increase the technical and economic components of urban attractiveness. But as a result, population density rises until the urban area once again reaches attractiveness equilibrium with its environment. The burden of forced reduction in other components of attractiveness falls on the quality of life variables—crowding, pollution, and psychological stress. These less tangible variables have been weak, hard to measure, and have been defenseless against the persuasiveness and the certainty of improvement shown by the technical and economic considerations. But we are entering a time when a reversal will occur between the formerly weak and strong variables. For a substantial fraction of our population, the standard of living is already

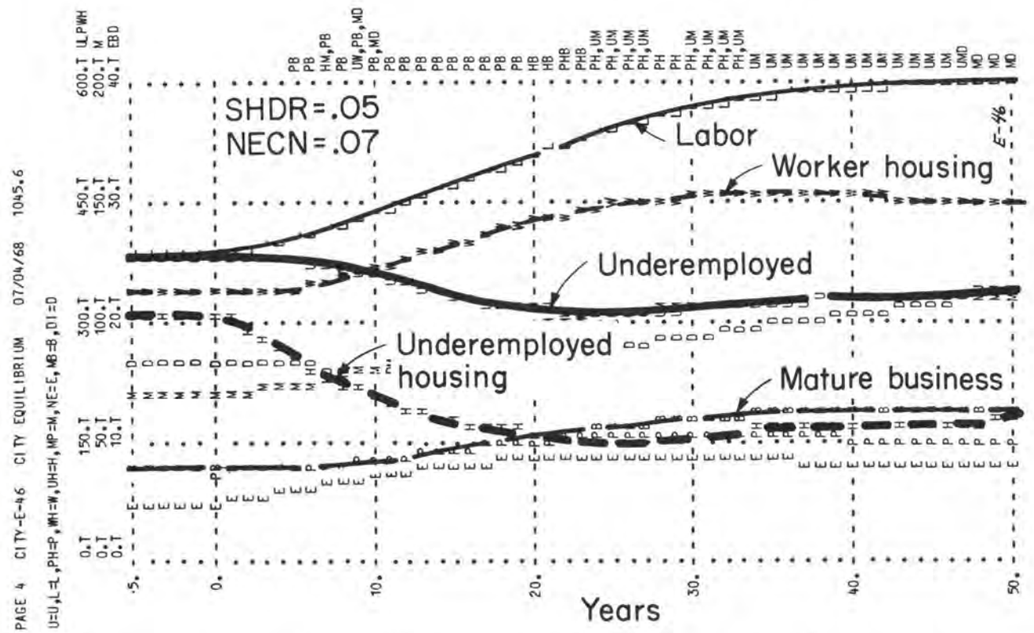

Figure 7. Revival caused by removing 5% of underemployed housing each year and encouraging business construction to generate jobs.

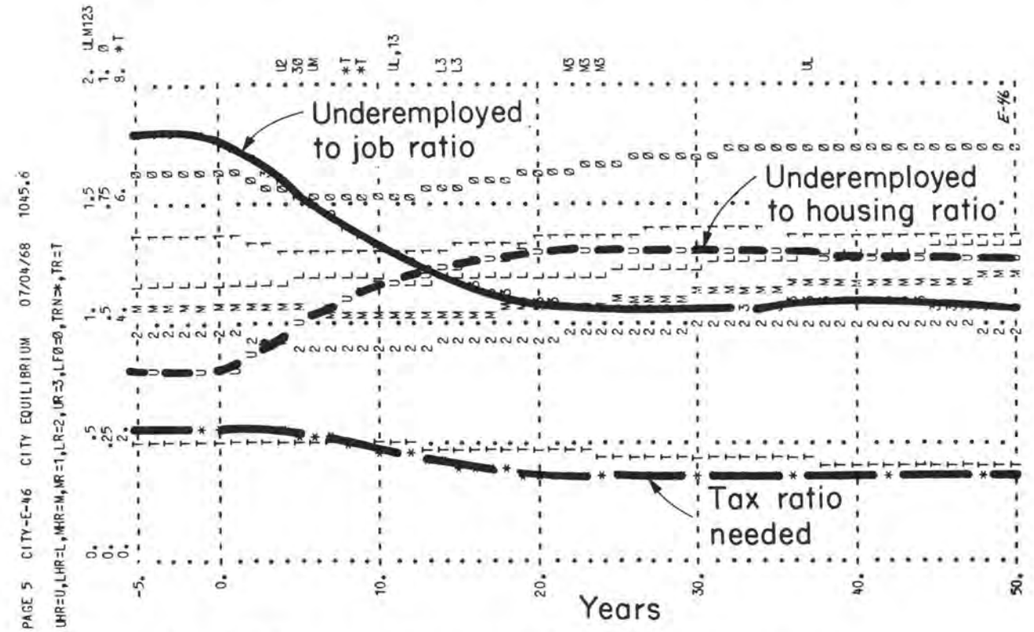

Figure 8. Falling unemployment and rise in housing occupancy.

high enough so that more gain in the economic and technical areas will come at too high a price in the quality-of-life components of our environment. The engineer, if he continues to serve society, must balance a greater number of social needs against one another. At one time his task was simply to balance financial cost against economic performance of his technology. Now the product and also the medium of payment are both expanding. Social value and quality of life become part of the product. Psychological stress, ugliness, and crowding become part of the cost. Engineers who fail to recognize this broadened role will be vilified and castigated by a society which perceives them as narrow and insensitive to the demands of the times.

When a system misbehaves, we should ask ourselves what policies within that system cause the undesirable characteristics. If we examine the laws under which a city operates, we see a structure of regulations which could hardly be better designed to create stagnation and decline. The aging and decay of buildings is central to the urban decline process, yet we see throughout our tax laws and regulations numerous incentives to keep old buildings in place. As the value of a building decreases, so do the assessed taxes. The reduced expense makes it possible to retain the old building longer. For income tax purposes under some circumstances the value of a building can be depreciated several times. This produces incentives to keep an old building in place. Here is not the place for detail, but it seems clear that a different set of tax laws and city regulations could be devised to produce the individual incentives necessary for continuous renewal. As an example, I recently saw a suggestion 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, you see, 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.

Our studies of managerial, urban, and other social systems have uncovered many general characteristics of complex systems to which we must be alert if we are to avoid continuing to create detrimental modes of behavior.

First, complex systems are counterintuitive. They behave in ways that are opposite to what most people expect. They are counterintuitive because our experience and intuition have been developed almost entirely from contact with simple systems. But 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.

Second, complex systems are strongly resistant to most policy changes. A new policy tends to warp the system so that slightly changed levels present new information to the policy points in the system. The new information, as processed through the new policies, tends to give the old results. There are inherent reasons within complex systems why so many of our attempts at correcting a city, a company, or an economy are destined to fail.

But, third, the converse is also true. There are points in systems from which favorable influence will radiate. Often these points are difficult to perceive. Often the action required is the opposite to that which might be expected. But when these points are found, they tend to radiate new information streams in such a way that the new circumstances, when processed through the old attitudes and policies, produce a new result.

Fourth, complex systems tend to counteract most active programs aimed at alleviating symptoms. For example, Chapter 4 in Urban Dynamics shows how a job training program can increase the number of underemployed in a city. When outside action tries to alter the condition of a system, the system relaxes its own internal processes aimed at the same result and throws the burden ever more onto the outside force which is attempting to produce a correction. The internal need for action is reduced and the external supplier of action must work ever harder.

Fifth, 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 often the very actions that eventually drive the system to ever-worsening performance. Short-run versus long-run reversal processes are all around us. If an agricultural country is to industrialize, it must accumulate railroads, factories, and steel mills. This capital accumulation can only be done by forgoing consumption and reducing the standard of living first in order that the standard of living may rise at a later time. If a company faces declining earnings because its products are obsolete, it must invest more heavily in product research and incur even deeper short-term losses if it is to recover in the more distant future to a profitable product stream. A student forgoes short-term earning opportunities by attending college in order to increase his longer-term earning capability. This reversal between the short run and the long run occurs repeatedly.

Sixth, a system contains internal dynamic mechanisms that produce the observed undesirable behavior. If we ignore the fundamental causes and simply try to overwhelm the symptoms, we pit two great sets of forces against one another. 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. The causes will outlast our persistence in overwhelming the symptoms. Furthermore, the internal pressures usually rise to counteract a corrective force from the outside. We can expend all 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 spontaneously moves to a new mode of behavior.

And as the last of these characteristics of complex systems, we must recognize that a certain ensemble of conditions goes with each possible mode of a system. More specifically, each mode of a system is accompanied by a set of pressures characteristic of that mode. We can not sustain a particular mode unless we are willing to accept the corresponding pressures. For example, contrast the depressed mode of a city in Figures 5 and 6 with the revived mode in Figures 7 and 8. The depressed mode is one characterized by the pressures that come from decaying buildings, low incomes, and social disorientation. But the revived mode also contains pressures. The revived mode is sustained by the housing shortage and the legal and tax pressures that generate a steady demolition and replacement of old buildings. But everyone in the system will want to alleviate the pressures. Active industry will want more employees; residents will want more floor space; and outsiders will want housing so they can move to the attractive job opportunities. Rents will be high. These pressures are easy to relieve by increasing the fraction of the land area permissible for housing, by keeping old buildings in place longer, and by allowing taller apartment buildings. But such moves will start the area back toward the depressed mode. We must decide the kind of system we want with knowledge of and acceptance of the accompanying pressures. Instead, much of our social legislation of the last several decades has consisted of trying to relieve one set of pressures after another. The result is a system mode characterized by inflexibility, conformity, crowding, frustration, supremacy of the organization over the individual, and a choking of the environment. And the resulting pressures, acting through the counterintuitive and short- versus long-term reversal characteristics of complex systems, may well move us further in the same direction.

I am suggesting that the time is approaching when we can design social systems to obtain far better behavior. Different policies could change our urban areas from ones which are designed to deteriorate into ones which are designed for self renewal. One can foresee a time when we will understand far better the relationships between monetary policy, interest rates, unemployment, and foreign exchange. Already such studies have thrown new light on the processes of corporate growth, on the reasons for product stagnation and loss of market share, and on the growth and decline of cities.

But to design new policies for social systems requires a level of skill which is rare. The kind of system modeling and policy design which I have been describing requires a professional training at least as extensive as that in any of the established professions. The proper training requires theory, laboratory, case studies, apprenticeship, and practicing experience.

But in the area of designing the dynamic behavior of social systems, there are as yet no adequate professional schools. The educational materials are still in the development stage. The few who show skill in this area have learned by apprenticeship and by trial and error.

This audience, interested as it is in the long-run improvement of society, can make its greatest contribution by encouraging research and educational programs aimed at developing a high level of talent. Again the long-run competes with the short-run. Creating educational materials and teachers will at first absorb money and talent which in the short run might instead be devoted to solving particular present social problems. Unless a proper balance is maintained, with substantial energy devoted to establishing an educational capability for enlarging the future pool of skills in social system design, the time when we can master our own systems will be further delayed.

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TOWARD A NATIONAL URBAN CONSENSUS*

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This paper proposes steps for reaching a national consensus on redirecting the forces of urban evolution. As background, it first discusses the nature of the urban system and the processes of city planning.

In Urban Dynamics* I have shown how business, housing, and people can interact to produce the growth and decline of a city. This is done by interrelating fairly noncontroversial assumptions about the urban components in a computer simulation model. The computer then shows the behavioral consequences of the social system that was described in the model. Such a computer model is based on assumptions like the ones we make in our mental models that we use for intuitive reasoning. In general it appears that such assumptions about the behavior of separate parts of a system are sound but that the human mind is poorly adapted to tracing the consequences of the assumptions. In reasoning, even from correct assumptions, we readily mislead ourselves. However, the strength of the computer is the reverse; although it can not provide the structure of a model, it can reliably and completely show the consequences of any assumed set of relationships. A new power in understanding our cities is achieved by combining newly emerging concepts of system structure and dynamics, the computer to simulate model behavior, and the knowledge of the urban components possessed by those who have experience in city living and leadership.

The method in Urban Dynamics, though not necessarily the particular model, can be used to examine the effect on a city from any proposed policy change. As seen in actual cities and also in the computer model of an urban area, the results from a policy change are often unexpected. Many past efforts to improve the city have been futile or detrimental. Unless we act to understand our social systems better, we can expect the same futility and failure in the future.

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*This discussion assumes the reader has first read my book Urban Dynamics (M.I.T. Press, Cambridge, Mass.) or at least my paper "Systems Analysis as a Tool for Urban Planning," presented at the National Academy of Engineering in Washington, D.C. on October 22, 1969.

The Nature of Urban Systems

From the study of complex systems we have learned many things:

1. The trouble symptoms of a social system (such as a city, a corporation, or a national economy) are usually produced by the interactions of obvious and well-known parts of the system. Because mental reasoning is unable to deduce dynamic behavior from a knowledge of the separate components, we fail to realize that known policies, actions, and relationships can be the cause of system malfunction.

2. Policy recommendations from model simulation are not highly sensitive to the input assumptions if those models properly reflect the structure of our actual systems. The nature of policy recommendations usually do not change when the input assumptions are changed throughout the range of our uncertainty as to their true values. But results do depend on proper modeling approaches and do depend on having the proper model structure. (See Appendix Section B.3 of Urban Dynamics.)

3. Our complex social systems do not behave in accordance with most intuitive reasoning. Very often the "corrections" we undertake to improve a system actually make matters worse. (See Chapter 4 of Urban Dynamics.)

4. Social systems are self-regulating, feedback organizations. As such, they resist efforts from the outside to change their condition. A simple example of this recalcitrant behavior is seen in a room that is too hot because the thermostat is set too high. If someone tries to cool the room by opening a window (that is, he brings in a force for change from the outside), the thermostat turns the heat higher to try to hold the room at the temperature set on the thermostat. (See Urban Dynamics Section 4.2 where job training can increase the number of underemployed, Section 4.3 where a financial subsidy to the city can increase the needed internal tax rate, and Section 5.6 where stricter standards and restrictions on middle-income housing may actually increase the amount of that housing.)

5. A policy change in a social system usually produces a short-run effect that is opposite in direction to the long-run effect. Actions that relieve immediate pressures can reverse their effect at a later time and cause even worse deterioration and stresses. (See Urban Dynamics Section 4.4 where a low-cost-housing program creates a small, brief reduction in unemployment followed by higher unemployment, or Section 4.2 where a job-training program at first reduces the number of underemployed followed by an increase.)

6. Each condition that a city may exhibit has a corresponding set of social or economic pressures. For any urban goal that a city chooses, the citizens must be prepared to live with the corresponding pressures or disadvantages. If the particular pressures are eliminated, the city shifts to a different mode with a different set of pressures. (See Section 7.5 of Urban Dynamics.)

7. The "attractiveness" of a city is a composite of dozens of factors that give a city its character. The components of attractiveness include housing, job opportunities, tax rates, public services, cultural activities, crowding, prices, pollution, accessibility, safety, location, weather, etc. (See Page 117 of Urban Dynamics.)

   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. (for example, falling job or housing availability, or rising land prices, pollution, commuting time, or crowding)

   d. Urban planning that fails to choose the negative factors that are to be used to limit population and population density will encounter unexpected negative factors being created by the dynamics of the system in response to population movement.

8. Humanitarian impulses and motives lead to actions that often have only fleeting value. Policies based on alleviating social distress often fall into the class of changes where short-term improvement is followed by long-term deterioration, even for the group that the policy change is intended to help. Many of our cities are now caught in a vicious circle of worsening troubles created by acting with the best of intent and humanitarian objectives but with results that accentuate the social trapping effect of ghetto areas, actually increase (not just move from place to place) the number of the low-income population, and reduce the chance of economic escape from poverty.

How We Have Designed Cities

Our cities have not been designed by city planners. What planner would claim to have designed Harlem in New York or Roxbury in Boston as those areas exist today? At best, urban planners launch only the initial phase in a cascade of changes through which an urban area relentlessly falls.

In a very real way, our cities are being designed by the dynamics of the urban structure itself. We have set in motion a self-directing system that is leading us into our "urban crisis." The present procedure for designing an urban system is to respond sequentially to the social pressures that develop. As each pressure arises, we attempt a direct assault on either the symptoms of difficulty or on what appears to be the immediate cause.

In searching for causes, we look close in time and location to the symptoms of difficulty. The nature of complex systems produces an apparent cause near to the symptoms. But this apparent cause is usually a coincident symptom and is not a lever through which the fundamental difficulty can be corrected. By accepting the apparent cause that the system presents, we are misled into action that merely shifts the symptoms of trouble to another point. We fail to reach the true causes that lie deeper and more remote within the system.

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

This pattern of reaction to one pressure after another is itself a system design procedure, but it is a defensive procedure. It leads to a result we do not like. We are led through a sequence that is generated by the structure and policies of the system itself. We are not working toward realizable goals that describe the best kind of city that is possible.

Unless the characteristics of complex systems become understood and recognized in city planning and in our national attitude toward the urban situation, those plans will fail. Most city development plans and national actions violate one or more of the requirements imposed by the fundamental dynamic nature of an urban system. By attempting the impossible, by adopting policies that have the reverse of the intended effect, by seeking utopia with means that produce disaster, and by attacking the very pressures that must accompany desired urban behavior, we sustain the national frustration while the urban crisis worsens.

In stressing the reasons for having arrived at our present urban dilemma, I do not imply either incompetence or lack of good intent on the part of past urban leaders. Our social systems are so complex and are of such a nature and structure that there has been almost no possibility that effective policies could have been established by judgement, argument, and compromise. Even a person well trained in the dynamics of complex systems does not correctly anticipate the behavior of even a laboratory model system although he may have complete knowledge of the structure and policies of the model. Only by going

through extensive computer simulation (that is, examination of the system in the laboratory under a variety of circumstances) does he develop insights about how the components of the system interact.

Defects in Current Urban Proposals

The following observations about the current urban condition sets the stage for discussing future directions:

1. The search for more money dominates almost all discussion of the "urban crisis." But no one stops to explain why we have a system that demands ever more outside support. At one time cities served themselves and the surrounding countryside. There are indications that more money will at best postpone the day when the fundamental causes of urban decline must be faced; at worst, more money can hasten the decline. For example, if traffic delays justify money for central arteries, that increase traffic, that require more parking garages, that bring in more people, that force up building heights, that produce more traffic, that cause traffic delays, we find "the faster we run, the behinder we get." Any tracing of proposed uses of more money brings us into such circular processes. Money from the outside is probably not a solution except under the impossible conditions of an ever-increasing rate of outside subsidy that can keep ahead of the further demands that the subsidy itself creates. We built our cities in the first place by internal economic processes, why do we believe it is impossible to maintain them? There are indications that cities would revive by themselves and be self-sustaining if we eliminate the positive incentives that cause decline.

2. The desperate effort to raise more money is leading to actions that are self-defeating even from the monetary viewpoint. Graduated state income tax, payroll tax, tax on improvements rather than land, the shift of tax from persons to business, and similar proposals, penalize the most mobile parts of the urban community. The result is a selective process that draws to the central city those people and activities that are not self-supporting and repels those people and activities that are most needed to maintain a heterogeneous community, social stability, and economic vitality. This destructive process is widely recognized, but the short-term pressures are thought to be so high that little is done to get off the declining spiral.

3. By reaching beyond the city for suburban and state tax support to compensate for the ill-advised policies that govern our urban areas, we are on the verge of converting whole states to the "urban crisis." The Northeast quadrant of the United States is especially vulnerable. This is the old industrial sector. Within the boundary connecting Milwaukee, St. Louis, Washington, Boston, Buffalo, Detroit and Milwaukee, lie the

oldest buildings in the country. Here are concentrated the declining areas. This entire area is showing "urban decline" symptoms. The other three quadrants of the United States are acting as the "suburbs" to this old industrial quadrant. As buildings age and taxes rise, the more mobile and more economically effective segments of business and population are moving to the "suburban" three quadrants of the country. The South and West are showing much more rapid economic growth than the Northeast. The "urban decline" spiral then begins to appear as low-income population concentrates in the Northeast quadrant to take the place of those who are moving away. Costs and taxes rise further, the population mix continues to shift in an unfavorable direction and more forcefully drives out those who have mobility.

4. As cities grow and become congested, it appears that total "overhead" costs are growing disproportionately. We should examine optimum size, design, and distribution of activities within a city. It is possible that the trend toward increasing the boundaries of metropolitan government should be reversed.

5. We seem to be in a cycle where communities disintegrate, crime rises, more police protection is required, but more police remove the need for community self-discipline and indirectly cause more crime. The hypotheses about these social cycles need to be modeled to see which assumptions agree with the observed behavior.

6. The demands for expanded metropolitan government should be questioned. Why do we want larger urban governments? Are the biggest cities free of problems? Is an extended urban boundary a solution to anything? Probably only in the short run. Annexing a suburb which has not yet started its economic decline may give a momentary boost to the tax base, but the action may hasten the decline of the annexed area and enlarge the area of urban blight. Metropolitan water districts and other self-supporting organizations that sell their services at full cost are probably necessary and not to be confused with expansion of city government. With larger government goes public futility, frustration and indifference, all of which become more debilitating with time.

Urban Goals

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. We must think that far ahead because the institutions, buildings, services, facilities and populations now being established will last that long.

Most organizations, be they corporations or 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 subscribe to all conceivable goals. But if separate steps are taken toward goals that are incompatible, the result may be failure in all of the 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 can not be better than its environment in every respect. Try to imagine a city that has less crowding and pollution, more jobs and housing, higher wages, lower rents, and finer amenities than its environment. What happens? People move in until prices rise or the urban system becomes so overloaded that it is no longer superior.

The "attractiveness principle" (see Urban Dynamics, page 117) asserts that if one aspect of a city is improved, another must and will decline. Each improvement will carry with it a negative compensation. I have seen no master plan that specifies the disadvantages that will be made severe enough to control population and population density to compensate for proposed improvements.

The current crop of plans for cities will not alleviate the urban difficulties. They will fail at one of two stages. First, most of them depend on huge infusions of money, money which will probably not be available, so the plans fail by not being implemented. Second, if such a plan is implemented, it will not be dynamically sound. It does not contain the necessary negative counterbalances to the proposed improvements and so the urban system will generate unfavorable factors in unexpected directions. The utopian plans are not viable and contain the mechanisms for their own destruction.

Directions for Thinking

If the troubles in a social system are created by its internal structure and policies (laws, tax regulations, zoning, etc.) and if external forces to correct the symptoms will usually be defeated, it means that the salvation of the city must originate from the inside. If forces for internal revival are to be established we must reverse our thinking in several crucial areas.

1. Money. Emphasis should be shifted away from money as the cure-all. In demanding more money as the solution to urban problems, people overlook the fundamental dynamic process now at work in the city. That process: as the city expenditures rise they reduce the pressures for fundamental solutions and allow the underlying causes to generate further demands to match the growing expenditures. In other words, the basic control process is for demands to rise to meet the available revenues. Is it not curious that all of the older cities are in approximately the same degree of difficulty regardless of their physical size or the magnitudes of their budgets? None are amply funded. None are conspicuously more desperate than the others. There must be a reason for this uniformity of distress that is independent of the size of the budget. The answer is that the problems and the budget grow hand in hand, neither can outrun the other. If the revenue resources get ahead,

they are spent in such a way that they generate matching problems. If the troubles get ahead, the pressures rise to increase revenue, or fundamental steps are taken to alleviate underlying causes, or enough population moves elsewhere to reduce the pressures within the particular system. Perhaps the quickest way to force a recognition and correction of the fundamental causes of urban decay would be to remove all expectation of future financial assistance to the cities by state and federal governments. The trend toward interpreting urban problems as a financial demand on higher levels of government must be reversed. Higher levels of government can be most effective in exerting pressures for local action and by altering the tax policies that encourage the perpetuation of old buildings in declining urban areas and by reversing the policies that favor housing over jobs so that residential construction will no longer rise beyond the economic population-supporting capacity of the area.

2. Tax Laws. The property and income tax laws favor old buildings. The aging of buildings is an intimate part of the urban decline process. Shifting taxes off from real estate and onto incomes means that the old buildings and the land they occupy need not be used effectively and can be allowed to decay with little tax penalty. Real estate taxation proportional to market value means that taxes decline as the property ages. This reduces the pressure for replacement of buildings. The income tax laws allow a building to be depreciated several times against current income, this gives an old building value and helps to keep it in place until it contributes to urban decline.

3. Population Density. Population densities in both residential and commercial zones are allowed to rise in response to the fallacious argument that rising land prices require more intense use. But land prices reflect the permitted use. Under rigid zoning, with no hope of relaxing the restrictions, land prices could not rise too high for the allowed use. But instead, we allow a land-price-population-density spiral to continue until excessive loads are thrown onto transportation, pollution, and psychological trauma, and other factors of the urban environment.

4. Zoning. Zoning has in the past divided land into blocks that are too large and too homogeneous. A large area with housing built all at one time and of a similar quality deteriorates as a whole into a substandard condition. If such an area is large enough, it is avoided by new construction and becomes a slum.

   Zoning also allocates too much area for residential use and not enough for industry; this is especially critical when the area begins to age with the concurrent decline of employment and increase of population. The ratio of residence to industry was satisfactory when the area was first being developed but becomes imbalanced with age. Unless there is rezoning to reduce residence

and increase industry, or unless land is held empty initially for later commercial use, the aging area lacks economic vitality to maintain all of its housing stock and the area begins to deteriorate.

The failure to zone so that only forest and agriculture are allowed in rural areas immediately adjacent to urban areas permits urban sprawl to develop and removes the necessity to rebuild and reuse the aging urban areas. Old areas are abandoned rather than being revived. This is a direct result of the ease and the lack of legal restrictions in moving onto nearby empty land. The ecological balance between city and agricultural land is destroyed at the same time that the old city is left to deteriorate. A sharp contrast is shown by cities like Copenhagen, Denmark, where open fields lie across a street from multi-story apartments. The reluctance to rezone farm land into city land keeps the expansion pressures within the city itself and forces maintenance and renovation of old structures and sustains their effective use until they are replaced.

5. Selected Stresses. As discussed in Urban Dynamics (Sec. 7.5) each mode of behavior of an urban area will exhibit characteristic pressures. We must cherish and preserve the pressures that go with the chosen style of urban environment. To alleviate those pressures means that the area shifts to a different mode with a change in character and style and a different set of pressures.

6. Realistic Goals. We must contemplate realistic urban goals that include negative forces powerful enough to limit population and population density. These might be ensembles of policies that can maintain high prices of land and rents, or a housing shortage, or a job shortage (that is, the unfortunate control in present ghetto areas), or limited transportation, or limited land area that does not communicate with other areas, or zoning to control density, or a bad array of "quality of life" conditions. The kind of control will determine the character of the city. We should consider the possible kinds of cities having different characters.

Next Steps

The ideas emerging from dynamic studies of urban systems are so contrary to contemporary thought that they will be accepted only after extensive examination. On the other hand, if they are right, we must not continue along past directions. The Urban Dynamics book has already led enough people to doubt the wisdom of present urban policies that a far more serious reexamination of the issues becomes an obligation.

It is now time to clarify further the urban process and to move toward a national urban consensus. Urban Dynamics may provide the basis. Three steps appear necessary--extending and completing the dynamic studies; interpreting the studies into legal and tax changes; and educating an initial group large enough to maintain momentum toward a change in national attitudes.

First, comments and criticism of the urban dynamics work to date must be carefully solicited and evaluated. Valid suggestions must be incorporated and made a part of the program. Doubts that are not relevant or useful must be explained and dispelled. Other aspects of the urban situation must be examined. New models of social behavior may be needed. For example, the forces, pressures and motivations in the welfare system should be treated in the same way that Urban Dynamics treats the housing-job-population structure. In the welfare substructure we may find that the welfare system is creating the welfare cases and may discover that the welfare system is an active part of the social trap that keeps people from becoming self-supporting. Various cities, especially those that appear different from one another in character, should be compared with the urban dynamics findings as a further test of the newly developing urban theory. The additional results must be made available in journal articles and books.

Second, the general directions for change must be interpreted into specific proposals for action. These will be recommendations for modifying state constitutions and laws, city ordinances, real estate and income tax regulations, and national laws and administrative procedures. This step will require participation by lawyers, real estate advisors, tax consultants and others with first-hand knowledge of how the present social-legal structure motivates people to make decisions that are detrimental to the urban system. This phase would develop specific recommendations for the minimum necessary changes in the tax and legal structure of the country.

Third, the tentative proposals would be exposed to selected people. The participants, perhaps some 500, would be chosen to represent the many viewpoints which must be reconciled in altering our urban social structure. This exposure would be intensive, consisting of documents to read in advance followed by a one-week series of discussions and seminars conducted in small groups. The purpose would be twofold. First, the comments and reactions would be used to further refine the proposals. Second, the participants should become a cadre of informed proponents who could provide leadership for changing the national attitude toward our cities.

In recommending steps toward a sound national urban policy, we must face the question of city goals and master plans. We will need to clarify the nature of such plans and the conditions necessary to make them achievable. We should deal more fully with the concept of "urban attractiveness" and the assertion that each urban improvement carries with it somewhere a compensating disadvantage. We should then identify the sets of attractiveness-unattractiveness ensembles that look reasonable and possible and that could serve as goals between which cities might choose. In doing so we would be discovering the different characters and atmospheres that a city might have and how to maintain the style, traditions, and quality of life that could distinguish one city from another.

[From Finance magazine, July 1970]

A New Approach to Economic Analysis

SOCIAL SYSTEMS DYNAMICS, DEVELOPED BY MIT PROF. JAY FORRESTER AND USED THUS FAR ON URBAN PROBLEMS, IS NOW AT A STAGE WHERE IT COULD FOCUS ON FISCAL AND MONETARY POLICIES AND THEIR RELATIONSHIPS TO THE BUSINESS CYCLE

(By Michael Christopher)

Engineers for decades have come forward with what seem to be straightforward solutions to economic ills. The logic of their vocation has lent itself easily to the problems of society. As applied scientists, they considered themselves both scientific and practical.

The trouble with nearly all of the engineering solutions was that they didn't work. They neglected too many factors, overlooked people's psychological and behavioral patterns, and often showed an ignorance of economics. Engineering theories about business cycles were woefully inadequate, with giant gaps in their conceptions of unemployment, price setting, monetary policy, competition, Government spending and taxation.

The engineers who worked up these theories sometimes gathered a small following, much like some religious sects, but more often spent their energies in "misunderstood" isolation.

Now comes one who may have made the successful crossing from physical science to social science, combining the two into a new integrated whole. He is Dr. Jay W. Forrester, a professor of management at Massachusetts Institute of Technology. His credentials as an engineer are impeccable. His work as a social scientist is unusual and challenging, and promises to build a momentum that could sweep aside whole bodies of thought. Widely held assumptions are opened to question. Accepted notions of economic relationships are likely to be shaken.

Dr. Forrester sees his field as the dynamics of social systems. His concepts and approach span the entire range from small groups to international affairs. Over the last 15 years, he and his associates at MIT have been expanding their horizons. First applications were to corporate policy and the way policies, information sources and organization produce growth, stability and market share behavior of a corporation. More recently, they have attracted attention by their exploration of the life cycle of a city and the causes of urban decay.

Professor Forrester believes his method has now reached a state of development where it could zero in on the whole structure of fiscal and monetary policies and their relationships to the business cycle.

He suspects that there are many wrong conclusions floating around in the heads of decision makers. Their ideas of how to correct imbalances in the economy may actually be helping to make the imbalances worse. Instead of reducing unemployment, they may tend to increase it. Instead of fostering economic growth, they may tend to stifle it.

Dr. Forrester would start with all the assumptions that decision makers make and then carry them out to their final result after letting them interact against each other. He calls this approach "social systems dynamics." It becomes feasible through the use of computers, which can compress the outcome of years of interactions into a span of minutes.

At the heart of the Forrester approach is the feedback loop. This is an old concept in physics and engineering, but one that has not before been adequately applied in the social sciences. A feedback loop is a group of activities influenced by their own past behaviors. Previous actions generate future actions.

NEGATIVE FEEDBACK

An example is the heating system of a house. If the temperature falls sufficiently, it closes the thermostat and the furnace turns on. This cycle repeats itself in a circular manner, forming a closed system. It is a "negative feedback" system because it aims at achieving a particular goal, a given temperature. It is self-controlling.

Every decision is made in the context of a feedback loop. The decision controls an action that changes the surrounding situations that supply new information to control future decisions. For example, one's state of tiredness is the information input to control the time spent sleeping which changes the state of being tired.

Or a corporation borrows money which changes its debt position which affects its future freedom to borrow.

Feedback loops govern all systems that change through time. Feedback loops determine equilibrium conditions, they cause instability, and they control growth.

Positive feedback loops cause growth; an example might be a pair of rabbits.

As they multiply, each generation will produce more rabbits at an increasing rate. Unless an external element is added, such as predators or a limitation on living area or food supply, there will be no end to the multiplication, which will continue geometrically.

Likewise, economic growth arises from positive feedback structures in our socio-monetary system. For example, investment generates production to create income, part of which becomes further investment.

But positive feedback would eventually lead to the impossible condition of growth without limit. Negative feedback (or goal-seeking) loops always enter to halt growth and establish an equilibrium. According to Dr. Forrester, the great stresses in our social systems often arise from the forces that suppress growth and trigger the transition to equilibrium.

Negative feedback systems, which adjust toward goals, can be unstable as they fluctuate back and forth in search of the goals. They may undercorrect or overcorrect much like a drunk trying to get a key into a keyhole or like a gasoline engine that runs at an unsteady speed because of a defective governor.

Examples of negative feedback systems in the economy would be the rise and fall of commodity prices as supply and demand move around each other, or the variations in industrial production.

Because the economy has so many feedback loops, or functions that interact upon each other, it is a tremendously complex system.

Complex systems, in many ways, behave the opposite of simple systems, but human judgment and intuition have been formed mostly from experience with simple systems. People are therefore led. Dr. Forrester says, into a mental framework that causes them to take counter-productive actions when they attempt to modify our complex social systems.

Dr. Forrester's approach is to construct a computer model of a social system so that the system can be observed and experiments can be tried in changing its governing policies. But the models have a very different structure from those now common in economic modeling.

Forrester's models are also very different in the source information from which they are created. Most past economic models have been created from statistical economic data and historical time series. But this ignores the wealth of information available in the operating arena. It fails to incorporate the interactions of the psychological, technological, political and humanistic aspects with the purely economic aspects.

Forrester starts from the other end. He asserts that all managerial and political decisions are already made on the basis of models—the mental models in the heads of managers, political leaders, and the public.

"We must developed new appreciation of the strengths and weaknesses of the mental models so that we can use their strengths and compensate for their weaknesses," Forrester says. He believes, contrary to the opinion of many social scientists, that most people are adequately reliable observers of their immediate environment. They are aware of their goals, the pressures under which they operate, their fears and the reasons for their decisions.

In short, their perceptions, after contradictions have been resolved and irrelevant material discarded, are the best raw material from which to construct models. Far more useful information is available from operators in the social system than exists in the combination of textbooks, periodical literature and statistics, Forrester believes.

HUMAN RELIABILITY

But here the reliability of the human input stops. A person can see correctly the behavior at each point in a social system and be completely wrong in what the system as a whole will do. But the computer model can compensate for the human weakness. The computer model can take the assumptions about the parts, combine them, and demonstrate without doubt, the resulting consequences, Forrester says. He feels he is combining the best of both the human and computer capabilities.

This, says Dr. Forrester, is the essence of the problem because "mental models of dynamic systems cannot be manipulated effectively. We often draw the wrong conclusions about system behavior, even if we start with a correct model of the system."

Inability to mentally manage the various pieces of a complex system leads to a natural tendency to deal with them individually. Conclusions reached about any of the subsystems do not show how they interact.

To take a more complicated example, economists and Government policymakers have theories about how a change in interest rates will affect business expansion and the supply of new housing. But they don't know how the supply of housing might affect business expansion by changing the flow of labor into certain areas, and perhaps even the flow of skills. This example can be made even more complicated by adding feedback loops for inventory decisions, marketing efforts, Government financing, money supply, accumulated corporate earnings, and any number of other real-life factors that play a role in the ups and downs of the business cycle.

Dr. Forrester's training makes him an expert on the possibilities of the computer, and its shortcomings. He was, from 1940 to 1956, not only an electrical engineer but a leader in the design and application of large-scale digital computers. He holds the basic patent on the memory device used in most of them. He guided the planning and technical design of the Air Force SAGE system for continental air defense, which is founded on computer techniques.

As to being an economist, Dr. Forrester makes no claims even though he is a member of the American Economic Association. He also is a member of the Academy of Management and the American Physical Society.

He does, however, claim to be a diagnostician. He can take apart a problem and break it down into its components. With the help of experts in their fields, he can identify the working parts of a system and how they are supposed to react with each other. It makes no difference whether the field is corporate management, medicine, ecology, crime or national economics.

Dr. Forrester asserts that any complex system can be programmed by identifying the parts and their relationships. More importantly, he concludes that the interactions are likely to produce results that are contrary to commonly accepted conceptions.

To prove his thesis and lay the groundwork for its applications in any field, Dr. Forrester did a major study of the crisis of the cities. It was published last year as a book, *Urban Dynamics*, by the MIT Press. The method was to sit down with John Collins, former mayor of Boston, and others who had practical experience in urban affairs and discuss the issues.

In Dr. Forrester's words, "I approached these discussions knowing the conceptual nature of the structure being sought, but not the specific details of the structure or the institutional components of behavior to be fitted into it. The others brought the knowledge of the pressures, motivations, relationships, reactions, and historical incidents needed to shape the theory and structure of the specific social system."

PROTEST RAISED

His conclusions raised a storm of protest, for they went counter to the notions of most social theorists. For one thing, the analysis suggested that programs to build new low-cost housing for overcrowded low-income tenants are likely to heighten the problems of unemployment and urban deterioration in the long run even though they are a short-run palliative. This happens because the programs attract an additional low-income population from other areas, raise the unemployment level, generate new welfare pressures, boost taxes, drive out middle-income residents, and cause industry to relocate.

Liberals accused Dr. Forrester of being a reactionary. On the other hand, because he suggested setting long-range social goals and then adjusting the systems to achieve them, conservatives called him a radical. But after sitting down and going through his work, opponents on both sides are gradually becoming converts.

Indeed, Dr. Forrester remarks in his book that "the intuitive solutions to the problems of complex social systems will be wrong most of the time." He emphasizes that solutions to social problems are usually designed to dispel symptoms. But the underlying causes remain. The therapy is either of no value or actually harmful.

He elaborates the point: "A particular change in policy may improve matters for a period of a year or two while setting the stage for changes that lower performance or desirability further in the future. But the natural interpretation is to observe that good resulted from the change and when matters become worse the original efforts are redoubled."

This thinking is slowly finding support. Ghetto leaders, politicians and businessmen are showing interest in exploring it further and applying it to particular cities. It could revolutionize current views about urban development. But it also will upset many long-standing theories, and long-standing theories die hard. Those who hold them have too much invested to give in easily.

Dr. Forrester acknowledges the possibility that his next assault might be on the fiscal-monetary front. It will depend on the degree of interest and participation from those working in the field. His method will be the same. He doesn't know what's wrong with the present techniques of managing the economy, only that something is wrong. That's clear from simple observation.

By sitting down with knowledgeable men in the field, such as Federal Reserve officials and leading bankers, businessmen, and Government people, he would expect to isolate the components of the system. The aim would be to get basic agreement on why actions are taken and what consequences they are expected to have. The model that is set up as a product of these discussions would incorporate the assumptions laid down by the participants, on its components and how they interact.

If Dr. Forrester is right in his expectations, the computerized output will show some surprising results about what really happens in the economy after various Government spending, taxing and money policies are adopted. They might be far different from what the policymakers think happens.

(Whereupon, at 12:15 p.m., the subcommittee adjourned, to reconvene subject to the call of the Chair.)

Correction to Page 226

As originally printed, the figures in point 6 on p. 226 are in error and should read as follows:

> The pollution and natural resource load placed on the world environmental system by each person in an advanced country is probably 10 to 20 times greater than the load now generated by a person in an underdeveloped country. With four times as much population in the underdeveloped countries as in the present developed countries, their rising to the economic level of the United States could mean an increase of 10 times in the natural resource and pollution load on the world environment.

BEHAVIORAL AND SOCIAL SCIENCE RESEARCH IN THE DEPARTMENT OF DEFENSE:

A FRAMEWORK FOR MANAGEMENT

Report of the

ADVISORY COMMITTEE ON THE MANAGEMENT OF BEHAVIORAL SCIENCE RESEARCH

IN THE DEPARTMENT OF DEFENSE

Division of Behavioral Sciences

National Research Council - National Academy of Sciences

1971

FOREWORD

The roots of this Advisory Committee's report are to be traced to the establishment of the Advisory Committee on Government Programs in the Behavioral Sciences by the National Academy of Sciences late in 1965. Its work, supported in part by the Department of Defense, resulted in the publication of *The Behavioral Sciences and the Federal Government* in 1968. This report led the Department of Defense to request the Academy the following year to provide advice on how its research programs in the behavioral and social sciences could best be organized and managed. An Advisory Committee on the Management of Behavioral Science Research in the Department of Defense, under the Division of Behavioral Sciences of the National Research Council, was established in the spring of 1969 to undertake this task.

The Executive Committee of the Division of Behavioral Sciences and the Advisory Committee were fully aware of the controversial issues embedded in the task of advising on the management of behavioral science research in the Department of Defense, as well as of the different ways in which it might be approached. In the course of our deliberations the controversies over these issues sharpened and their substance became increasingly a matter of public, and often prickly, debate in the Congress, the academic world, and in other quarters.

By intention, different perspectives on both the critical questions to be addressed and how they should be answered were brought into the Advisory Committee through the selection of its

members. Moreover, we differed among us in our knowledge of and our experience working in or for the Department of Defense or other national security agencies. Some of us had had no past connection with the Defense Department.

The members of the Advisory Committee could have been tempted by the numerous opportunities they encountered for developing irreconcilable positions. As Chairman, consequently, I must congratulate them publicly on their determination to fashion a single framework for viewing and analyzing the cluster of difficult problems associated with the management of behavioral and social science research not only in the Department of Defense but also for the national security community as a whole. The perspective and set of guidelines offered in this report for research management on different levels of the Department of Defense have the endorsement of every member of the Advisory Committee. Moreover, every member approves of the specific recommendations we have set forth. These achievements would not have been possible, I should note, if one of our members, Michael D. Reagan, had not undertaken to draft the document that served as the basis for this report. To him we owe and are happy to acknowledge a special debt of gratitude. I must add, however, that I do not wish to give the impression that each of us necessarily subscribes fully to every shade of meaning or emphasis that can be found in this report.

We are also indebted to others. I am pleased to acknowledge the Committee's gratitude for the valuable contributions made to its work by its Executive Secretary, Albert H. Cantril, Jr., who prepared early working drafts for a report, and by Nancy I. Groves,

who carried the secretarial burdens. Peter N. Gillingham, Charles M. Herzfeld, and Bromley K. Smith, as well as others, contributed advice and assistance. So, too, did members of the staff of the Division of Behavioral Sciences: Alexander L. Clark, Vincent P. Rock, and Henry David, the Executive Secretary of the Division, who has served us well beyond the requirements of his office. I must acknowledge also the contributions made to the Advisory Committee's work through the rigorous review of an earlier draft report undertaken by the Chairman of the Division of Behavioral Sciences, Herbert A. Simon, and the members of its Executive Committee. Finally, I should note that we were fortunate in having Davis B. Bobrow, then special assistant in the Office of the Director of Defense Research and Engineering, serve as staff liaison to the Advisory Committee from the Department of Defense.

William W. Kaufmann

Chairman

February, 1971

ADVISORY COMMITTEE ON THE MANAGEMENT OF BEHAVIORAL SCIENCE RESEARCH IN THE DEPARTMENT OF DEFENSE

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Dr. Robert Bierstedt, Department of Sociology, New York University

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Dr. Michael D. Reagan, Chairman of the Department of Political Science, University of California at Riverside

Dr. S. Rains Wallace, Chairman, Department of Psychology, Ohio State University

Dr. Eugene J. Webb, Graduate School of Business, Stanford University

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RECOMMENDATIONS AND FINDINGS

The Advisory Committee recommends that--

- The Department of Defense should actively seek the transfer of responsibility for the support and management of foreign area research, and it should strongly endorse the creation of a government-wide institutional structure--to which it would have access and in which it would have a chance to voice its informational needs--in which this responsibility should be lodged.

- The Department of Defense give concentrated attention to the development of a first-rate in-house social and behavioral science capability, both for conducting pilot studies and for monitoring external research.

- The national security agencies jointly establish a task force on social and behavioral science research priorities in the area of national security policy.

- The Department of Defense make a deliberate decision to multiply several times over the amount of funding available to the social and behavioral sciences under the 6.3 - 6.5 research program levels.

- The Department of Defense, in order to bring about a more effective managerial relationship between the producers and consumers of research:

    1. assign formal responsibility for research allocation and supervisory functions among the major consumer offices in the Department of Defense, such as International Security Affairs, Installations and Logistics, and Manpower and Reserve Affairs, as well as to the Advanced Research Projects Agency; or, alternatively, give each of the major consumer offices a role in requesting and sponsoring research, similar to the role performed by the services, under the oversight of the Director of Defense Research and Engineering

    2. upgrade the research bureaus within the principal offices of the Secretary of Defense by giving the bureau chief a super-grade status, provided that individuals meriting this grade can be found

3. provide funds for retrospective studies in the social and behavioral sciences designed to establish the relationship, if any, between basic research and programmatically useful results

4. allocate funds for evaluative studies of on-going programs that allow for the questioning of policy assumptions and the proposal of programs alternative to those under analysis, in order to suggest how programs might be modified in the future

5. create an internal research information retrieval system designed not only to prevent the "loss" of previous research but also to compensate for the compartmentalization that exists within the Department

6. provide more precise formulations of Department of Defense research needs and work toward better anticipation of those needs, so that potential contractors for research will have adequate time for the preparation of proposals

▲ The Department of Defense bring to the attention of other agencies with similar needs for a policy-research interface the desirability of and opportunities for encouraging the development of applied social and behavioral scientists.

The Advisory Committee finds that--

▲ A national security policy process informed by first-rate research and assuring clear communication between policymakers and researchers deserves encouragement, and that to ensure the responsiveness of behavioral and social science research to the needs of the national security community, it will be necessary to achieve four objectives: (1) the improved overview and coordination of agency research programs; (2) the conduct of targeted research on specific problems of concern to the national security community as a whole; (3) the development of an effective information system; and (4) the provision of an expanded policy analysis capability at the Presidential level.

I. *Introduction*

In the relationship of the federal government to scientific research, the role of the social and behavioral sciences has been causing increasing concern in the past three or four years. This is partly a reflection of a larger problem in the government-academic relationship and partly a simple matter of growth in the volume of research in these fields supported by federal departments and agencies. Even more important, it is a result of differing expectations regarding the potential contributions of the social and behavioral sciences held by their practitioners and by government officials. At least some social scientists want recognition in such forms as greater representation on the President's Science Advisory Committee, and implicitly claim that, merely by being brought into decision-making processes more frequently and at higher levels, they will necessarily make useful contributions. Government officials, on the other hand, want the behavioral and social sciences to prove their utility, about which the greatest skepticism is, perhaps, found in agencies that have the least well-developed relationships with these sciences, as, for example, the Bureau of Public Roads or the Federal Bureau of Investigation.

The Department of Defense accounts for approximately half of the total federal funds for all research and development. However, it does not loom nearly so large with regard to the social and behavioral sciences, accounting for only about 11 percent of federal funds for research in these disciplines in fiscal year 1970. Of the Department's total research and development budget of approximately $7.5

billion for that year, the behavioral and social science segment is approximately $37 million, or only one-half of one percent. Quantitative proportions and policy significance are not, however, inevitably correlated, as a very large amount of concern over the social science research operations of the Department of Defense has recently evidenced.

The relationship between the federal government and the social sciences generally and historically, while substantial in scope, has not been altogether harmonious. The quality of the relationship has been well expressed in the title of an excellent historical account by Gene M. Lyons.* An inherently difficult relationship has had its frictions greatly exacerbated, of course, by the Vietnam war and the widespread alienation that war has caused, especially in the intellectual community. Sponsorship of scientific research by the Department of Defense, whether in the physical, biological, or social sciences, has been a major source of tension and turmoil on college and university campuses. Concern has been expressed that the sources of independent criticism represented by the universities may dry up as a result of federal subvention. Further, there has recently emerged a rapidly growing concern over the scope of Department of Defense research. Specifically, it has been charged that the Department is not bound by a sufficiently narrow definition of military affairs, and is too much engaged in broad foreign policy matters that are more properly the province of the Department of State.

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* The Uneasy Partnership: Social Science and the Federal Government in the Twentieth Century. (New York: Russell Sage Foundation, 1969).

Even before the Vietnamese war and reactions against it intensified problems of the relationship between academic researchers and government agencies, efforts were under way from both sides to attempt to improve the fruitfulness of those relationships. One important attempt in that direction was a report entitled The Behavioral Sciences and the Federal Government, prepared by the Advisory Committee on Government Programs in the Behavioral Sciences of the National Research Council.* This Committee, chaired by Dr. Donald R. Young, examined how the knowledge and methods of the behavioral sciences could be brought to bear more effectively on the programs and policy processes of the federal government. Its recommendations focused on strengthened and improved social science staffing in government agencies; the development of research strategies in major departments and agencies; the creation of an interagency planning group headed by the Department of State to exercise continual review of research in the area of foreign affairs; greater representation of social scientists in key science policy agencies of the government; and the creation of a National Institute for Advanced Research and Public Policy "to provide a forum in the nation's capital for the full exploration of the growth and application of knowledge from all the sciences to the major issues of the society."

Subsequent to the publication of that report, the Department of Defense requested the National Academy of Sciences to address itself more specifically to the management of behavioral science research

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* Washington, D. C.: National Academy of Sciences, 1968, Publication No. 1680.

within the Department of Defense. The task was undertaken by an Advisory Committee on the Management of Behavioral Science Research in the Department of Defense, and this report is the outcome of its work.

II. *Ground Rules*

In undertaking to advise on the "management" of behavioral science research one must make clear the level of one's response. Our Committee made two crucial assumptions very early in its discussions.

The first is that we must treat of management in the broadest sense of the word. To manage is to plan, direct, coordinate, and evaluate. Such activities are not undertaken in a vacuum. They occur in a context, and an understanding of the context is the primary managerial question. Only as the total context is clearly understood can one sensibly make recommendations regarding detailed management and procedural matters. This means that we are more concerned with the scope, premises, and nature of the relationships between the Department of Defense and outside researchers, and with major dimensions of the types of research supported, than we are with detailed questions of, say, the "G.S." level (that is, the civil service status) of social scientists in military departments, or the exact procedures by which external research contracts are let.

As a Committee of outsiders, some of whom have had substantial working contact with the Department of Defense and others of whom have had virtually none, we do not propose to advise on internal working details. Such advice would have required a close and intimate scrutiny of the day-to-day work of managers and scientists within the Department,

which we were not in a position to undertake. We may, however, be in a better position than those in the Department to examine its relationship to the social and behavioral science research communities, which it partially supports and upon which it draws in the process of pursuing its major goals.

Our second assumption is that national security policy, with which (like it or not) the Department of Defense is intimately and ineluctably related, has many dimensions to which the knowledge and advice potential contained within the behavioral and social sciences are relevant.

The civil-military relationship is complex, not simple.* While the rule of thumb in American constitutional doctrine is that military policy is a subordinate extension of foreign policy, and that civilian authorities determine policies which it is then the obligation of the uniformed services to implement, it is an axiom of public administration and policy development that ends and means are not in fact separable. Rather, they continually interact. Thus, those charged with the "how" of policy--i.e., its implementation--will necessarily want to have an opportunity to understand fully the "what" of policy and even to make contributions to it. A good example is provided by the Office of Scientific Research and Development in World War II. Its civilian scientists, when called upon by the military to provide weapons to fit requirements as defined by the services, insisted upon being informed about all the dimensions of the problem they were

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* Some of the complexities are summarized and reviewed in Walter Millis, Arms and the State (New York: The Twentieth Century Fund, 1958).

called upon to solve, and then often redefined the requirements as a prelude to devising appropriate weapons systems.

If the role of military power has permeated American thinking about international politics, it is equally true that political, psychological, sociological, and economic dimensions of international political relations have penetrated the realm of military policy. It is when military objectives are artificially separated from political concerns (as, for example, in the late General Douglas MacArthur's desire to extend the Korean War in the name of military victory without consideration of the political dimensions of this objective) that trouble occurs. It is the Committee's conviction that to insist that military affairs be separated by an impenetrable wall from foreign policy affairs is to invite disaster. It follows that no such wall should exist between the organization charged with the nation's military security and the researchers who generate, articulate, and interpret knowledge of other nations, international problems, and United States policy ideas.

The National Security Council, established in 1947, constitutes a post-war institutionalization of the recognition developed during World War II of the inextricable relatedness of military and non-military factors in national security policy. The State Department cannot perform its functions adequately without a sophisticated understanding of military developments concerning both weapon systems and strategies. Similarly, the Department of Defense cannot pursue sound military policies--that is, cannot adequately pursue the policy implementation of goals given to it by the President--without equally intimate knowledge of the broader political context of national security developments.

Such knowledge could often be developed as well outside of the Department of Defense as inside it. Often, however, it has not been developed in fact, except as the Department has sponsored it. Hence, one of the important issues in the management of Department of Defense behavioral and social science research concerns, first, the total national security policy research context and, second, the Department's place in that context in relation to the other agencies that together constitute what may be called the national security community--namely, the Department of Defense, the Department of State, the Agency for International Development, the Arms Control and Disarmament Agency, the U. S. Information Agency, the National Security Council staff, and the intelligence agencies. In our view, one cannot meaningfully discuss the management of Department of Defense social science research without considering the other aspects of national security policy research. This does not necessarily mean that the Department of Defense should itself be engaged in what is essentially political research, but it does mean that the Department has an interest in being assured that the required political research is done somewhere.

The aftermath of Project Camelot made it all too clear that military sponsorship of social science research pertaining to the internal politics of other nations may have adverse repercussions on American foreign policy. Yet the questions which Project Camelot addressed are "fundamental: the nature of social change, the factors

of instability, the causes of violence."* While understanding of social change in different societies might be considerably enhanced by research of the kind envisioned by Project Camelot, insensitivity to the implications of its military sponsorship strongly indicates that the defense establishment's need for certain types of information does not necessarily make it the best sponsor of research designed to provide that information. The question has also been raised whether the United States government should collect this kind of information at all.

We make the further assumption that, although the Department of Defense has requested and is supporting the work of the Advisory Committee, this report must be addressed to interested social scientists throughout the nation, as well as to the Department and other national security agencies. For, the quality, characteristics, and terms of the relationship between the Department of Defense and the outside world of social scientists lies at the heart of the research management question within the Department itself. And, because each party to the relationship naturally has its separate perspective, we assume it to be important that our analysis take account of the user viewpoint, as well as that of the social science "producers." In this respect, we deal with matters not given prominence in the report of the Young Committee, whose recommendations to the government were almost exclusively answers to the implicit questions: "What can the government do for the social sciences, and what can it do to get more from the social sciences?" While we are concerned with what the Department of Defense

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* Lyons, op cit, p. 169.

can do in its particular sphere along these lines, we are equally concerned with the question, "What can social scientists do to make their own contributions more effective in the government, and, particularly, in the Department of Defense?"

III. *What to Manage?*

The most important questions in research management are: Toward what kinds of problems does one direct research? What is the scope of the research? What are the major purposes and categories of the research? After these questions have been resolved, one can move to the level of choices regarding allocations of research funds among different approaches to the problems and among different types of research-performing institutions.

The Department of Defense presently divides its social science research into five substantive categories:

1. Human performance--measuring individual physiological and psychological capabilities related to military operations.

2. Manpower selection and training--developing methods to improve selection, classification, training, and use of military human resources.

3. Human factors engineering--designing equipment to ensure that it can be effectively, reliably, and safely used by military personnel.

4. Foreign military security environments--understanding cultural, psychological, and political-military characteristics of foreign defense organizations and their members and their environments. Departmental statements list three subcategories:

a. improving U. S. armed service capacities for non-combat aspects of counterinsurgency operations;

b. determining costs and benefits of different U. S. military aid and advisory policies for strengthening the internal defense capacities of allied military establishments in developing countries requesting such assistance;

c. developing and testing methods to clarify future U. S. security environment in terms of foreign military intentions and capabilities in military elements.

5. Policy-planning studies--synthesizing and applying existing knowledge to formulate and critically evaluate some aspects of threat analysis, contingency planning, force structure needs, and hardware research and development requirements.

Each of these categories may at some point be interdependent with any of the others. Thus, the problems of selection and training servicemen for overseas assignments, for example, clearly fall into both the manpower and the foreign military security-environment categories. Yet the first three (which can be subsumed under the generic heading of manpower studies) are clearly differentiable from the last two. By and large, the manpower studies use the social science discipline of psychology, while security-environments and policy-planning research relies most upon the disciplines of political science, economics, and sociology. The distribution of Department of Defense

funds among these categories is very heavily weighted on the manpower side. In the fiscal year 1971 budget request, the three manpower categories totaled $35.3 million, and the last two only $9.9 million. In terms of disciplines, in fiscal 1969 the Department spent $36.5 million on the social and behavioral sciences; of this total, $29.5 million were spent for psychology.

The most significant distinction among the categories of research is that foreign military security-environments and policy-planning research is inherently politically sensitive, while manpower research is not, although it, too, has had its controversial projects. Indeed, research on man-machine relationships and "human engineering" has an Orwellian tone, but by and large a psychologist could work on problems of improving selection and training choices through psychological testing without having to confront possible conflicts between his own value system and the value system implicit in the area of research. This is less true for categories of security-environments and policy-planning studies. Regardless of questions of political sensitivity, much policy-planning research has to be done by and for the Department of Defense because it deals with issues of strategy, force structure, and budgets. The Department of Defense should not be foreclosed from undertaking such research.

Research management in these areas must, therefore, immediately concern itself with the question of possible conflict between a potential researcher's political values and the military-foreign policies represented by the activities of the Department of Defense. To put it sharply, policy-planning research for the Vietnam war is very different from research on appropriate diets for Army personnel stationed

in arctic regions. Given the present climate, however, one would not be surprised to hear objections to university research on the appropriate diets for Green Beret personnel in Vietnam.

From a management viewpoint, the problems and needs of these major social science research areas differ substantially. Manpower research has long been well institutionalized in the military services. It is the Advisory Committee's understanding, moreover, that such management relationships between the consumers and producers of research are relatively satisfactory. That is to say, manpower officials in the Department of Defense have been able to define their problems in ways that researchers have been able to understand and respond to. Conversely, the researchers have made substantial contributions to the practical needs of manpower officials. Hence, there is a considerable degree of mutual respect, and a firm foundation of economic and pragmatic justification for the manpower research programs. The user-producer relationship in the foreign area and policy-planning research has been much less happy. There is substantial evidence, as will be seen later, that users are very dissatisfied with social science contributions to the solution of policy-planning problems.

Even the very meaning of research differs in the two contexts. Human performance and manpower research is, by and large, more often quantitative and testable, approaching the modes of research in the physical sciences, while some foreign-environments inquiry and much policy-planning research are more qualitative and judgmental. Because the management problems are different in the two broad areas, and the national security policy sphere has been most strongly subjected to

questioning, the Advisory Committee's focus is largely on that area.

It is also informative to divide research into different categories with respect to purpose. Most social science research aims at providing information, usually concrete and specific, on particular problems. It involves the gathering and analysis of data, as, for example, in the content analysis of propaganda broadcasts from other countries. It is research that performs, at least in some measure, an "intelligence" function. There is a second purpose of research, however, somewhat different in character from that usually pursued by scientists, whether physical or social. It seeks to provide a longer-range--and, perhaps, more speculative--perspective, removed from current operations or policy issues. Such research employs rational, knowledge-based, intellectual analysis not so much to solve present problems as to affect current decision-making by placing it in a broader or different context. The search for fundamentally new policy options is an important example of that kind of research, and a concrete illustration is provided by the RAND study of overseas bases.* It should be noted that research is frequently sought, but not often found, which tests and compares policy hypotheses before they are implemented.

If research can be said to include both the development of information and the providing of perspective and conceptual thinking, it may also include a third category, defined by the use of researchers as consultants on an ad hoc, short-range basis. The policy-maker

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* See Bruce O. R. Smith, The RAND Corporation (Cambridge: Harvard University Press, 1966).

considers that he is doing "research" on his problem when he calls in an outside expert for advice regarding, say, the probable outcome of a posited alternative. (There is an important distinction here between the viewpoints of the user and the producer.) Social as well as physical scientists--certainly, those who think of themselves as basic researchers--are not likely to label consulting and advising as research, even though they might be willing to admit that good advising is based on knowledge provided by research. From the viewpoint of the Department of Defense (or any other government agency) it makes sense, however, not to employ so restrictive a conception of research. From the user perspective, research should be taken to encompass not only the development of information through data gathering and the provision of written, formal analyses but also discussion, in the form of a phone call or a two-day visit to Washington, for example, between a policy-maker and a researcher who knows the area of the world or the type of problem with which the former is concerned.

The difference between user and producer perspectives on what constitutes research and the knowledge basis for action is well expressed in a recent comment on two general complaints about social scientists as consultants. The first is that communication is impeded because social scientists speak in a jargon incomprehensible to laymen. The second--the relevant one here--is that, social scientists, "When faced with a specific problem that has no ready-made conceptual answer . . . frequently retreat to the laboratory for more research and more facts. But the client would ordinarily settle for less than a scientifically adequate answer. He simply wants the consultant to

apply his trained intelligence, and give help based on the information on hand." Of course, there is another side to this, for it is also observed that, "When the consultant tells him he has formulated his problem in such a way that advice is impossible, too often the client retreats to his office. And often any reformulation the consultant suggests is ignored, to the detriment of communication between them." (These observations were not made by a disgruntled policy-maker. They appear in the report of the National Science Board's Special Commission on the Social Sciences, Knowledge Into Action: Improving the Nation's Use of the Social Sciences.*)

A major problem concerning the scope of research, with which research managers have recently had to contend in a very disturbed context, is the question of the degree of direct relationship or relevance that it must bear to the military mission. Partly, of course, the answer to this question depends on how one defines the military mission. If it is narrowly defined as the application of physical force to international political relations, much research would be excluded as irrelevant. When broadly defined as participation in national security operations, much more research becomes directly relevant.

This question needs to be placed in the larger context of how appropriate it is for mission-oriented agencies of the national government to support basic research. A tradition of pluralism in the support of research by the federal government is of long standing

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* Washington: Government Printing Office, 1969, pp. 15-16.

and has been vigorously defended. At the time the National Science Foundation was being designed, thought was given to making it the single agency of the federal government responsible for basic research in all the sciences. However, owing to delays in the establishment of the National Science Foundation, other operating agencies (following the leadership of the Office of Naval Research) developed their own research and development programs and have since retained them. Furthermore, the policy commitment to diversification of support for scientific activities grew out of an awareness that no individual or institution is competent to make all the decisions about what research and development should be supported and how support should be provided. In general, most observers of the science policy scene have been convinced that mission-oriented agencies must perform or support some basic research in their areas of interest, partly so that the pool of knowledge on which their applied research is based is maintained at an appropriate level, and partly as a way of attracting and holding a high quality in-house scientific staff. Such staffs may be structured, without necessary damage to management effectiveness, on either a mission-derived or a discipline-oriented basis, and in either a basic or applied context. Some of the current debate over whether the Department of Defense should sponsor research designed to advance a discipline seems to ignore the possibility that this might be a necessary result of mission-derived research.

On the whole, scientists have been satisfied with the situation of relying upon mission-oriented agencies for support of basic

research. There are two major reasons for this: first, it gives them multiple opportunities to seek support, as compared with a situation in which all grants come from a single agency; second, they recognize the political fact of life that the Congress has not seen fit to expand the National Science Foundation's research funds at a rate commensurate with the growing demands for support in the scientific community.

Recently, however, there has been a considerable degree of alarm, especially in the universities, over the reliance of basic researchers upon Department of Defense support. It is now often suggested that all basic research, if not all academic research, be removed from the "contamination" of Department of Defense sponsorship. There is a measure of naiveté in the view that research can be neatly categorized as either basic or applied within this context. Research may be basic yet very directly related to the mission of an agency, or it may be applied yet not of any particularly greater relevance to one agency's mission than to another. There are more important issues that attach to the sponsorship of academic research by the Department of Defense. One is whether an academic institution should undertake the performance of classified research, and the current overwhelmingly dominant view in the academic world is strongly negative. A second is whether problems of national security do not deserve the attention of academic researchers simply because of the sponsoring agency.

A different and useful mode of classifying basic research supported by mission-oriented agencies is proposed by Harvey Brooks, who

suggests that such research falls into three categories:

1. fields of science in which the mission orientation admits of no clear limits to agency interest, and requirements differ in both kind and volume from those of any other component of the nation's technological community;
2. fields which are of vital importance to the agency mission, but whose importance is shared almost equally with many other agencies; and
3. fields which presently show no obvious promise as sources of concepts or results for near-term agency exploitation, but which are so much in the main stream of imaginatively advancing science that they have a strong potential for ultimately significant repercussions on the programs and perspectives of the agency.*

If this typology were used for the Department of Defense, research that falls in the first category should continue to be supported by the Department of Defense. Here, research on problems of human response to stress and situations of threatened death may serve as an example. The second category would include much of what is done under the headings of foreign military security environments and some of what is done in policy-planning. Such research overlaps in substance with the missions and needs of the Department of State and other operating agencies of the national security community.

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* Harvey Brooks, The Government of Science (Cambridge: MIT Press, 1968), p. 115.

Research of this kind must be accessible to the Department of Defense, but all of it need not, in principle, be performed or financed by it. Until now, one reason why the Department of Defense has supported such a large share of this research is the political difficulty experienced by other agencies in obtaining appropriations comparable with those of the Department of Defense for research in these areas. It must also be said, however, that other agencies (notably the State Department) have not been nearly as alert or sympathetic to social science research on foreign affairs matters as has the Department of Defense. To the Committee it appears that to say that the Department of Defense, among the national security agencies, has had a disproportionately large share of total foreign area and international affairs research funds in recent years, is also to assert that the other agencies have had disproportionately small shares. In fiscal year 1969, for example, the Department spent $11 million in these categories, while the State Department's Office of External Research was funded at only $125,000, the U. S. Information Agency's research at $589,000, and that of the Arms Control and Disarmament Agency at $678,000.

The State Department has long faced great difficulties in securing funds for research. Many of its officers are not convinced that the social and behavioral sciences have something to offer that is both useful and not obtainable elsewhere. Until very recently, the Department of State has been singularly lacking in initiative in inquiring into the potentialities of these sciences for making significant contributions in the national security area. Until recently, it rejected the idea of accepting additional research funds offered

to it on a transfer basis by the Department of Defense. In fiscal year 1971, arrangements were effected by which the State Department can contract for research with the use of Department of Defense funds.*

The Committee believes strongly that the Department of Defense needs competition in the fields of foreign area research and policy-planning studies in order to sharpen both the management of the effort and the quality of the end products. Knowledge is power; and, as the possessor of the most knowledge, the Department of Defense tends to be in a commanding position, and, therefore, is not compelled to try to do the best possible job in analyzing and defining any situation. It is difficult for other agencies to present and argue for a different picture in the absence of knowledge even approaching that possessed by the Department of Defense.

If a better balance in social science research were the sole objective, it could, presumably, be secured by simply cutting the Department of Defense's national securities affairs research funds down to a level similar to that of the other agencies. The Committee

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* See FAR Horizons, Vol. III, No. 5, September, 1970.

> "This fiscal year the Department of State will expand its contract and consultant research program. The aim is to make more use of the special knowledge and insights to be found outside the Government in universities, nonprofit research organizations, and among private foreign affairs experts. The State Department has requested from Congress an appropriation of $350,000 for the program, up from $125,000 last year. And the Department of Defense has agreed to allocate to State $483,000 for studies in the broad field of national security of interest to both departments. The goal is a $833,000 program in fiscal year 1971."

rejects this approach. We hold that more research, along with better management, is needed, not less. The sensible way to correct the long-standing imbalance is to build up the research strength of other agencies, and this we strongly recommend. The Department of Defense, of course, does not determine the allocation of research funds or their division among the relevant agencies. Consequently, when we urge the need for increased foreign area research by the Department of State and other agencies, our recommendation is addressed to them and to the appropriate committees of the Congress.

All the members of this Committee recommend a phased transfer of responsibilities and funds for foreign area research from the Department of Defense to the Department of State and other national security agencies. However, we do not agree upon a single answer to the question, "What should be done if increased funds for the other agencies are not forthcoming?" Some of us believe that the crucial requirement is that the information needs of the national security community be met. If other agencies are not equipped to meet these needs, then some of us would have the Department of Defense continue to sponsor foreign area research and policy-planning studies at present levels (even though this may be unrealistic, in the light of developing congressional attitudes) until that situation changes. Other members of the Committee, however, are convinced that the transfer of research funds to other agencies is the decisive consideration. Those who take this position would end the Department of Defense's support of this kind of research and trust that other agencies and the appropriate congressional committees would then see the necessity of assuming

responsibilities for it. The assumption is that, unless the drastic step is taken, the natural inertia of the bureaucracy will serve to delay unconscionably, if not completely thwart, the transfer of responsibility that is required.

Every member of the Committee, however, agrees that the Department of Defense should actively seek the transfer of responsibility for the support and management of foreign area research. Moreover, we agree that it should strongly endorse the creation of a government-wide institutional structure--to which it would have access and in which it would have a chance to voice its informational needs--in which this responsibility should be lodged.

IV. *Institutional Choices*

The pluralistic character of research performance in the United States is exhibited by the variety of institutions that carry out what is generically spoken of as "government research." Such research may be conducted in an internal (in-house) federal laboratory; in a federally owned facility operated under contract by a nongovernmental organization; in a private for profit corporation; in a privately-owned not-for-profit corporation, all or almost all of whose business is obtained through contract with one or more government agencies; in public or private universities, either by contracts with research centers or grants to individual faculty members; and even by independent, individual consultants.

The pluralism in research performance poses a basic question: "What balance should be struck between intramural and extramural research?" More than 85 percent of the federal government's research

and development budget is currently used to purchase extramural research from the whole range of institutions just listed. About 25 percent of all research and development funded by the Department of Defense is performed intramurally, ranging from 36 percent in the Department of the Army to 15 percent in the Department of the Air Force.

The use of extramural research performers has had advantages that are generally recognized throughout the federal government. Contracting-out avoids civil service constraints and complications; it develops private sector interests in and support for government programs; permits access to talent that the government might not otherwise be able to recruit or employ on a full-time basis; and is easier (at least in principle) to turn off, as well as on, than is an in-house laboratory.

While most research contracts are of a "hardware" nature, a strong tendency to use extramural sources for both policy research and policy advice has developed in recent years. Prominent examples in this area include studies by the RAND Corporation on a variety of strategic policy questions for the Air Force and by the Institute for Defense Analyses on behalf of the Office of the Secretary of Defense. Even congressional committees have made occasional use of policy research contracts--for example, the series of studies on foreign policy topics contracted for with university groups by the Senate Committee on Foreign Relations a few years ago.

Although extramural contractors have been widely used for all kinds of research, it is not clear whether adequate criteria exist for determining which research should be performed extramurally and which on an in-house basis.

In the hardware area, the so-called Bell Report of 1962 on government contracting for research and development expressed considerable unease, if not alarm, over the inability of contracting units to monitor their extramural research effectively, largely because they had denuded themselves of in-house capabilities. That report urged that more of the important research tasks be retained for intramural laboratories on the ground that their senior scientists would then constitute a pool of advisory experts needed to help policy makers select extramural research teams or monitor on-going extramural work.*

The Committee has the impression that on the social science side it might be somewhat easier to follow this urging with respect to manpower than to foreign-area and policy-planning research. This may depend in part, however, on just where the research is located internally, and what kinds of personnel (policy-making or research management bureaucracy) exercise day-by-day direction of it.

One of the major recommendations of the Bell Report was for parity of salaries between governmental and nongovernmental employers. Legislative developments since 1962 have made a considerable advance toward this objective. In the social sciences, however, the number of supergrade positions for senior scientists is apparently insufficient. Strong representation by the Department of Defense to the Civil Service Commission, in collaborative effort with other agencies, is in order regarding the need for high level

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* U. S. Bureau of the Budget, Report to the President on Government Contracting for Research and Development (Washington: Government Printing Office, 1962). David E. Bell was then Director of the Bureau of the Budget.

social scientists. Even more important than salaries in enabling the government to maintain first class intramural research establishments, in the judgment of the Bell Report, is having "significant and challenging work to do." The Department of Defense should, therefore, ensure that research problems assigned to intramural staff are such as to attract and hold first-class scientists. "No matter how heavily the Government relies on private contracting," states the Bell Report, "it should never lose a strong internal competence in research and development." This observation carries even greater weight in connection with policy-planning than with hardware. And in this area, it may be added, there is good reason for the government to be aware of what arises on both the producer and consumer sides of the research relationship.

We recommend that the Department of Defense give concentrated attention to the development of a first-rate in-house social and behavioral science capability, both for conducting pilot studies and for monitoring external research.

An intramural research staff in daily contact with policy-making officials, on the one hand, and with contractor research performers, on the other, might possibly alleviate one of the most crucial of all institutional problems, that of ineffective communication between research producers and users. If intramural research staff were to be organized by assignment to policy-making offices (e.g., some to the Assistant Secretary for International Security Affairs, some to the Assistant Secretary for Manpower and Reserve Affairs), rather than located in an isolated set of rooms called a research laboratory, they could be particularly effective in a liaison

capacity between policy-makers and the outside research communities.

A strong effort is needed to re-think the Department's pattern of intramural and extramural research generally. Certain criteria are immediately apparent for determining which social science work should be done inside and which outside. For example, external research is obviously inappropriate for "fire-fighting" tasks, but it is appropriate for much long-term work. Some long-term work, however, should also be done in-house, by way of maintaining the monitoring capacity of the Department's social science research staff.

Another criterion, for example, arises from the very situation of internal researchers, which makes them most unlikely to be able to escape from the constraints imposed by their positions and deal effectively with tasks calling for fundamental questioning of the assumptions of current policy. Indeed, it is dubious whether even retainer organizations--such contract research centers as the Center for Naval Analyses or the Center for Research in Social Systems, for example--are sufficiently outside the agency framework to engage in this kind of independent re-thinking of accepted policy, or, if they can do it, whether they will also be eager to transmit results. Ideally, every government department should have an "Assistant Secretary for the Questioning of Assumptions." Practically, it must be recognized that no bureaucratic organization can be expected to permit and reward the degree of self-criticism that should be generated internally. Indeed, the most penetrating criticism of national security policies and programs is often likely to come from those whose perspective would not permit them to accept Department of Defense support for their research, let alone to become employees of the Department.

This is not to say, however, that incisively critical policy-planning research can never be sponsored by the military agencies. There are, after all, many gradations of disagreement and criticism. Even internal staff are expected to alert their principals to weak spots and inadequacies in existing or proposed programs. The Department's policy-planning research should continue to include some that is performed extramurally, but personnel in the contract research centers or the universities engaged in such work have an obligation to keep Department of Defense sponsors fully informed of their own perspectives and assumptions. It is important to national security policy that, when there is a lack of consensus about the direction of policy, even among objective, competent researchers, the major divergent views should be fully developed and strongly presented to policy-making officials.

This is to say, first, that the Department of Defense needs to expose its own thinking and assumptions to outside criticism, and, in consequence, has an obligation to provide at least some outside critics with sufficient information about its assumptions to provide a basis for intelligent criticism. Second, it also means that policy-related social science researchers who are critical of United States policy should not withdraw from the task of analyzing national security policy merely because they are at odds with it or made angry by it. The appropriate institutional arrangement for critical research is probably one in which the Department contracts with an independent research institute, or a university-affiliated research center, in such a way that it relies upon and ensures the freedom of the capability--presumably selected because it meets the highest

standards of professional competence--to pick its own researchers and its own research topics. An agency in need of having its programs criticized is never in a good position to advise the potential critics on the most fruitful focus and techniques of inquiry and evaluation.

Another aspect of the institutional criteria for defense-related social and behavioral science research involves the distinction between inquiry in which the intended end product is a set of data, a descriptive statement, or a training manual, and that which focuses on categorizing, analyzing, developing, and presenting different perspectives and policy possibilities. The first types of research can often well be performed by teams in a relatively bureaucratic setting. The second may suffer from "group think" approaches, and, to the extent that it does, is an appropriate area for individual research.

This suggests a related point about the institutional structure of Department of Defense research. It has already been observed that the term "research" should have a broader meaning for the Department than for academics, and that the Department should specifically think of its research as including the contributions of individual consultants. On this point, the Committee recognizes that individuals possessing specialized knowledge are, perhaps, the Department's greatest resource in the research community. Its experience with the development and use of a roster of consultants has proved beneficial. Such individuals may be called in for two or three days of consultation as problems arise in their areas of expertness. Sometimes this is for the purpose of drafting papers; sometimes for the purpose of sharing

specific information and perspectives with those in policy positions. Consultation involves the application of a researcher's competence as an expert, as well as his total background, to an immediate problem rather than new research. Frequently, however, the immediate problem will inspire the consultant to do new and useful research. But, from the viewpoint of the user, it is research. In his relationship to consultants, the research administrator's primary function is not that of receiving information from the researcher and then reinterpreting it to the policy-maker. It is, rather, that of helping the policy-maker find the individual in the research community whose background and competence are best suited to the problem at hand, and who is known for an ability to speak the policy-maker's language, as well as the occasionally arcane jargon of his own specialty.

V. *Research Planning and Implementation*

The emphasis needed in research management on the qualities of the research effort itself should not be pursued at the expense of appropriate attention, first, to the planning of the entire research program before research is begun and, second, to the implementation of tentative findings when they emerge from the initial stages of research.

Cyril E. Black, in a recent evaluation of government-sponsored research and international studies,* states that one of his principal impressions is that "there seems to have been no government-wide

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* Cyril E. Black, "Government-Sponsored Research in International Studies," World Politics (1970).

effort to establish research priorities based on what is already known, what is already being done by privately supported research, and what the needs of the nation and of scholarship are." It would be wasteful in the extreme if this situation were to continue. The Committee does not believe that the Department of Defense should unilaterally determine research priorities in foreign area studies and policy-planning, as we later make clear. We hold that the Department should cooperate with the Department of State and other national security agencies in supporting problem-related studies of research needs and resources. Such studies would differ significantly from the survey of the behavioral and social sciences, completed in 1969,* which is concerned primarily with the needs of these disciplines for their own conceptual development. What are required are assessments of research needs and resources from the point of view of policy-makers.

We recommend that the national security agencies jointly establish a task force on social and behavioral science research priorities in the area of national security policy. Its charge would be to prepare a statement that (1) assesses the present "state of the art" in the sciences; (2) details specific research needs from a policy perspective; and (3) identifies and evaluates the intramural and extramural resources required to meet various levels of needs. This task force should be composed of both research administrators in the national security agencies who are knowledgeable on policy and nongovernmental members of the national security policy research

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* Behavioral and Social Sciences Survey, National Academy of Sciences and Social Science Research Council, The Behavioral and Social Sciences: Outlook and Needs (Washington, D. C.: National Academy of Sciences, 1969).

community.*

There is, perhaps, an even greater inadequacy in government social science research than the failure to develop an adequate inventory of research needs and statement of priorities. That is the lack of realization on the part of research users that the social and behavioral sciences have developed to the point of providing more than "armchair" analyses, and require in some instances large-scale opportunities for exploratory development and experimental testing. Certain operational problems, as well as fundamental assumptions, relating to the development of an all volunteer army, it would appear, could be effectively investigated by way of well-conceived, properly evaluated field experiments.

The Department of Defense divides its research program into five levels, ranging from "fundamental research" (identified as 6.1 funding) through "exploratory development" (6.2), "advance development" (6.3), and "engineering development" (6.4), to "studies and analyses" (6.5). Until very recently, funding for the behavioral and social sciences has been limited to the 6.1 and 6.2 levels. Larger sums for development and testing in the 6.3 to 6.5 categories have been unavailable. It may well be that the utility of research in these sciences has been limited because projects in the more applied areas have been thwarted by lack of support.

The idea of field testing social science hypotheses is not yet

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* The Committee understands that consideration is being given to the establishment of an interagency group that could undertake the task of developing the priorities for research in the social and behavioral sciences on national security policy.

widely accepted by either researchers or policy-makers. Yet there is a sufficient number of successful examples of applied social science research on a large scale, and of the testing of social hypotheses, to make it impossible to deny the potential value of such work. One fascinating current example on the civilian side might be cited: the experimentation with a negative income tax approach to public assistance payments which is being sponsored by the Office of Economic Opportunity. Preliminary reports on the New Jersey field testing of the negative income tax approach have provided the first empirical data ever applied in a systematic way to the widely believed adage that any kind of governmental "welfare" benefit must destroy personal work incentives. Other controlled social experiments in the educational field that will serve to test hypotheses have also been planned by the Office of Economic Opportunity.

In the national security area, the methodology of social science research now permits and warrants substantial funding for such efforts as simulations of the operational environments that policy-makers may posit as constituting the range of possibilities for which the nation must be prepared. Computer-based simulation studies on a large scale are likely to be expensive. They may be used either for fundamental research or for engineering development, and it is particularly difficult in the social sciences to draw a dividing line between different stages of research and development. But, under whatever label, they constitute a qualitatively different mode of behavioral research than is encompassed by the traditional expectations of many foreign-affairs practitioners, who believe that the social sciences can provide little

or nothing beyond humanistic, individual, historical research. The limits of utility on "engineering development studies" in the behavioral and social science areas of Department of Defense research are not yet known with any precision. However, it is clear that those limits have not been approached and that an adequate effort to develop the engineering side of behavioral and social science research has not yet been undertaken. The potential for such work is perhaps especially great in the area of manpower research (psychological testing mechanisms, for example), but it also exists in the policy-planning and foreign-area spheres.

We recommend, therefore, that the Department of Defense make a deliberate decision to multiply several times over the amount of funding available to the social and behavioral sciences under the 6.3 - 6.5 research program levels. In implementing this recommendation, the Department's research administrators should undertake the special task of identifying a number of promising development and testing projects in the social sciences. These projects could be selected with an eye to enhancing the value of research in the 6.1 and 6.2 categories and thus further developing the state of the art.

VI. *Fitting Research to Policy Needs*

Published commentaries on the relationship between the federal government and the research community tend to be written by members of the latter group and thus inevitably to reflect the perspectives of research producers more strongly than those of the government officials who sponsor and use research. Some individuals, of course, embody both a professional social science background and high-level

governmental experience. Many of these have exhibited (either privately or publicly) skepticism and even hostility toward extramural research. These views appear to be engendered by a sense that social science research is often irrelevant.

High-level officials, both in the Department of Defense and in the former Bureau of the Budget, believe that research should be more useful to them than it is. Non-mission oriented basic research is considered to have lacked policy payoffs and to have constituted both a subsidy to producers and a source of difficulty and irritation with the Congress. Research producers are sometimes viewed as being more interested in furthering their academic disciplines than providing operational help to the Department of Defense. Part of this set of negative attitudes reflects an apparent failure on the part of producers to learn enough about the problems of the research consumers to be able to design concretely applicable programmatic proposals. To its critics, much social science research has appeared to be simply fact-gathering unrelated to hypotheses, and, when used, the hypotheses seem to be those generated by their relevance to the discipline rather than to consumers of research and the Department of Defense. So run the criticisms from the user perspective--a perspective which, it must be admitted, is not as strongly represented as it should be in many panels that have commented on the relationship between researcher and policy-maker.

Obviously, these criticisms taken alone constitute a one-sided picture of the actual relationship. Research producers, too, can register valid complaints--among them, for example, the inability of

many policy-makers to pose their problems in researchable terms, or their unwillingness to make an effort to understand some necessary conceptual complexities when they first encounter them. Some members of the Committee believe that the demands upon policy-makers require that sympathetic and detailed interpretation of problems be done by research administrators who have regular contact with them. All too often, however, research administrators are at lower levels in the bureaucracy, and communicate primarily with research producers. As a result, their formulation of research needs tends to reflect the propensities of the latter. Researchers voice two other major complaints. First, they maintain that some policy-makers are interested only in research that seems likely to result in desired answers. Second, and perhaps more important, they hold that policy-makers show a proclivity to impose burdensome reviews of research reports by unqualified persons and unnecessary security classifications.

The objective now, of course, is not to assess blame, but to bridge the managerial gap between policy-makers and researchers, taking into account the criticisms from both perspectives, in order that the relationship may become more mutually beneficial. Demand and supply simply are not meeting in a usefully meaningful way today. Producers continue to feel that they have something to offer, and consumers continue to feel that research is not but should be useful. What can be done by way of remedy?

Some positive steps have already been taken. Research funds have been allocated to operational agencies such as Systems Analysis and International Security Affairs on the assumption that these

offices can better define their needs than can the Directorate of Defense Research and Engineering. The military services have been given funds with the intent that they offer research proposals for competitive bidding by the research community, and Systems Analysis has instituted training programs for in-house research and analysis. These modest steps are to the good, but they are not sufficient. Additional measures, we believe, would help.

In order to bring about a more effective managerial relationship between the consumers of research in the Department of Defense and its producers, we recommend the following six actions:

1. Assign formal responsibility for research allocation and supervisory functions among the major consumer offices in the Department of Defense, such as International Security Affairs, Installations and Logistics, and Manpower and Reserve Affairs, as well as to the Advanced Research Projects Agency; or, alternatively, give each of the major consumer offices a role in requesting and sponsoring research, similar to the role performed by the services, under the oversight of the Director of Defense Research and Engineering.
2. Upgrade the research bureaus within the principal offices of the Secretary of Defense by giving the bureau chief a super-grade status, provided that individuals meriting this grade can be found. Such individuals should not only understand traditional social science research but also have access to and enjoy the confidence of policy-

making consumers at the level of Assistant Secretary and Deputy Assistant Secretary of Defense. If a choice has to be made, a staff person who understands the policy context and has some familiarity with research may be preferable to one with very strong disciplinary research background but no acquaintance with or feel for policy-making.

3. Provide funds for retrospective studies in the social and behavioral sciences designed to establish the relationship, if any, between basic research and programmatically useful results.

4. Allocate funds for evaluative studies of on-going programs that allow for the questioning of policy assumptions and the proposal of programs alternative to those under analysis, in order to suggest how programs might be modified in the future.

5. Create an internal research information retrieval system designed not only to prevent the "loss" of previous research but also to compensate for the compartmentalization that exists within the Department. It would be desirable to include within such a system internal staff studies as well as external research, even though this would make the system more sensitive and highly classified.

6. Provide more precise formulations of Department of Defense research needs and work toward better anticipation of those needs, so that potential contractors for research

will have adequate time for the preparation of proposals.

These are steps that the Department of Defense can take. The members of the national security research community can also contribute to improving their relationship with the security agencies. They can develop a greater willingness to participate in research seeking to determine the operational payoffs resulting from basic research in the main disciplines of the social sciences, and to help define areas of programmatic research in which results of definite operational utility to consumers could be produced. They could express greater interest than they have in the past in engaging in program evaluation as an important function, both as an aid to policy-makers and as a mechanism for training research producers with an operational bent. Continuing interchange of personnel between the Department of Defense and the research community would be of obvious value to an improved relationship. This, however, will be understandably difficult to achieve in the present atmosphere unless it is part of a more general "in-and-out" exchange program between government agencies, on the one hand, and universities and research institutes, on the other.

VII. *Social Science Translators*

The value of such an exchange program would be doubled or tripled if in association with it there were developed university training programs looking toward the creation of a new breed of applied social scientists, or what might be called "social science engineers." Some recognition has already been given to the need for social science professionals who are not wholly "pure researchers."

To some extent, schools of public administration and schools of international affairs have worked for years toward this goal by focusing their curricula to some degree on use of the social sciences in governmental program contexts. Perhaps the new programs in public policy analysis that are springing up in a number of universities will come closer to filling the need. Such programs may, however, be too general and too much a mixture of disciplines for developing applied social scientists in each of the various disciplines, as in the case of the relationship of chemical engineers to the disciplines of chemistry. Economics and psychology perhaps lead among all the social and behavioral sciences in already possessing an "engineering" dimension. They need further development in this direction, and political science and sociology have only begun to focus attention upon developing the kinds of professional competence envisioned.

Existing training programs in the universities that use the social sciences tend to assume that their graduates will occupy operating administrative positions. The personnel need the Committee has in mind is for researchers specifically attuned to operational contexts, rather than administrators. Policy-planning and evaluation, whether in the area of national security or health and education programs, are looming larger every day as important dimensions of the operations of government. The principal consumers of evaluative program research are unable to spend time on the formulation and definition of their research needs. Evaluative studies, therefore, frequently tend to be quite general in character and to require sympathetic and detailed interpretation. If a cadre of applied social scientists could

be developed, they might perform this dual role of interpretation and operational definition of research needs. They would, as part of their training, presumably learn how to communicate both in the research language of their discipline and in the language of the policy-making user of research.

While the Department of Defense needs applied social science, it cannot be said that it has a primary responsibility for inaugurating major efforts toward the establishment of educational patterns designed to produce the required talents. It can, however, serve to stimulate and encourage such efforts.

We recommend that the Department of Defense bring to the attention of other agencies with similar needs for a policy-research interface the desirability of and opportunities for encouraging the development of applied social and behavioral scientists. The National Security Council and the Domestic Council in the Executive Office of the President--both of which must be very conscious of this need--might be appropriate sources of an interdepartmental statement on this need and the ways to fulfill it.

VIII. *A Foreign-Area Research Structure*

We have already recommended the creation of a new institutional structure, government-wide, to which the Department of Defense would have access, which would include all the national security agencies.* We recommend also the phased transfer of Department of Defense responsibility for foreign-area research to this organization.

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* See above, p. 22.

A critical dimension of the problem of securing effective foreign area and policy-planning studies lies in the institutional arrangements for managing these kinds of research. Also needed are means for developing among researchers awareness of the importance of shaping their investigations so as to make them meaningful to policy-makers. This does not, of course, imply a style in research that represents an unthinking response to the bidding of policy-makers.

As an outside group, the Committee does not believe that it is in a position to prescribe detailed institutional blueprints for the effective management of foreign area and policy-planning research. We think we can, however, suggest certain principles and parameters for consideration in working out the details.

To ensure the responsiveness of behavioral and social science research to the needs of the national security community, it will be necessary to achieve four objectives:

1. Improved overview and coordination of agency research programs: Better means are needed for the coordination of the many social and behavioral science research programs undertaken by agencies of the national security community in order to avoid unnecessary substantive overlap, as well as to construct an overarching framework within which specific agency programs may be formulated.

2. Conduct of targeted research on specific problems of concern to the national security community as a whole: There are many substantive needs that the national security agencies share. Examples of such needs are analyses of Soviet perspectives on the strategic arms race and the impact of the United States' involvement in

Vietnam upon the attitudes of Asian leaders. This type of research is of interest to the national security community as a whole. Moreover, frequently it must also be undertaken on short notice and with a highly specific focus that can be articulated only if the points of view of several agencies are taken into account.

3. Develop an effective information system: We referred earlier to the need for an information retrieval-system that can marshal sources of relevant information both quickly and unobtrusively. Such a system would be concerned principally with non-classified information, such as social science studies of particular nations or international situations. It would be designed primarily to provide a quick retrieval capability at times when research or in-depth staff studies are precluded by the press of events.

4. Provide policy analysis capability at the Presidential level: The President and his senior advisers should have at their disposal a research and analytic capability that will permit handling issues of the utmost sensitivity, as already exists to a small but important degree in the National Security Council staff. Research on such issues must perforce be undertaken without alerting layers of bureaucracy either to their existence or to the policy alternatives being considered.

A research management structure to meet these needs would have certain identifiable characteristics. Among these is a linkage between research administrators and decision-makers sufficiently close to enable (1) translating information needs of decision-makers into researchable questions; (2) indicating to decision-makers when research might contribute to the resolution of their problems;

(3) interpreting research findings to decision-makers, so that they can be alerted to both the significance and limitations of findings; and (4) ensuring that research findings reach the right decision-maker at the right time.

The research-management structure must provide both the overview responsibility and the authority to monitor agency research programs, to reduce redundancy, and to contribute a broader perspective within which agency programs can place their own work. Moreover, it must be capable of serving as final arbiter in jurisdictional disputes between agencies and of undertaking research of interest to the national security community as a whole, but perhaps not particularly appropriate for any single agency to sponsor.

Of the numerous institutional alternatives that might be considered for meeting these requirements, the Committee believes that the following are most worthy of attention and careful evaluation, for each has disadvantages as well as advantages:

a. National Security Council Staff: It has been suggested that the National Security Council staff be enlarged to include individuals whose function it would be to manage foreign-area research and policy-planning studies. The policy responsibility would lie with the President's National Security Adviser and his staff.

b. Interdepartmental Groups Within the National Security Council Structure: According to this approach, the research management function would be built into the National Security Council operating structure. Policy responsibility would rest with the five regional Interdepartmental Groups. These Groups would be supported by a staff of demonstrated competence in both research and

its administration.

c. Interagency Committee Within the Research Community: Another form of interagency grouping, suggested by a subcommittee of the Defense Science Board, would consist of representatives from appropriate research programs within the national security community. They would sit on a committee under the chairmanship of either the Director of Defense Research and Engineering or the Under Secretary of State. This committee would have both policy and managerial responsibilities relating to research.

A choice among these possibilities should, we have concluded, not be recommended by the Committee. That determination is better made by officials intimately in touch with the situation, for there are matters of prudential judgment involved that would modify the application of the principles enunciated here. These principles can, however, guide the practical decision.

IX. *Conclusion*

Research management comprises tasks on many levels. As we have already observed, only those intimately involved can speak with authority about the most desirable specific arrangements. What an outside group, such as this Committee, can best do is provide a perspective and a set of guidelines. This we have attempted to do.

Although there is bitter feeling today between the Department of Defense and some segments of the social science community, and although some tensions will always exist between policy-making users of research and outside researchers, there is, nevertheless, an ongoing relationship that is potentially productive and that needs to

be better managed than it is. Those who wish to see national security policy changed, as well as those who endorse present policies, can surely agree that a policy process informed by first-rate research and assuring clear communication between policy-makers and researchers deserves encouragement.

The Committee hopes that the frame of reference provided here will be conducive to such a better relationship.

Item 1b

FEB 16 1971

Public Participation in the Evolution of Change --
(extract of a letter from Dr. Edward E. David, Jr.)

Your inquiry concerning Toffler's book, Future Shock, has stimulated a great deal of discussion and soul-searching among PSAC'ers and others in OST. An examination of several specific cases indicates that there is no evidence for the future shock phenomenon as described by Toffler. For example, our parents and grandparents who moved from the farms, first had railroads, electricity, autos and aircraft, and gave up fundamentalism under the impact of science and urbanization, experienced drastic change, yet they did not experience future shock.

Stress or shock in individuals and societies appears to arise not from change itself but from a feeling of losing control over one's fate, which sometimes accompanies change. Thus, public shock, if any, arises because people do not feel adequately in control of their own destinies. Social science studies on resistance to change in organizations shows that people adapt to rapid change very well when they think they are causing it. They find it shocking when they believe it is being done to them. It is indeed true that many people do feel that change is being imposed. The incomprehensibility of technology is a major source of this feeling.

These conclusions do not suggest that the solution to the problem is simple. They do suggest that the situation can be remedied in part by providing broader, informed public participation in decision-making. The implied solution in Toffler's book, namely constraining change by technocratic techniques derived from "futurology", is likely to increase rather than decrease the unease of the man on the street. However, techniques are appearing which can help in forecasting the effects of technology and in tailoring it to human purposes.

A number of us in OST have thoughts about means for increasing public participation in this process. One of the most effective would bring decision-making as it affects daily lives down to the state and local level in line with the New Federalism. This direction implies more public education so that people will be prepared for enlightened decision-making and the incomprehensibility of technology will be reduced. People must

have a feeling for both humanistic and scientific cultures. Not all people can have a foot in both camps, but they can be fans who know the score and can cheer or boo appropriately. Other techniques for encouraging public participation are better information programs to avoid surprises, solicitation of advice and counsel by public officials, and Presidential progress reports on national problems such as air and water pollution and air traffic control. I would be glad to develop these ideas further should you so desire.

April 7, 1971

COPY

Dr. Herbert A. Simon
Professor of Computer Science and Psychology
Graduate School of Industrial Administration
Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213

Dear Herb:

Enclosed is a copy of Jay Forrester's note on the world model. When Jay isn't crusading for his results, his ideas on technique are very interesting and could be very useful.

Sincerely yours,

KHO/d
Enclosures (2)

Cc: Mr. David Z Beckler

Jay W. Forrester*
Professor of Management, M.I.T.

Reprinted from Technology Review
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Counterintuitive Behavior of Social Systems

This paper addresses several issues of broad concern in the United States: population trends; the quality of urban life; national policy for urban growth; and the unexpected, ineffective, or detrimental results often generated by government programs in these areas.

The nation exhibits a growing sense of futility as it repeatedly attacks deficiencies in our social system while the symptoms continue to worsen. Legislation is debated and passed with great promise and hope. But many programs prove to be ineffective. Results often seem unrelated to those expected when the programs were planned. At times programs cause exactly the reverse of desired results.

It is now possible to explain how such contrary results can happen. There are fundamental reasons why people misjudge the behavior of social systems. There are orderly processes at work in the creation of human judgment and intuition that frequently lead people to wrong decisions when faced with complex and highly interacting systems. Until we come to a much better understanding of social systems, we should expect that attempts to develop corrective programs will continue to disappoint us.

The purpose of this paper is to leave with its readers a sense of caution about continuing to depend on the same past approaches that have led to our present feeling of frustration and to suggest an approach which can eventually lead to a better understanding of our social systems and thereby to more effective policies for guiding the future.

A New Approach to Social Systems

It is my basic theme that the human mind is not adapted to interpreting how social systems behave. Our social systems belong to the class called multi-loop nonlinear feedback systems. In the long history of evolution it has not been necessary for man to understand these systems until very recent historical times. Evolutionary processes have not given us the mental skill needed to properly interpret the dynamic behavior of the systems of which we have now become a part.

*This paper is copyright 1971 by Jay W. Forrester. It is based on testimony for the Subcommittee on Urban Growth of the Committee on Banking and Currency, U.S. House of Representatives, on October 7, 1970. This text appeared in the January 1971 issue of *Technology Review*, published by the Alumni Association of the Massachusetts Institute of Technology.

In addition, the social sciences have fallen into some mistaken "scientific" practices which compound man's natural shortcomings. Computers are often being used for what the computer does poorly and the human mind does well. At the same time the human mind is being used for what the human mind does poorly and the computer does well. Even worse, impossible tasks are attempted while achievable and important goals are ignored.

Until recently there has been no way to estimate the behavior of social systems except by contemplation, discussion, argument, and guesswork. To point a way out of our present dilemma about social systems, I will sketch an approach that combines the strength of the human mind and the strength of today's computers. The approach is an outgrowth of developments over the last 40 years, in which much of the research has been at the Massachusetts Institute of Technology. The concepts of feedback system behavior apply sweepingly from physical systems through social systems. The ideas were first developed and applied to engineering systems. They have now reached practical usefulness in major aspects of our social systems.

I am speaking of what has come to be called industrial dynamics. The name is a misnomer because the methods apply to complex systems regardless of the field in which they are located. A more appropriate name would be *system dynamics.* In our own work, applications have been made to corporate policy, to the dynamics of diabetes as a medical system, to the growth and stagnation of an urban area, and most recently to world dynamics representing the interactions of population, pollution, industrialization, natural resources, and food. System dynamics, as an extension of the earlier design of physical systems, has been under development at M.I.T. since 1956. The approach is easy to understand but difficult to practice. Few people have a high level of skill; but preliminary work is developing all over the world. Some European countries and especially Japan have begun centers of education and research.

Computer Models of Social Systems

People would never attempt to send a space ship 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.

Our social systems are far more complex and harder to understand than our technological systems. Why, then, do we not use the same approach of making models of social systems and conducting laboratory experiments on those models before we try new laws and government programs in real life? The answer is often stated that our knowledge of social systems is insufficient for constructing useful models. But 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 directly design new social systems by passing laws and starting new social programs? I am suggesting that we now do know enough to make useful models of social systems. Conversely, we do not know enough to design the most effective social systems directly without first going through a model-building experimental phase. But I am confident, and substantial supporting evidence is beginning to accumulate, that the proper use of models of social systems can lead to far better systems, laws, and programs.

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 action.

Before going further, I should emphasize that there is nothing new in the use of models to represent social systems. Each of us uses models constantly. Every person in his private life and in his business life instinctively uses models for decision making. The mental image of the world around you which you carry in your head is a model. One does not have a city or 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. All of our decisions are taken on the basis of models. All of our laws are passed on the basis of models. All executive actions are taken on the basis of models. The question is not to use or ignore models. The question is only a choice among alternative models.

The mental model is fuzzy. It is incomplete. It is imprecisely stated. Furthermore, within one individual, a mental model changes with time and even during the flow of a single conversation. The human mind assembles a few relationships to fit the context of a discussion. As the subject shifts so does the model. When only a single topic is being discussed, each participant in a conversation employs a different mental model to interpret the subject. Fundamental assumptions differ but are never brought into the open. Goals are different and are left unstated. It is little wonder that compromise takes so long. And it is not surprising that consensus leads to laws and programs that fail in their objectives or produce new difficulties greater than those that have been relieved.

For these reasons we stress the importance of being explicit about assumptions and interrelating them in a computer model. Any concept or assumption that can be clearly described in words can be incorporated in a computer model. When done, the ideas become clear. Assumptions are exposed so they may be discussed and debated.

But the most important difference between the properly conceived computer model and the mental model is in the ability to determine the dynamic consequences when the assumptions within the model interact with one another. The human mind is not adapted to sensing correctly the consequences of a mental model. The mental model may be correct in structure and assumptions but, even so, the human mind—either individually or as a group consensus—is most apt to draw the wrong conclusions. There is no doubt about the digital computer routinely and accurately tracing through the sequences of actions that result from following the statements of behavior for individual points in the model system. This inability of the human mind to use its own mental models is clearly shown when a computer model is constructed to reproduce the assumptions held by a single person. In other words, the model is refined until it is fully agreeable in all its assumptions to the perceptions and ideas of a particular person. Then, it usually happens that the system that has been described does not act the way the person anticipated. Usually there is an internal contradiction in mental models between the assumed structure and the assumed future consequences. Ordinarily the assumptions about structure and internal motivations are more nearly correct than are the assumptions about the implied behavior.

The kind of computer models that I am discussing are strikingly similar to mental models. They are derived from the same sources. They may be discussed in the same terms. But computer models differ from mental models in important ways. The computer models are stated explicitly. The "mathematical" notation that is used for describing the model is unambiguous. It is a language that is clearer, simpler, and more precise than such spoken languages as English or French. Its advantage is in the clarity of meaning and the simplicity of the language syntax. The language of a computer model can be understood by almost anyone, regardless of educational background. Furthermore, any concept and relationship that can be clearly stated in ordinary language can be translated into computer model language.

There are many approaches to computer models. Some are naive. Some are conceptually and structurally inconsistent with the nature of actual systems. Some are based on methodologies for obtaining input data that commit the models to omitting major concepts and relationships in the psychological and human reaction areas that we all know to be crucial. With so much activity in computer models and with the same terminology having different meanings in the different approaches, the situation must be confusing to the casual observer. The key to success is not in having a computer; the important thing is how the computer is used. With respect to models, the key is not to computerize a model, but instead to have a model structure and relationships which properly represent the system that is being considered.

I am speaking here of a kind of computer model that is very different from the models that are now most common in the social sciences. Such a computer model is not derived statistically from time-series data. Instead, the kind of computer model I am discussing is a statement of system structure. It contains the assumptions being made about the system. The model is only as good as the expertise which lies behind its formulation. Great and correct theories in physics or in economics are few and far between. A great computer model is distinguished from a poor one by the degree to which it captures more of the essence of the social system that it presumes to represent. Many mathematical models are limited because they are formulated by techniques and according to a conceptual structure that will not accept the multiple-feedback-loop and nonlinear nature of real systems. Other models are defective because of lack of knowledge or deficiencies of perception on the part of the persons who have formulated them.

But a recently developed kind of computer modeling is now beginning to show the characteristics of behavior of actual systems. These models explain why we are having the present difficulties with our actual social systems and furthermore explain why so many efforts to improve social systems have failed. In spite of their shortcomings, models can now be constructed that are far superior to the intuitive models in our heads on which we are now basing national social programs.

This approach to the dynamics of social systems differs in two important ways from common practice in social sciences and government. There seems to be a common attitude that the major difficulty is shortage of information and data. Once data is collected, people then feel confident in interpreting the implications. I differ on both of these attitudes. The problem is not shortage of data but rather our inability to perceive the consequences of the information we already possess. The system dynamics approach starts with the concepts and information on which people are already acting. Generally these are sufficient. The available perceptions are then assembled in a computer model which can show the consequences of the well-known and properly perceived parts of the system. Generally, the consequences are unexpected.

Counterintuitive Nature of Social Systems

Our first insights into complex social systems came from our corporate work. Time after time we have gone into a corporation which is having severe and well-known difficulties. The difficulties can be major and obvious such as a falling market share, low profitability, or instability of employment. Such difficulties are known throughout the company and by anyone outside who reads the management press. One can enter such a company and discuss with people in key decision points what they are doing to solve the problem. Generally speaking we find that people perceive correctly their immediate environment. They know what they are trying to accomplish. They know the crises which will force certain actions. They are sensitive to the power structure of the organization, to traditions, and to their own personal goals and welfare. In general, when circumstances are conducive to frank disclosure, people can state what they are doing and can give rational reasons for their actions. In a troubled company, people are usually trying in good conscience and to the best of their abilities to sólve the major difficulties. Policies are being followed at the various points in the organization on the presumption that they will alleviate the difficulties. One can combine these policies into a computer model to show the consequences of how the policies interact with one another. In many instances it then emerges that the known policies describe a system which actually causes the troubles. In other words, the known and intended practices of the organization are fully sufficient to create the difficulty, regardless of what happens outside the company or in the marketplace. In fact, a downward spiral develops in which the presumed solution makes the difficulty worse and thereby causes redoubling of the presumed solution.

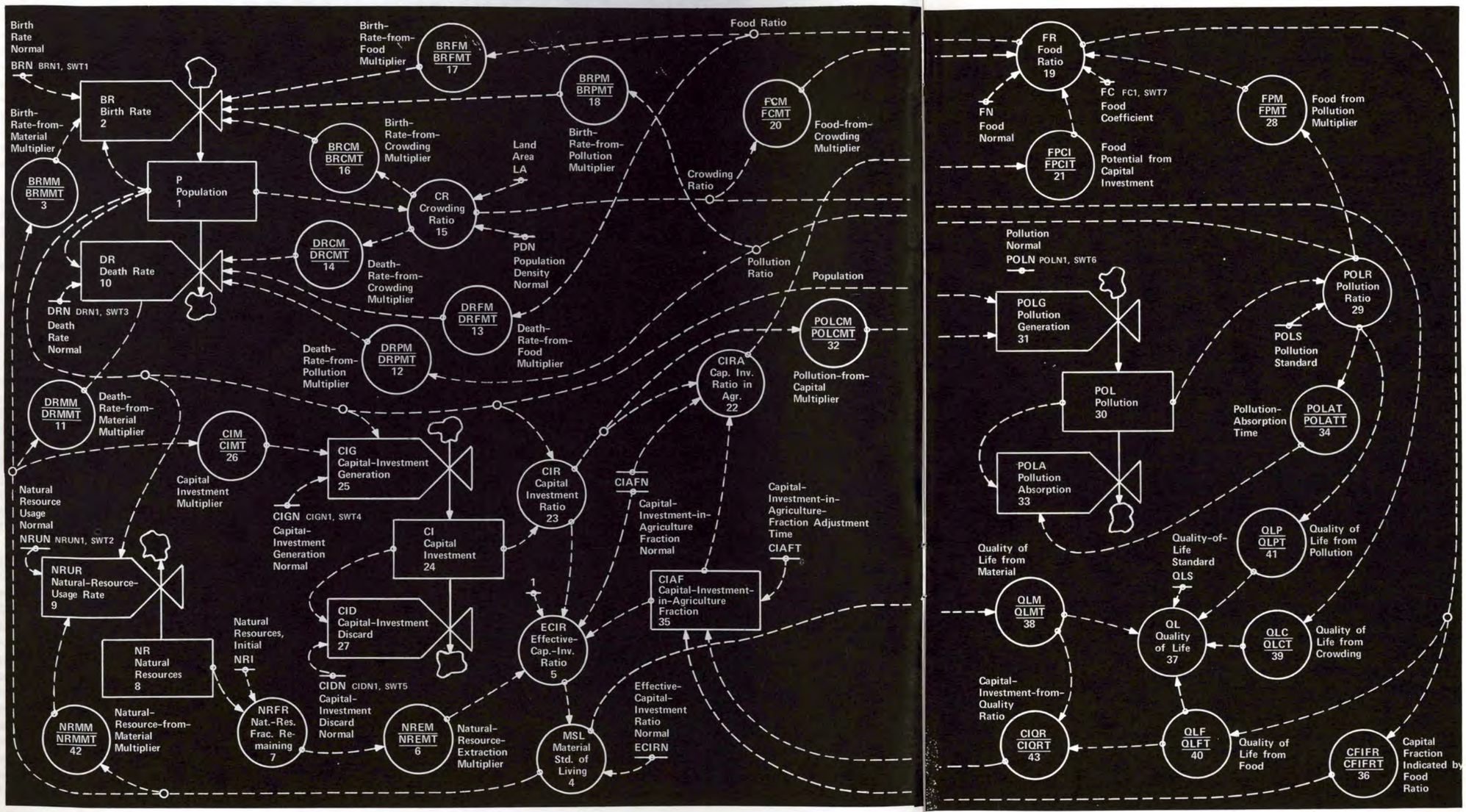
The same downward spiral frequently develops in government. Judgment and debate lead to a program that appears to be sound. Commitment increases to the apparent solution. If the presumed solution actually makes matters worse, the process by which this happens is not evident. So, when the troubles increase, the efforts are intensified that are actually worsening the problem.

Dynamics of Urban Systems

Our first major excursion outside of corporate policy began in February, 1968, when John F. Collins, former mayor of Boston, became Professor of Urban Affairs at M.I.T. He and I discussed my work in industrial dynamics and his experience with urban difficulties. A close collaboration led to applying to the dynamics of the city the same methods that had been created for understanding the social and policy structure of the corporation. A model structure was developed to represent the fundamental urban processes. The proposed structure shows how industry, housing, and people interact with each other as a city grows and decays. The results are described in my book *Urban Dynamics*, and some were summarized in *Technology Review* (*April, 1969, pp. 21-31*).

I had not previously been involved with urban behavior or urban policies. But the emerging story was strikingly similar to what we had seen in the corporation. Actions taken to alleviate the difficulties of a city can actually make matters worse. We examined four common programs for improving the depressed nature of the central city. One is the creation of jobs as by bussing the unemployed to the suburbs or through governmental jobs as employer of last resort. Second was a training program to increase the skills of the lowest-income group. Third was financial aid to the depressed city as by federal subsidy. Fourth was the construction of low-cost housing. All of these are shown to lie between neutral and detrimental almost irrespective of the criteria used for judgment. They range from ineffective to harmful judged either by their effect on the economic health of the city or by their long-range effect on the low-income population of the city.

Figure 1. *Upon this world model are based the author's analyses of the effects of changing population and economic growth factors in the next 50 years. It shows the interrelation of population, capital investment, natural resources, pollution, and the fraction of capital devoted to agriculture on which is based the following discussion.*



The results both confirm and explain much of what has been happening over the last several decades in our cities.

In fact, it emerges that the fundamental cause of depressed areas in the cities comes from *excess* housing in the low-income category rather than the commonly presumed housing shortage. The legal and tax structures have combined to give incentives for keeping old buildings in place. As industrial buildings age, the employment opportunities decline. 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, accommodates more low-income urban population than can find jobs. A social trap is created where excess low-cost housing beckons low-income people inward because of the available housing. They continue coming to the city until their numbers so far exceed the available income opportunities that the standard of living declines far enough to stop further inflow. Income to the area is then too low to maintain all of the housing. Excess housing falls into disrepair and is abandoned. One can 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.

Any change which would otherwise raise the standard of living only takes off the economic pressure momentarily and causes the population to rise enough that the standard of living again falls to the barely tolerable level. A self-regulating system is thereby at work which drives the condition of the depressed area down far enough to stop the increase in people.

At any time, a near-equilibrium exists affecting population mobility between the different areas of the country. To the extent that there is disequilibrium, it means that some area is slightly more attractive than others and population begins to move in the direction of the more attractive area. This movement continues until the rising population drives the more attractive area

down in attractiveness until the area is again in equilibrium with its surroundings. Other things being equal, an increase in population of a city crowds housing, overloads job opportunities, causes congestion, increases pollution, encourages crime, and reduces almost every component of the quality of life.

This powerful dynamic force to re-establish an equilibrium in total attractiveness means that any social program must take into account the eventual shifts that will occur in the many components of *attractiveness*. As used here, attractiveness is the composite effect of all factors that cause population movement toward or away from an area. Most areas in a country have nearly equal attractiveness most of the time, with only sufficient disequilibrium in attractiveness to account for the shifts in population. But areas can have the same composite attractiveness with different mixes in the components of attractiveness. In one area component A could be high and B low, while the reverse could be true in another area that nevertheless had the same total composite attractiveness. If a program makes some aspect of an area more attractive than its neighbor's, and thereby makes total attractiveness higher momentarily, population of that area rises until other components of attractiveness are driven down far enough to again establish an equilibrium. This means that efforts to improve the condition of our cities will result primarily in increasing the population of the cities and causing the population of the country to concentrate in the cities. The overall condition of urban life, for any particular economic class of population, cannot be appreciably better or worse than that of the remainder of the country to and from which people may come. Programs aimed at improving the city can succeed only if they result in eventually raising the average quality of life for the country as a whole.

On Raising the Quality of Life

But there is substantial doubt that our urban programs have been contributing to the national quality of life. By concentrating total population, and especially low-income population, in urban locations, undermining the strength and cohesiveness of the community, and making government and bureaucracy so big that the individual feels powerless to influence the system within which he is increasingly constrained, the quality of life is being reduced. In fact, if they have any effect, our efforts to improve our urban areas will in the long run tend to delay the concern about rising total population and thereby contribute directly to the eventual overcrowding of the country and the world.

Any proposed program must deal with both the quality of life and the factors affecting population. "Raising the quality of life" means releasing stress and pressures, reducing crowding, reducing pollution, alleviating hunger, and treating ill health. But these pressures are exactly the sources of concern and action aimed at controlling total population to keep it within the bounds of the fixed world within which we live. If the pressures are relaxed, so is the concern about how we impinge on the environment. Population will then rise further until the pressures reappear with an intensity that can no longer be relieved. To try to raise quality of life without intentionally creating compensating pressures to prevent a rise in population density will be self-defeating.

Consider the meaning of these interacting attractiveness components as they affect a depressed ghetto area of a city. First we must be clear on the way population density is, in fact, now being controlled. There is some set of forces determining that the density is not far higher or lower than it is. But there are many possible combinations of forces that an urban area can exert. The particular combination will determine the population mix of the area and the economic health of the city. I suggest that the depressed areas of most American cities are created by a combination of forces in which there is a job shortage and a housing excess. The availability of housing draws the lowest-income group until they so far exceed the opportunities of the area that the low standard of living, the frustration, and the crime rate counterbalance the housing availability. Until the pool of excess housing is reduced, little can be done to improve the economic condition of the city. A low-cost housing program alone moves exactly in the wrong direction. It draws more low-income people. It makes the area differentially more attractive to the poor who need jobs and less attractive to those who create jobs. In the new population equilibrium that develops, some characteristic of the social system must compensate for the additional attractiveness created by the low-cost housing. The counterbalance is a further decline of the economic condition for the area. But as the area becomes more destitute, pressures rise for more low-cost housing. The consequence is a downward spiral that draws in the low-income population, depresses their condition, prevents escape, and reduces hope. All of this is done with the best of intentions.

My paper, "Systems Analysis as a Tool for Urban Planning" from a symposium in October, 1969, at the National Academy of Engineering, suggests a reversal of present practice in order to simultaneously reduce the aging housing in our cities and allocate land to income-earning opportunities. The land shifted to industry permits the "balance of trade" of the area to be corrected by allowing labor to create and export a product to generate an income stream with which to buy the necessities of modern life from the outside. But the concurrent reduction of excess housing is absolutely essential. It supplies the land for new jobs. Equally important, the resulting housing shortage creates the population-stabilizing pressure that allows economic revival to proceed without being inundated by rising population. This can all be done without driving the present low-income residents out of the area. It can create *upward economic mobility* to convert the low-income population to a self-supporting basis.

The first reaction of many people to these ideas is to believe that they will never be accepted by elected officials or by residents of depressed urban areas. But some of our strongest support and encouragement is coming from those very groups who are closest to the problems, who see the symptoms first-hand, who have lived through the failures of the past, and who must live with the present conditions until enduring solutions are found.

Over the last several decades the country has slipped into a set of attitudes about our cities that are leading to actions that have become an integral part of the system that is generating greater troubles. If we were malicious and wanted to create urban slums, trap low-income people in ghetto areas, and increase the number of people on welfare, we could do little better than follow the present policies. The trend toward stressing income and sales taxes and away from the real estate tax encourages old buildings to remain in place and block self-renewal. The concessions in the income tax laws to encourage low-income housing will in the long run actually increase the total low-income population of the country. The highway expenditures and the government loans for suburban housing have made it easier for higher-income groups to abandon urban areas than to revive them. The pressures to expand the areas incorporated by urban government, in an effort to expand the revenue base, have been more than offset by lowered administrative efficiency, more citizen frustration, and the accelerated decline that is triggered in the annexed areas. The belief that more money will solve urban problems has taken attention away from correcting the underlying causes and has instead allowed the problems to grow to the limit of the available money, whatever that amount might be.*

Characteristics of Social Systems

I turn now to some characteristics of social systems that mislead people. These have been identified in our work with corporate and urban systems and in more recent work that I will describe concerning the world-wide pressures that are now enveloping our planet.

First, social systems are inherently insensitive to most policy changes that people select in an effort to alter the behavior of the system. In fact, a social system tends to draw our attention to the very points at which an attempt to intervene will fail. Our experience, which has been developed from contact with simple systems, leads us to look close to the symptoms of trouble for a cause. When we look, we discover that the social system presents us with an apparent cause that is plausible according to what we have learned from simple systems. But this apparent cause is usually a coincident occurrence that, like the trouble symptom itself, is being produced by the feedback-loop dynamics of a larger system. For example, as already discussed, we see human suffering in the cities; we observe that it is accompanied (some think caused) by inadequate housing. We increase the housing and the population rises to compensate for the effort. More people are drawn into and trapped in the depressed social system. As another example, the symptoms of excess population are beginning to overshadow the country. These symptoms appear as urban crowding and social pressure. Rather than face the population problem squarely we try to relieve the immediate pressure by planning industry in rural areas and by discussing new towns. If additional urban area is provided it will temporarily reduce the pressures and defer the need to face the underlying population question. The consequence, as it will be seen 25 years hence, will have been to contribute to increasing the population so much that even today's quality of life will be impossible.

A second characteristic of social systems is that all of them seem to have a few sensitive influence points through which the behavior of the system can be changed. These influence points are not in the locations where most people expect. Furthermore, if one identifies in a model of a social system a sensitive point where influence can be exerted, the chances are still that a person guided by intuition and judgment will alter the system in the wrong direction. For example in the urban system, housing is a sensitive control point but, if one wishes to revive the economy of a city and make it a better place for low-income as well as other people, it appears that the amount of low-income housing must be reduced rather than increased. Another example is the world-wide problem of rising population and the disparity between the standards of living in the developed and the underdeveloped countries, an issue arising in the world system to be discussed in the following paragraphs. But it is beginning to appear that a sensitive control point is the rate of generation of capital investment.

And how should one change the rate of capital accumulation? The common answer has been to increase industrialization, but recent examination suggests that hope lies only in reducing the rate of industrialization. This may actually help raise quality of life and contribute to stabilizing population.

As a third characteristic of social systems, there is usually a fundamental conflict between the short-term and long-term consequences of a policy change. A policy which produces improvement in the short run, within five to ten years, is usually one which degrades the system in the long run, beyond ten years. Likewise, those policies and programs which produce long-run improvement may initially depress the behavior of the system. This is especially treacherous. The short run is more visible and more compelling. It speaks loudly for immediate attention. But a series of actions all aimed at short-run improvement can eventually burden a system with long-run 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.

A Global Perspective

I have mentioned social organizations at the corporate level and then touched on work which has been done on the dynamics of the city. Now we are beginning to examine issues of even broader scope.

In July, 1970, we held a two-week international conference on world dynamics. It was a meeting organized for the Club of Rome, a private group of about 50

*Our continuing examination of urban behavior has been made possible through a grant to M.I.T. from the Independence Foundation of Philadelphia.

systems at the world level. Their interest lies in the same problems of population, resources, industrialization, pollution, and world-wide disparities of standard of living on which many groups now focus. But the Club of Rome is devoted to taking actions that will lead to a better understanding of world trends and to influencing world leaders and governments. The July meeting at M.I.T. included the general theory and behavior of complex systems and talks on the behavior of specific social systems ranging from corporations through commodity markets to biological systems, drug addiction in the community, and growth and decline of a city. Especially prepared for this conference was a dynamic model of the interactions between world population, industrialization, depletion of natural resources, agriculture, and pollution. A detailed discussion of this world system will soon appear in my book *World Dynamics,* and its further development is the purpose of the "Project on the Predicament of Mankind" being sponsored by the Club of Rome at M.I.T. for a year under the guidance of Professor Dennis Meadows. The plan is to develop a research group of men from many countries who will eventually base their continuing efforts in a neutral country such as Switzerland. The immediate project will reexamine, verify, alter, and extend the preliminary dynamic study of the world system and will relate it to the present world-wide concern about trends in civilization. *

The simple model of world interactions as thus far developed shows several different alternative futures depending on whether population growth is eventually suppressed by shortage of natural resources, by pollution, by crowding and consequent social strife, or by insufficient food. Malthus dealt only with the latter, but it is possible for civilization to encounter other controlling pressures before a food shortage occurs.

It is certain that resource shortage, pollution, crowding, food failure, or some other equally powerful force will limit population and industrialization if persuasion and psychological factors do not. Exponential growth cannot continue forever. 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 to choose, the social system by its internal processes will choose for us. The natural mechanisms for terminating exponential growth appear to be the least desirable. Unless we understand and begin to act soon, we may be overwhelmed by a social and economic system we have created but can't control.

Figure 1** shows the structure that has been assumed. It interrelates the mutual effects of population, capital investment, natural resources, pollution, and the fraction of capital devoted to agriculture. These five system "levels" are shown in the rectangles. Each level is

Figure 2. *Basic world model behavior showing the mode in which industrialization and population are suppressed by falling natural resources.*

Figure 3. *Pollution crisis precipitated by lower usage rate of natural resources. In 1970 natural resource usage is reduced 75 per cent by more effective technology without affecting material standard of living.*

caused to change by the rates of flow in and out, such as the birth rate and death rate that increase and decrease population. As shown by the dotted lines, the five system levels, through intermediate concepts shown at the circles, control the rates of flow. As an example, the death rate at Symbol 10 depends on population P and the "normal" lifetime as stated by death rate normal DRN. But death rate depends also on conditions in other parts of the system. From Circle 12 comes the influence of pollution that here assumes death rate to double if pollution becomes 20 times as severe as in 1970; and, progressively, that death rate would increase by a factor of 10 if pollution became 60 times as much as now. Likewise from Circle 13 the effect of food per capita is to increase death rate as food becomes less available. The detailed definition of the model states how each rate of flow is assumed to depend on the levels of population, natural resources, capital investment, capital devoted to food, and pollution.

Individually the assumptions in the model are plausible, create little disagreement, and reflect common discussions and assertions about the individual responses within the world system. But each is explicit and can be subjected to scrutiny. From one viewpoint, the system of Figure 1 is very simplified. It focuses on a few major factors and omits most of the substructure of world social and economic activity. But from another viewpoint, Figure 1 is comprehensive and complex. The system is far more complete and the theory described by the accompanying computer model is much more explicit than the mental models that are now being used as a basis for world and governmental planning. It incorporates dozens of nonlinear relationships. The world system shown here exhibits provocative and even frightening possibilities.

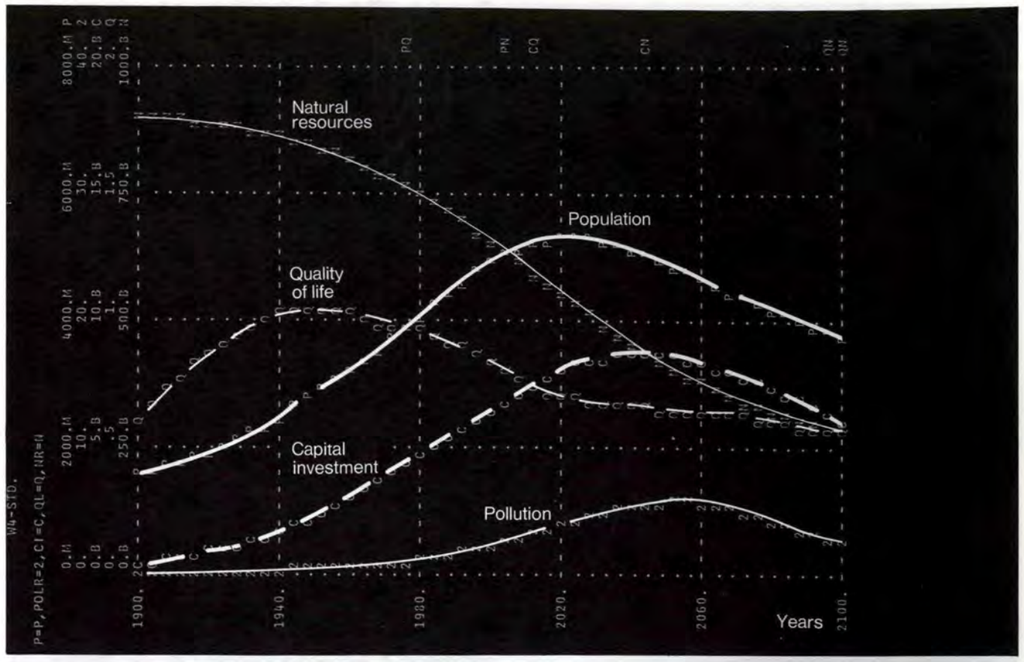
Transition from Growth to Equilibrium

With the model specified, a computer can be used to show how the system, as described for each of its parts, would behave. Given a set of beginning conditions, the computer can calculate and plot the results that unfold through time.

The world today seems to be entering a condition in which pressures are rising simultaneously from every one of the influences that can suppress growth—depleted resources, pollution, crowding, and insufficient individuals drawn from many countries who have joined together to attempt a better understanding of social

*The continuing project was made possible by financial support from the Volkswagen Foundation (Stiftung Volkswagenwerk) of West Germany.

**All figures are taken from the manuscript for *World Dynamics* by Jay W. Forrester, Wright-Allen Press, 238 Main Street, Cambridge, Mass. 02142, available about February, 1971.



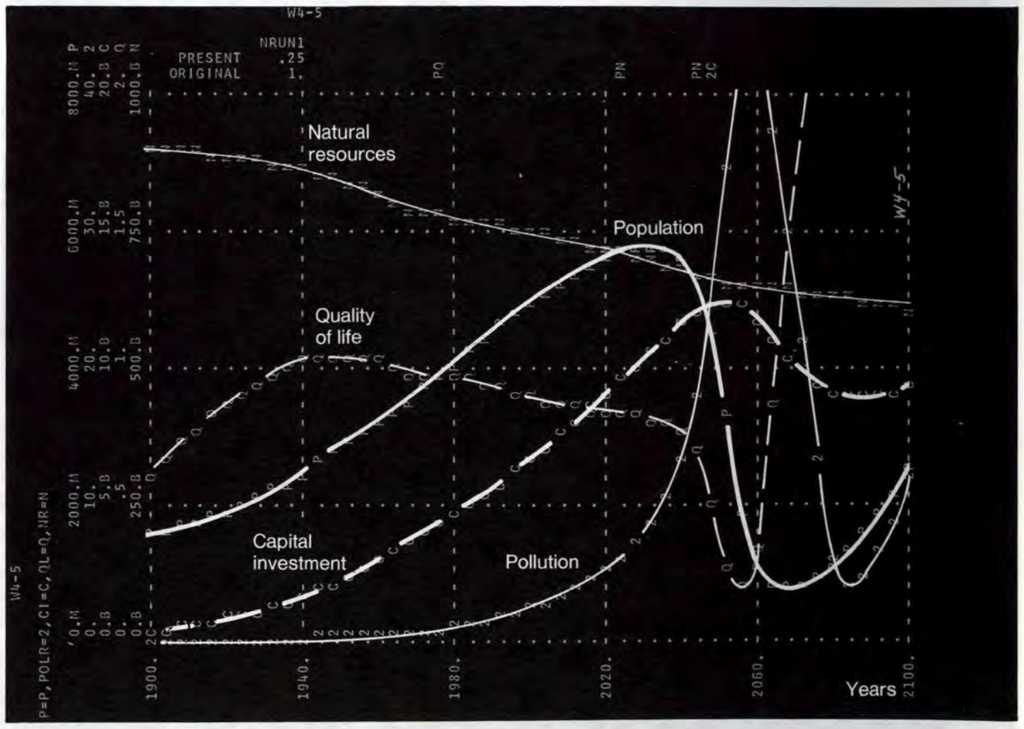


Figure 4. *In 1970 the rate of capital accumulation is increased 20 per cent in an effort to reverse the beginning decline in quality of life. The pollution crisis occurs before natural resources are depleted.*

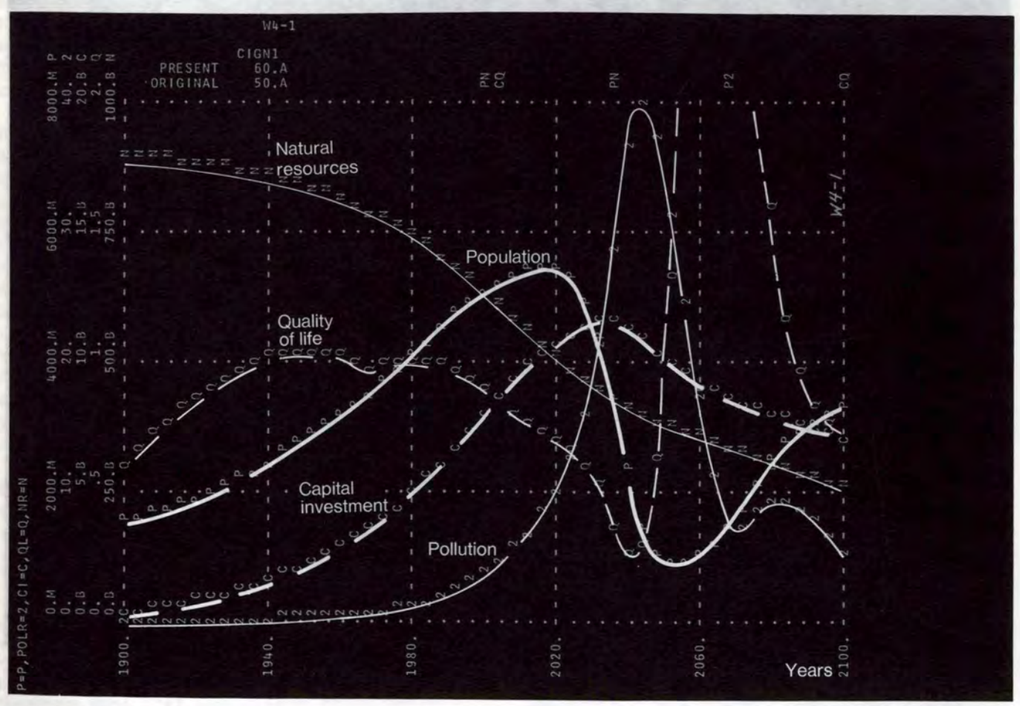
Figure 5. *In 1970 the 20 per cent increase in capital accumulation of Figure 4 is retained and "normal" birth rate is reduced 50 per cent. Capital investment continues to grow until the pollution crisis develops. After an initial decline, population is again pushed up by the rapid rise in quality of life that precedes the collapse.*

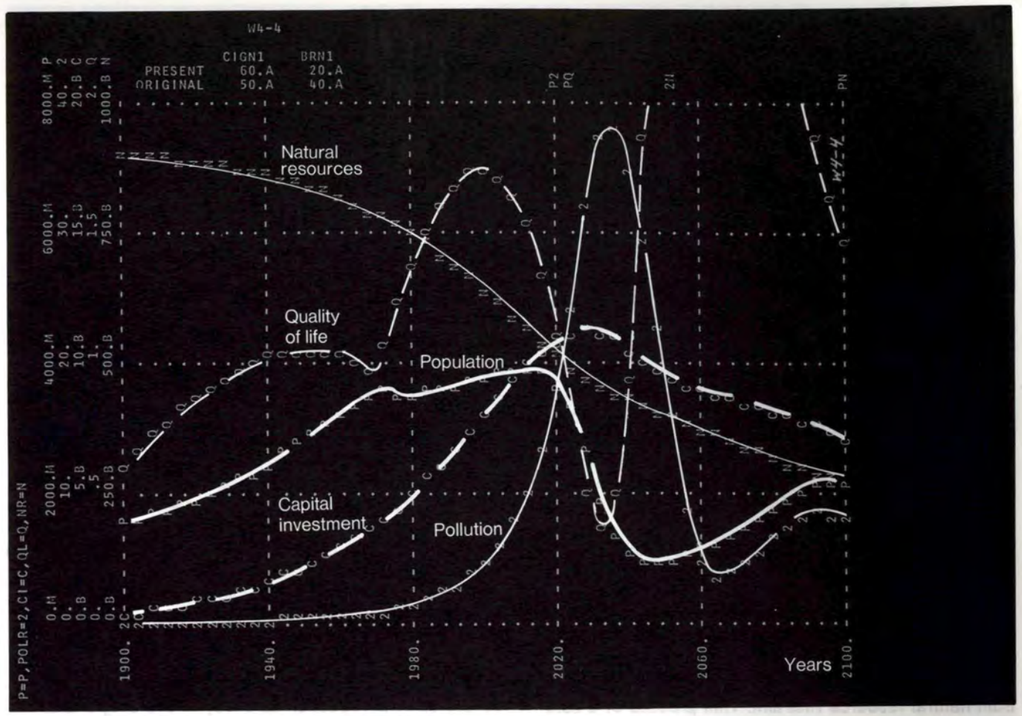
Figure 6. *The 20 per cent increase of capital investment from Figure 4 and the 75 per cent reduction of natural resource usage from Figure 3 are combined.*

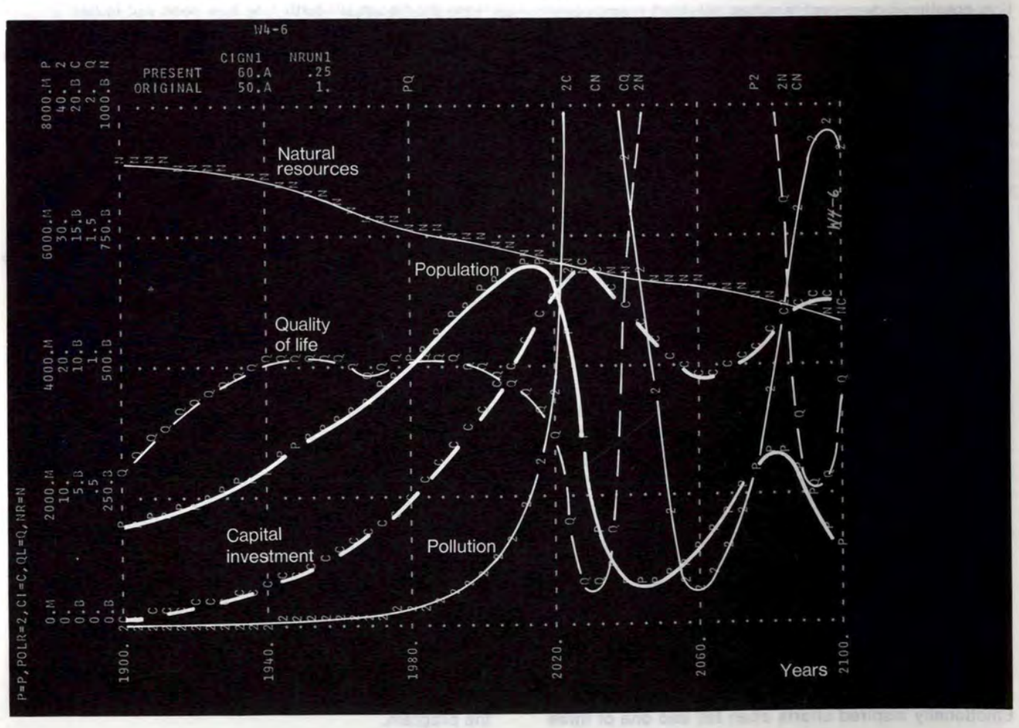
food. It is still unclear which will dominate if mankind continues along the present path. Figure 2 shows the mode of behavior of this world system given the assumption that population reaches a peak and then declines because industrialization is suppressed by falling natural resources. The model system starts with estimates of conditions in 1900. Adjustments have been made so that the generated paths pass through the conditions of 1970.

In Figure 2 the quality of life peaks in the 1950's and by 2020 has fallen far enough to halt further rise in population. Declining resources and the consequent fall in capital investment then exert further pressure to gradually reduce world population.

But we may not be fortunate enough to run gradually out of natural resources. Science and technology may very well find ways to use the more plentiful metals and atomic energy so that resource depletion does not intervene. If so, the way then remains open for some other pressure to arise within the system. Figure 3 shows what happens within this system if the resource shortage is foreseen and avoided. Here the only change from Figure 2 is in the usage rate of natural resources after the year 1970. In Figure 3, resources are used after 1970 at a rate 75 per cent less than assumed in Figure 2. In other words, the standard of living is sustained with a lower drain on the expendable and irreplaceable resources. But the picture is even less attractive! By not running out of resources, population and capital investment are allowed to rise until a pollution crisis is created. Pollution then acts directly to reduce birth rate, increase death rate, and to depress







food production. Population which, according to this simple model, peaks at the year 2030 has fallen to one-sixth of the peak population within an interval of 20 years—a world-wide catastrophe of a magnitude never before experienced. Should it occur, one can speculate on which sectors of the world population will suffer most. It is quite possible that the more industrialized countries (which are the ones which have caused such a disaster) would be the least able to survive such a disruption to environment and food supply. They might be the ones to take the brunt of the collapse.

Figure 3 shows how a technological success (reducing our dependence on natural resources) can merely save us from one fate only to fall victim to something worse (a pollution catastrophe). There is now developing throughout the world a strong undercurrent of doubt about technology as the savior of mankind. There is a basis for such doubt. Of course, the source of trouble is not technology as such but is instead the management of the entire technological-human-political-economic-natural complex.

Figure 3 is a dramatic example of the general process discussed earlier wherein a program aimed at one trouble symptom results in creating a new set of troubles in some other part of the system. Here the success in alleviating a natural resource shortage throws the system over into the mode of stopping population caused by industrialization which has been freed from natural resource restraint. This process of a solution creating a new problem has defeated many of our past governmental programs and will continue to do so unless we devote more effort to understanding the dynamic behavior of our social systems.

Alternatives to Decline or Catastrophe

Suppose in the basic world system of Figures 1 and 2 we ask how to sustain the quality of life which is beginning to decline after 1950. One way to attempt this, and it is the way the world is now choosing, might be to increase the rate of industrialization by raising the rate of capital investment. Models of the kind we are here using make such hypothetical questions answerable in a few minutes and at negligible cost. Figure 4 shows what happens if the "normal" rate of capital accumulation is increased by 20 per cent in 1970. The pollution crisis reappears. This time the cause is not the more efficient use of natural resources but the upsurge of industrialization which overtaxes the environment before resource depletion has a chance to depress industrialization. Again, an "obvious" desirable change in policy has caused troubles worse than the ones that were originally being corrected.

This is important, not only for its own message but because it demonstrates how an apparently desirable change in a social system can have unexpected and even disastrous results.

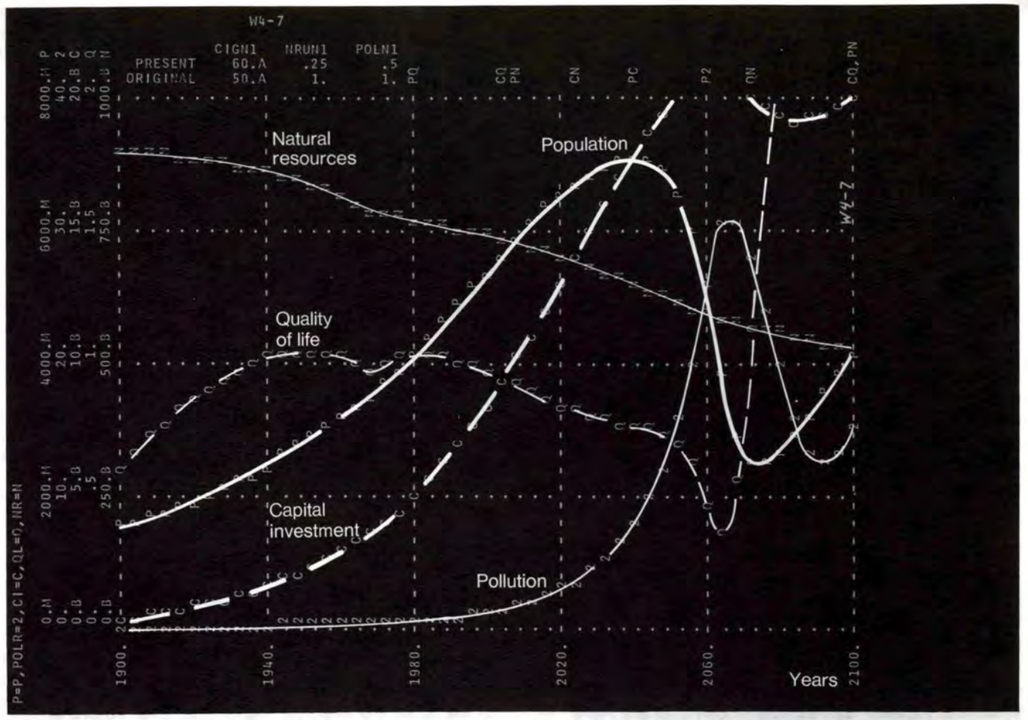
Figure 4 should make us cautious about rushing into programs on the basis of short-term humanitarian impulses. The eventual result can be anti-humanitarian. Emotionally inspired efforts often fall into one of three traps set for us by the nature of social systems: The programs are apt to address symptoms rather than causes and attempt to operate through points in the system that have little leverage for change; 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; and the effect of a program can be along an entirely different direction than was originally expected, so that suppressing one symptom only causes trouble to burst forth at another point.

Figure 5 retains the 20 per cent additional capital investment rate after 1970 from Figure 4 but in addition explores birth reduction as a way of avoiding crisis. Here the "normal" birth rate has been cut in half in 1970. (Changes in normal rates refer to coefficients which have the specified effect if all other things remain the same. But other things in the system change and also exert their effect on the actual system rates.) The result shows interesting behavior. Quality of life surges upward for 30 years for the reasons that are customarily asserted. Food-per-capita grows, material standard of living rises, and crowding does not become as great. But the more affluent world population continues to use natural resources and to accumulate capital plant at about the same rate as in Figure 4. Load on the environment is more closely related to industrialization than to population and the pollution crisis occurs at about the same point in time as in Figure 4.

Figure 5 shows that the 50 per cent reduction in "normal" birth rate in 1970 was sufficient to start a decline in total population. But the rising quality of life and the reduction of pressures act to start the population curve upward again. This is especially evident in other computer runs where the reduction in "normal" birth rate is not so drastic. Serious questions are raised by this investigation about the effectiveness of birth control as a means of controlling population. The secondary consequence of starting a birth control program will be to increase the influences that raise birth rate and reduce the apparent pressures that require population control. A birth control program which would be effective, all other things being equal, may largely fail because other things will not remain equal. Its very incipient success can set in motion forces to defeat the program.

Figure 7. *Increased capital investment rate and reduced natural resource usage from Figure 6 are retained. In addition in 1970 the "normal" rate of pollution generation is reduced 50 per cent. The effect of pollution control is to allow population to grow 25 per cent further and to delay the pollution crisis by 20 years.*

Figure 8. *One set of conditions that establishes a world equilibrium. In 1970 capital investment rate is reduced 40 per cent, birth rate is reduced 50 per cent, pollution generation is reduced 50 per cent, natural resource usage rate is reduced 75 per cent, and food production is reduced 20 per cent.*



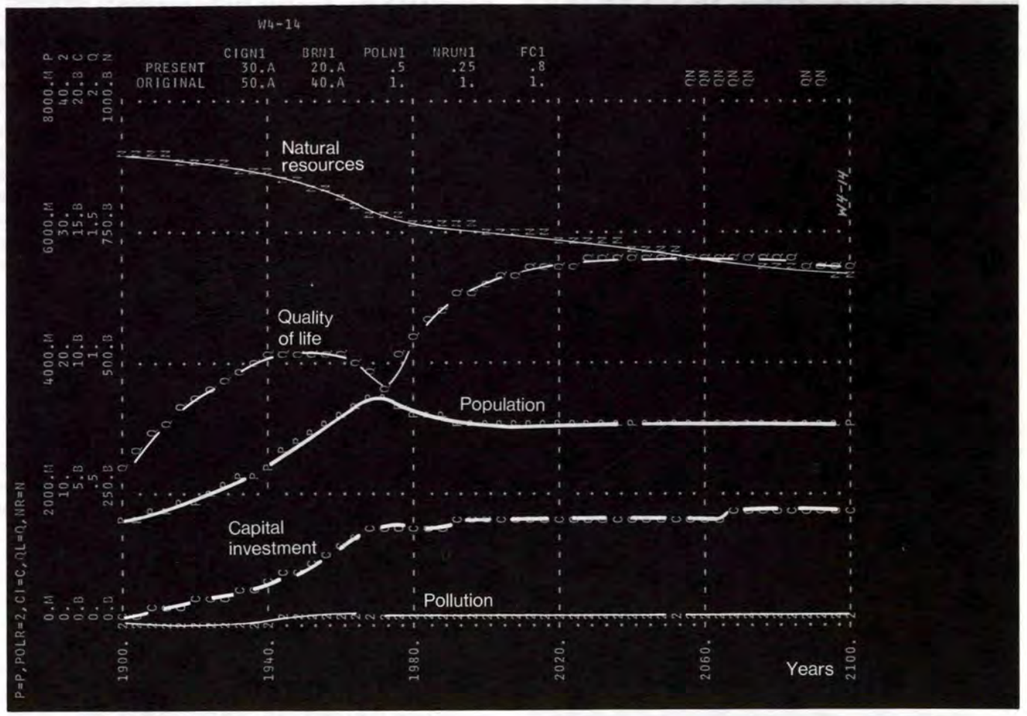


Figure 6 combines the reduced resource usage rate and the increased capital investment rate of Figures 3 and 4. The result is to make the population collapse occur slightly sooner and more severely. Based on the modified system of Figure 6, Figure 7 then examines the result if technology finds ways to reduce the pollution generated by a given degree of industrialization. Here in Figure 7, the pollution rate, other things being the same, is reduced by 50 per cent from that in Figure 6. The result is to postpone the day of reckoning by 20 years and to allow the world population to grow 25 per cent greater before the population collapse occurs. The "solution" of reduced pollution has, in effect, caused more people to suffer the eventual consequences. Again we see the dangers of partial solutions. Actions at one point in a system that attempt to relieve one kind of distress produce an unexpected result in some other part of the system. If the interactions are not sufficiently understood, the consequences can be as bad as or worse than those that led to the initial action.

There are no utopias in our social systems. There appear to be no sustainable modes of behavior that are free of pressures and stresses. But there are many possible modes and some are more desirable than others. Usually, the more attractive kinds of behavior in our social systems seem to be possible only if we have a good understanding of the system dynamics and are willing to endure the self-discipline and pressures that must accompany the desirable mode. The world system of Figure 1 can exhibit modes that are more hopeful than the crises of Figures 2 through 7. But to develop the more promising modes will require restraint and dedication to a long-range future that man may not be capable of sustaining.

Figure 8 shows the world system if several policy changes are adopted together in the year 1970. Population is stabilized. Quality of life rises about 50 per cent. Pollution remains at about the 1970 level. Would such a world be accepted? It implies an end to population and economic growth.

In Figure 8 the normal rate of capital accumulation is *reduced* 40 per cent from its previous value. The "normal" birth rate is reduced 50 per cent from its earlier value. The "normal" pollution generation is reduced 50 per cent from the value before 1970. The "normal" rate of food production is *reduced* 20 per cent from its previous value. (These changes in "normal" values are the changes for a specific set of system conditions. Actual system rates continue to be affected by the varying conditions of the system.) But reduction in investment rate and reduction in agricultural emphasis are counterintuitive and not likely to be discovered or accepted without extensive system studies and years of argument—perhaps more years than are available. The changes in pollution generation and natural resource usage may be easier to understand and to achieve. The severe reduction in world-wide birth rate is the most doubtful. Even if technical and biological methods existed, the improved condition of the world might remove the incentive for sustaining the birth reduction emphasis and discipline.

Future Policy Issues

The dynamics of world behavior bear directly on the future of the United States. American urbanization and industrialization are a major part of the world scene. The United States is setting a pattern that other parts of the world are trying to follow. That pattern is not sustainable. Our foreign policy and our overseas commercial activity seem to be running contrary to overwhelming forces that are developing in the world system. The following issues are raised by the preliminary investigations to date. They must, of course, be examined more deeply and confirmed by more thorough research into the assumptions about structure and detail of the world system.

◊ Industrialization may be a more fundamentally disturbing force in world ecology than is population. In fact, the population explosion is perhaps best viewed as a result of technology and industrialization. I include medicine and public health as a part of industrialization.

◊ Within the next century, man may be facing choices from a four-pronged dilemma—suppression of modern industrial society by a natural resource shortage, collapse of world population from changes wrought by pollution, population limitation by food shortage, or population control by war, disease, and social stresses caused by physical and psychological crowding.

◊ We may now be living in a "golden age" where, in spite of the world-wide feeling of malaise, the quality of life is, on the average, higher than ever before in history and higher now than the future offers.

◊ Efforts for direct population control may be inherently self-defeating. If population control begins to result as hoped in higher per capita food supply and material standard of living, these very improvements can generate forces to trigger a resurgence of population growth.

◊ The high standard of living of modern industrial societies seems to result from a production of food and material goods that has been able to outrun the rising population. But, as agriculture reaches a space limit, as industrialization reaches a natural-resource limit, and as both reach a pollution limit, population tends to catch up. Population then grows until the "quality of life" falls far enough to generate sufficiently large pressures to stabilize population.

◊ There may be no realistic hope for 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 an advanced country is probably 10 to 20 times greater than the load now generated by a person in an underdeveloped country. With four times as much population in underdeveloped countries as in the present developed countries, their rising to the economic level of the United States could mean an increase of 10 times in the natural resource and pollution load on the world environment. Noting the destruction that has already occurred on land, in the air, and especially in the oceans, no capability appears to exist for handling such a rise in standard of living for the present total population of the world.

◊ 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 is possible, the international strife over "pollution and environmental rights" may 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 to industrialize along Western patterns may be unwise. They may now be closer to the 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. When one of the several forces materializes that is strong enough to cause a collapse in world population, the advanced countries may suffer far more than their share of the decline.

A New Frontier

It is now possible to take hypotheses about the separate parts of a social system, to combine them in a computer model, and to learn the consequences. The hypotheses may at first be no more correct than the ones we are using in our intuitive thinking. But the process of computer modeling and model testing requires these hypotheses to be stated more explicitly. The model comes out of the hazy realm of the mental model into an unambiguous model or statement to which all have access. Assumptions can then be checked against all available information and can be rapidly improved. The great uncertainty with mental models is the inability to anticipate the consequences of interactions between the parts of a system. This uncertainty is totally eliminated in computer models. Given a stated set of assumptions, the computer traces the resulting consequences without doubt or error. This is a powerful procedure for clarifying issues. It is not easy. Results will not be immediate.

We are on the threshold of a great new era in human pioneering. In the past there have been periods characterized by geographical exploration. Other periods have dealt with the formation of national governments. At other times the focus was on the creation of great literature. Most recently we have been through the pioneering frontier of science and technology. But science and technology are now a routine part of our life. Science is no longer a frontier. The process of scientific discovery is orderly and organized.

I suggest that the next frontier for human endeavor is to pioneer a better understanding of the nature of our social systems. The means are visible. The task will be no easier than the development of science and technology. For the next 30 years we can expect rapid advance in understanding the complex dynamics of our social systems. To do so will require research, the development of teaching methods and materials, and the creation of appropriate educational programs. The research results of today will in one or two decades find their way into the secondary schools just as concepts of basic physics moved from research to general education over the past three decades.

What we do today fundamentally affects our future two or three decades hence. If we follow intuition, the trends of the past will continue into deepening difficulty. If we set up research and educational programs, which are now possible but which have not yet been developed, we can expect a far sounder basis for action.

The Nation's Real Alternatives

The record to date implies that our people accept the future growth of United States population as preordained, beyond the purview and influence of legislative control, and as a ground rule which determines the nation's task as finding cities in which the future population can live. But I have been describing the circular processes of our social systems in which there is no unidirectional cause and effect but instead a ring of actions and consequences that close back on themselves. One could say, incompletely, that the population will grow and that cities, space, and food must be provided. But one can likewise say, also incompletely, that the provision of cities, space, and food will cause the population to grow. Population generates pressure for urban growth, but urban pressures help to limit population.

Population grows until stresses rise far enough, which is to say that the quality of life falls far enough, to stop further increase. Everything we do to reduce those pressures causes the population to rise farther and faster and hastens the day when expediencies will no longer suffice. The United States is in the position of a wild animal running from its pursuers. We still have some space, natural resources, and agricultural land left. We can avoid the question of rising population as long as we can flee into this bountiful reservoir that nature provided. But it is obvious that the reservoirs are limited. The wild animal usually flees until he is cornered, until he has no more space. Then he turns to fight, but he no longer has room to maneuver. He is less able to forestall disaster than if he had fought in the open while there was still room to yield and to dodge. The United States 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 space to flee.

What does this mean? Instead of automatically accepting the need for new towns and the desirability of locating industry in rural areas, we should consider confining our cities. If it were possible to prohibit the encroachment by housing and industry onto even a single additional acre of farm and forest, the resulting social pressures would hasten the day when we stabilize population. Some European countries are closer to realizing the necessity of curtailing urban growth than are we. As I understand it, farm land surrounding Copenhagen cannot be used for either residence or industry until

the severest of pressures forces the government to rezone small additional parcels. When land is rezoned, the corresponding rise in land price is heavily taxed to remove the incentive for land speculation. The waiting time for an empty apartment in Copenhagen may be years. Such pressures certainly cause the Danes to face the population problem more squarely than do we.

Our greatest challenge now is how to handle the transition from growth into equilibrium. 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. But that is not the path of the future. Many of the present stresses in our society are from the pressures that always accompany the conversion from growth into equilibrium.

In our studies of social systems, we have made a number of investigations of life cycles that start with growth and merge into equilibrium. There are always severe stresses in the transition. Pressures must rise far enough to suppress the forces that produced growth. Not only do we face the pressure that will stop the population growth; we also encounter pressures that will stop the rise of industrialization and standard of living. The social stresses will rise. The economic forces will be ones for which we have no precedent. The psychological forces will be beyond those for which we are prepared. Our studies of urban systems demonstrated how the pressures from shortage of land and rising unemployment accompany the usual transition from urban growth to equilibrium. But the pressures we have seen in our cities are minor compared to those which the nation is approaching. The population pressures and the economic forces in a city that was reaching equilibrium have in the past been able to escape to new land areas.

But that escape is becoming less possible. Until now we have had, in effect, an inexhaustible supply of farm land and food-growing potential. But now we are reaching the critical point where, all at the same time, population is overrunning productive land, agricultural 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. For the first time demand is rising into a condition where supply will begin to fall while need increases. The crossover from plenty to shortage can occur abruptly.

The fiscal and monetary system of the country is a complex social-economic-financial system of the kind we have been discussing. It is clear the country is not agreed on behavior of the interactions between government policy, growth, unemployment, and inflation. An article by a writer for *Finance* magazine in July, 1970, suggests that the approach I have been discussing be applied in fiscal and monetary policy and their relationships to the economy. I estimate that such a task would be only a few times more difficult than was the investigation of urban growth and stagnation. The need to accomplish it becomes more urgent as the economy begins to move for the first time from a history of growth into the turbulent pressures that will accompany the transition from growth to one of the many possible kinds of equilibrium. We need to choose the kind of equilibrium before we arrive.

In a hierarchy of systems, there is usually a conflict between the goals of a subsystem and the welfare of the broader system. We see this in the urban system. The goal of the city is to expand and to raise its quality of life. But this increases population, industrialization, pollution, and demands on food supply. The broader social system of the country and the world requires that the goals of the urban areas be curtailed and that the pressures of such curtailment become high enough to keep the urban areas and population within the bounds that are satisfactory to the larger system of which the city is a part. If this nation chooses to continue to work for some of the traditional urban goals, and if it succeeds, as it may well do, the result will be to deepen the distress of the country as a whole and eventually to deepen the crisis in the cities themselves. We may be at the point where higher pressures in the present are necessary if insurmountable pressures are to be avoided in the future.

I have tried to give you a glimpse of the nature of multiloop feedback systems, a class to which our social systems belong. I have attempted to indicate how these systems mislead us because our intuition and judgment have been formed to expect behavior different from that actually possessed by such systems. I believe that we are still pursuing national programs that will be at least as frustrating and futile as many of the past. But there is hope. We can now begin to understand the dynamic behavior of our social systems. Progress will be slow. There are many cross-currents in the social sciences which will cause confusion and delay. The approach that I have been describing is very different from the emphasis on data gathering and statistical analysis that occupies much of the time of social research. But there have been breakthroughs in several areas. If we proceed expeditiously but thoughtfully, there is a basis for optimism.

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

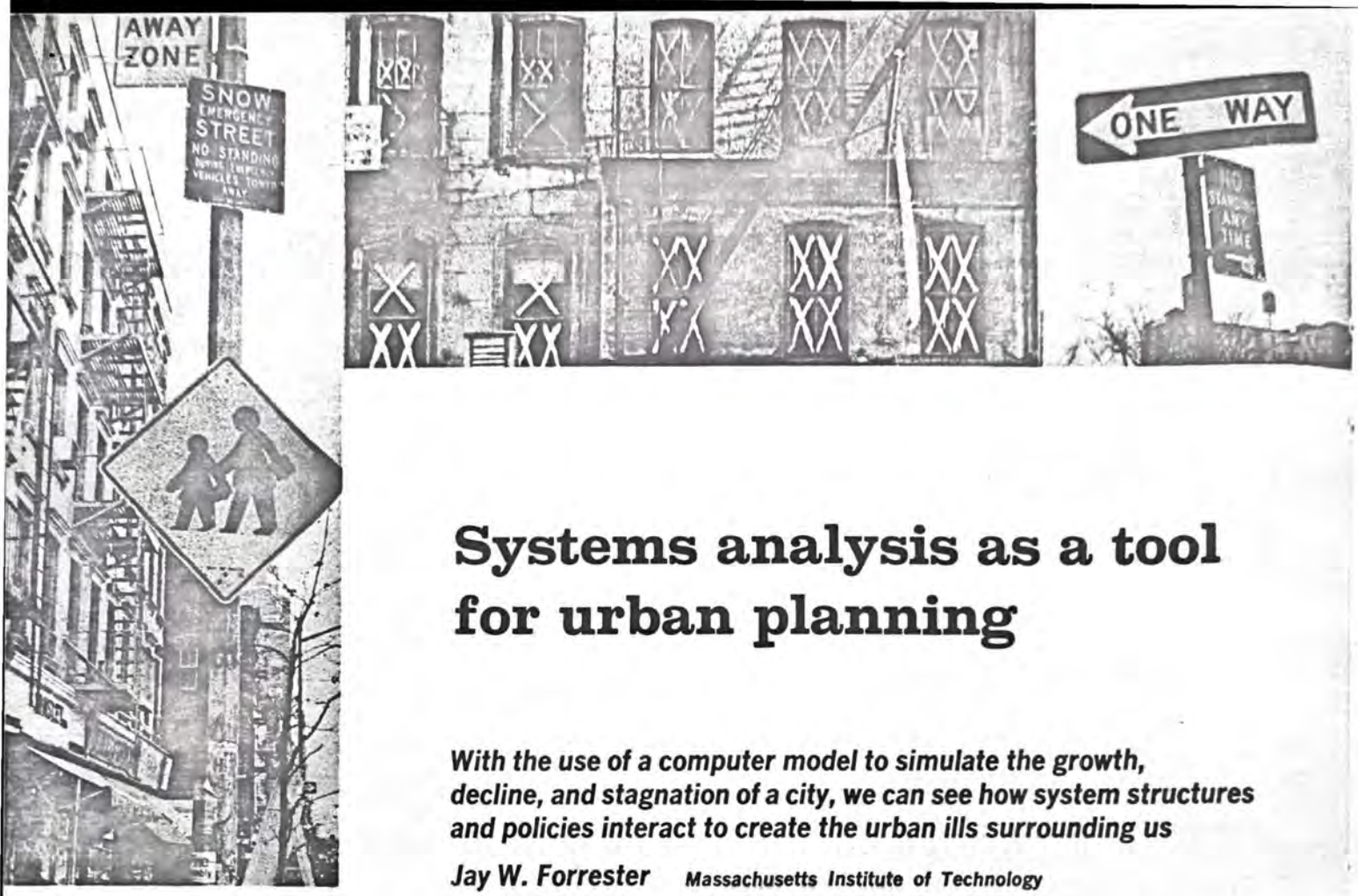
Jay W. Forrester, *Principles of Systems.* Wright-Allen Press, 238 Main St. Cambridge, Mass. 1968.

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

Jay W. Forrester, *World Dynamics.* Wright-Allen Press, 238 Main St., Cambridge, Mass., 1971.

Meadows, Dennis L., *Dynamics of Commodity Production Cycles.* Wright-Allen Press, 238 Main St., Cambridge, Mass., 1970.

Jay W. Forrester studied electrical engineering at the University of Nebraska and M.I.T. and made outstanding contributions to digital computer technology in the Digital Computer and Lincoln Laboratories at M.I.T. before joining the Sloan School of Management, where he has developed what has become known as "industrial dynamics." In 1968 he received the Inventor of the Year Award from George Washington University and in 1969 the Valdemar Poulsen Gold Medal from the Danish Academy of Technical Sciences. His book Industrial Dynamics *received the Academy of Management award in 1962 and his* Urban Dynamics *was chosen as best publication in 1969 by the Organization Development Council.*



Systems analysis as a tool for urban planning

With the use of a computer model to simulate the growth, decline, and stagnation of a city, we can see how system structures and policies interact to create the urban ills surrounding us

Jay W. Forrester *Massachusetts Institute of Technology*

Ways for analyzing social systems result in new policies for improving the behavior of systems in which we live. Such policies can change urban slums into areas designed for self-renewal. Already, studies into the relationships between monetary policy, interest rates, and foreign exchange have thrown new light on the processes of corporate growth, product stagnation, and loss of market share, and on the growth and decline of cities. At one time the engineer's task was simply to balance financial cost against the economic performance of his technology. Now, psychological stress, ugliness, and crowding have become part of the cost. Engineers who fail to realize this broadened role will be vilified by a society that views them as insensitive to the needs of the times.

Most of the traditional steps taken to alleviate the conditions of our cities may actually be making matters worse. This is one of the conclusions of my book, *Urban Dynamics*,[1] which shows the city as an interacting system of industry, housing, and people. By presenting a computer model that interrelates these components of the city, the book shows how interacting processes produce urban growth, then cause growth to give way to stagnation. Job training programs, job creation by bussing to suburban industries or by the government as an employer of last resort, financial subsidies to the city, and low-cost-housing programs—these presently popular proposals are tested and shown to lie between neutral and detrimental in their effect on a depressed urban area.

The evolution of an urban area from growth into stagnation creates a condition of excess housing compared with the population and the availability of income-earning opportunities. Reducing the inherent excess housing of depressed areas and converting part of the land to industrial use appear necessary to reestablish a healthy economic balance and a continuous process of urban renewal. Such actions can produce a large enough wage and salary stream from the outside economy to make the area self-sustaining.

These results are controversial but, if right, they mean that many policies for remedying urban troubles may be turning growth into decline. Although I present here some results from the book, my principal emphasis is on the importance of systems analysis as a bridge between engineering and the social sciences.

Industrial dynamics

Over a decade ago at M.I.T. we began to examine the dynamic characteristics of managerial systems. The field known as *industrial dynamics* resulted.[2] Industrial dynamics belongs to the same general subject area as feedback systems, servomechanisms theory, and cybernetics. Industrial dynamics is the study of how the feedback loop structure of a system produces the dynamic behavior of that system. In managerial terms industrial dynamics makes possible the structuring of the components and policies of a system to show how the resulting dynamic behavior is produced. In terms of social systems it deals

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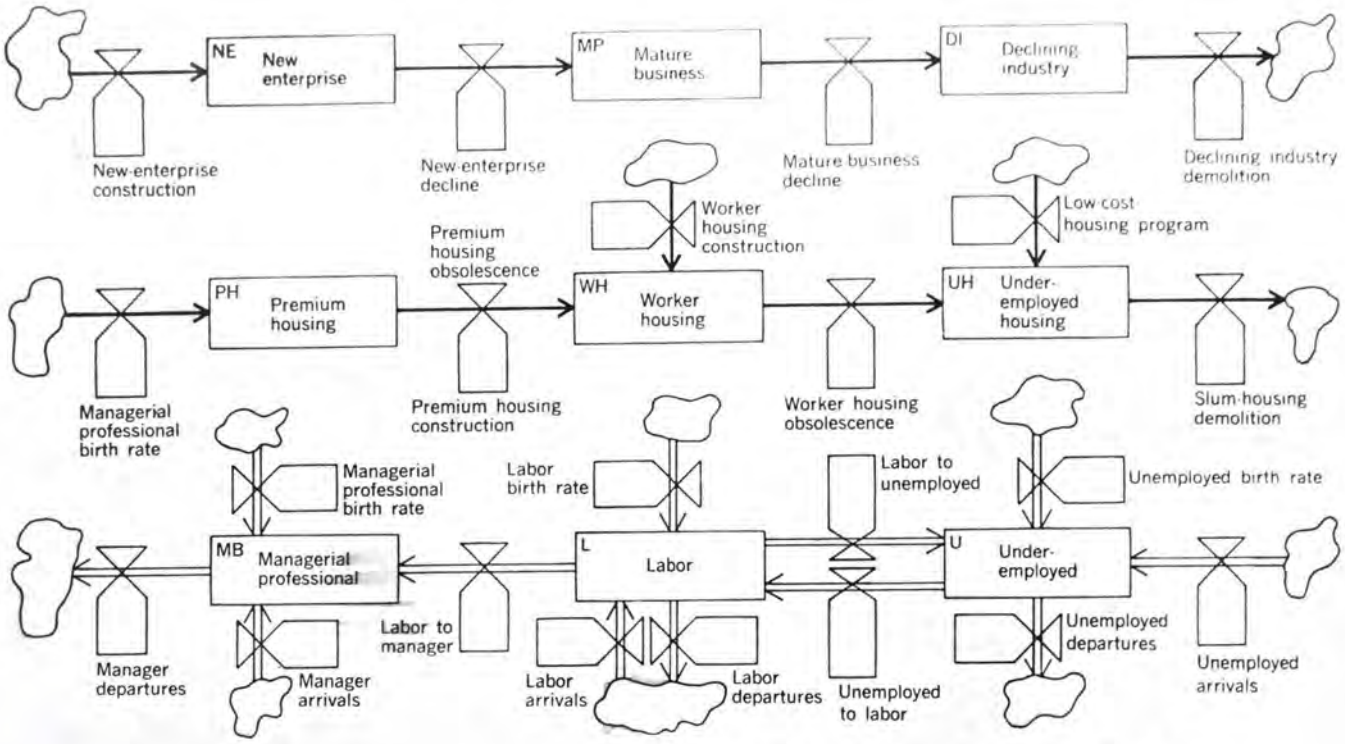


FIGURE 1. In this simplified urban system, nine levels are grouped into three subsystems. Across the top the industrial sector contains commercial buildings in three categories distinguished primarily by age. Across the center are residential buildings in three categories, also distinguished by age and condition. Across the bottom are three economic categories of population. Because of their complexity, the information linkages connecting the systems levels to the system rates are not shown. In this figure, the levels (rectangles) and rates (valves), along with the information linkages, represent the system components within the dynamic boundary. The "cloud" symbols are the sources or destinations of flows going from or to the outside environment. The flows from or to the outside are controlled only by conditions within the system.

with the forces that arise within a system to cause changes through time.

A design study of a social system seeks changes in structure and policies that will improve the behavior of the system. Some people recoil at the thought of designing social systems. They feel that designing a society is immoral. But we have no choice about living in a system that has been designed. The laws, tax policies, and traditions of a society constitute the design of a social system. Our only available choice is between different designs. If we lament the functioning of our cities or the persistence of inflation or the changes in our environment, we mean that we prefer a social system of a different design.

The six steps in the design process are: (1) observe the behavior modes of a system to identify the symptoms of trouble; (2) search for the feedback structures that might produce the observed behavior; (3) identify the level and rate variables making up that structure and explicitly describe them in the equations of a computer simulation model; (4) using the computer model, simulate in the laboratory the dynamic behavior implicit in the identified structure; (5) modify the structure until components and the resulting behavior agree with the observed conditions in the actual system; (6) introduce modified policies into the simulation model to find usable and acceptable policies that give improved behavior.

Surprising discoveries come from this combination of theory and laboratory experimentation: relatively simple structures produce much of the complex behavior of real-life systems, and people's skills in perception appear very different from those commonly supposed. It is often asserted in the social sciences that people are unreliable in analyzing their own actions, yet we find time and again that the policies and practices that people know they are following are the ones that interact to produce the most troublesome consequences. Conversely the vaunted powers of judgment and intuition usually deceive the person who tries to guess the time-varying consequences that follow even from a completely known system structure. We find that the modes of behavior that are most conspicuous in managerial, urban, and economic systems are produced by nonlinearities within those systems. The linearized models that have been used in much of engineering and the social sciences cannot even approximate the important modes of manifestations of nonlinear interactions. Including the so-called intangible factors relating to psychological variables, attitudes, and human reactions is relatively straightforward. Again, if the influences can be discussed and described, they can be inserted in the policy structure of a model. Any person who discusses why people act the way they do, or explains a past decision, or anticipates a future action is relating the surrounding circumstances to the corresponding human response. Any such discussion is a description of decision-making policy. Any such policy statement can be put into a system model.

Urban systems

A body of dynamic theory and principles of structure is emerging that allows us to organize and understand

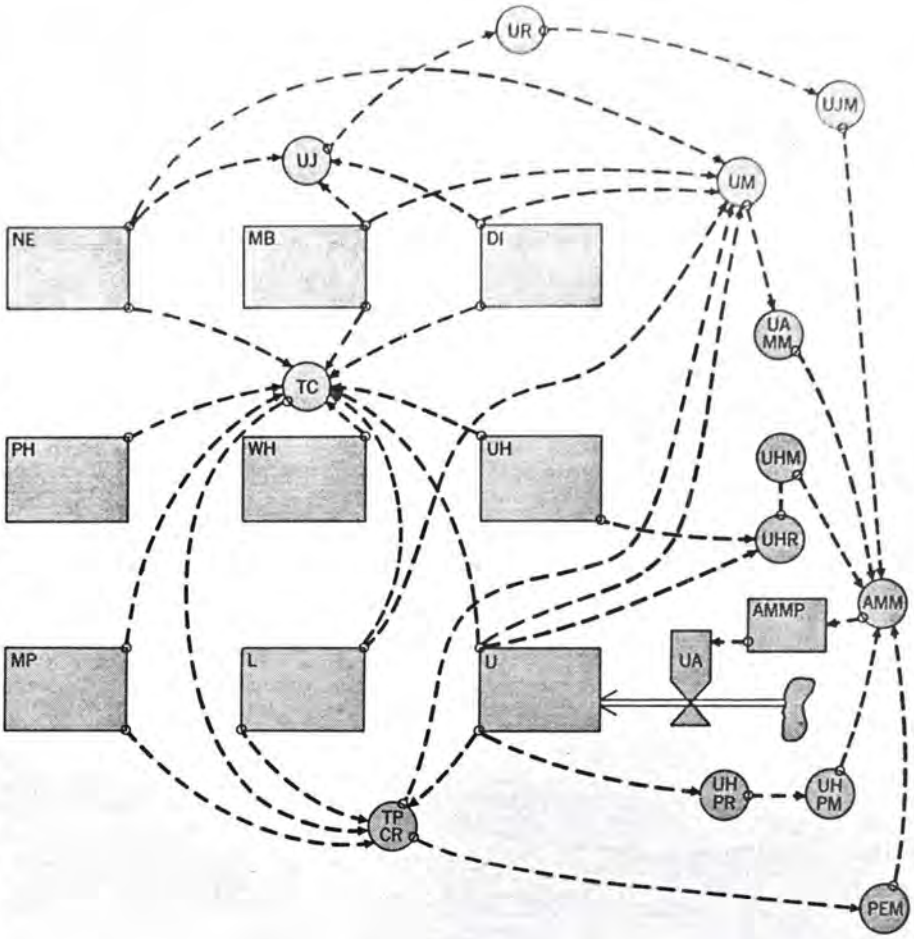


FIGURE 2. Information links to the underemployed-arrival rate. Five components of attractiveness are shown here. In the upper right corner UJM (underemployed/job multiplier) relates the population to available jobs and represents the income earning attractiveness of the area. The circle UAMM generates the attractiveness created by upward economic mobility. In other words, an area with high upward economic mobility is more attractive than one offering no hope of advancement. The circle UHM relates the underemployed population to the available housing. The area becomes more attractive as housing becomes more available. UHPM represents the attractiveness of a low-cost-housing program, if such exists. In the lower right corner PEM is the influence on attractiveness of the public expenditure per capita. As per-capita expenditure rises, it means better public services, better schools, and higher welfare budgets.

complex systems.[3] For example, the feedback loop becomes the basic building block of systems. Within the feedback loop there are two, and only two, kinds of variables. One is the *level variable* produced by integration; the other is the policy statement or *rate variable* that governs the changes in a system. The level variables are changed only by the rates of flow. The rate variables depend only on the levels. Any path through a system network encounters alternating level and rate variables. These and many other principles of structure are universal in the entire sweep of systems that change through time. Furthermore, the structure of a system determines its possible modes of behavior. Identical structures recur as one moves between apparently dissimilar fields. These identical structures behave in identical ways wherever they are found.

The same principles of structure and the same relationships between structure and behavior apply to a simple swinging pendulum, a chemical plant, the processes of management, internal medicine, economics, power politics, and psychiatry. A universal approach to time-varying systems that seems capable of dealing with systems of any complexity is emerging. Students, as they master the principles and practice of dynamic analysis, develop a remarkable mobility between fields of endeavor. The same person can clarify the dynamics of how a transistor functions, organize the processes of a public health epidemic, design new management policies to avoid stagnation in product growth, discover the sensitive factors in ecological change, and show how government policies affect the growth and decline of a city.

Figure 1 shows the central structure of an urban area. The nine rectangles represent the selected level variables. The twenty-two valve symbols represent the rates of flow that cause the nine system levels to change. Engineers often refer to these level variables as the state variables of a system. The distinction between level and rate variables is also familiar to anyone who examines financial statements. Balance sheet variables are always separated from variables on the profit-and-loss statement. They are separate because they are conceptually quite different. The balance sheet variables are system levels. They are created by accumulating financial flows. The profit-and-loss variables are system rates. This sharp distinction is found in all systems.

In Fig. 1 one can begin to detect the reasons for urban decline. The age of a building tends to determine the character of its occupants. A new commercial building is occupied by a healthy, successful commercial organization that uses relatively more managers and skilled workers than those who are unskilled. As the building ages, it tends to house a progressively less successful enterprise with lower employment skills. In addition to the changing employment mix as the industrial building ages, there is a tendency for total employment per unit of floor space to decline. On the other hand, as residential buildings age there is a tendency for occupancy to increase as well as to shift to a lower economic category of population. One perceives then a condition where the aging of buildings in an urban area simultaneously reduces the opportunities for employment and increases the population. The average income and standard of living decline.

Figure 2 shows the same nine system levels and one of

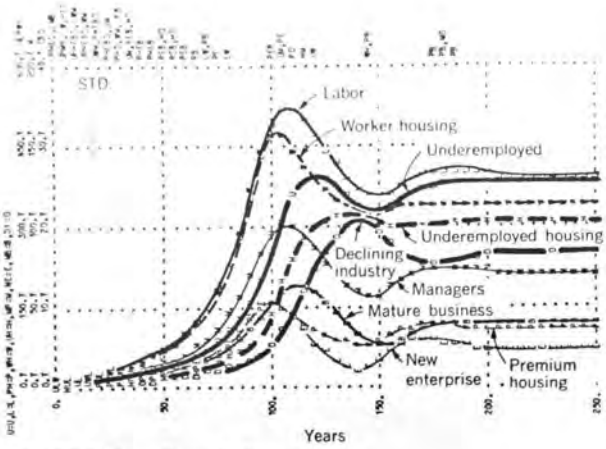


FIGURE 3. Growth and stagnation.

FIGURE 4. Changes in housing and employment.

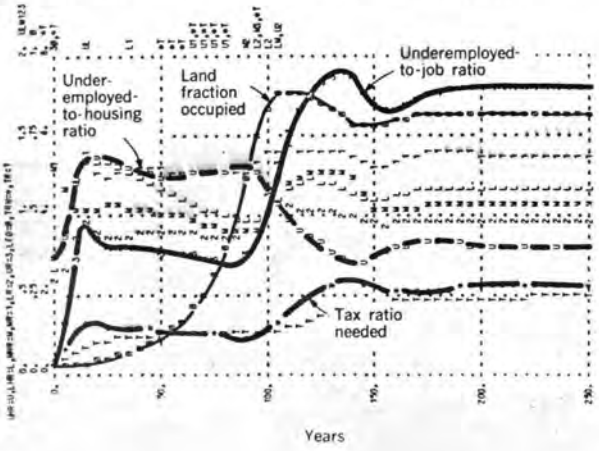
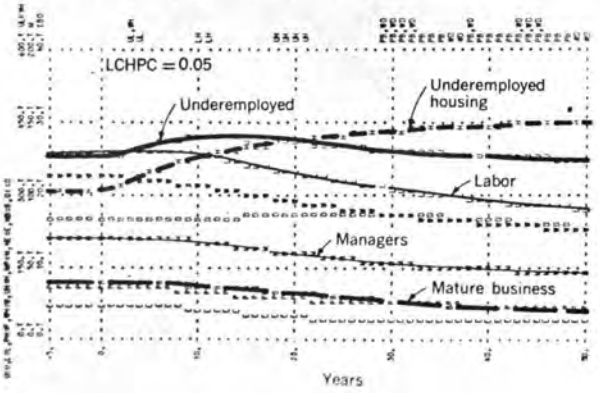


FIGURE 5. Decline of urban area caused by low-cost-housing construction each year for 2.5 percent of the underemployed population of a city.



the twenty-two flow rates. The dotted lines are the information linkages from the system levels to control the one flow rate—here the arrival of underemployed population into the urban area. The various levels of the system combine to create a composite *attractiveness*, which determines the inflow rate to the area. If the area is more attractive than those from which people might come, a net inward population flow occurs. If the area is less attractive, an outward flow dominates.

The concept of attractiveness is fundamental to the population flows. All of the characteristics of an area that make it attractive, these five and many more, combine to influence migration. An attractive area draws people. But almost every component of attractiveness is driven down by an increase in population. If there is an excess of housing, the area is attractive but a rising population crowds the housing. If there is an excess of jobs the area is attractive but the incoming flow of people fills these jobs. In other words, migration continues until the attractiveness of the area falls and becomes equal to any other places people might come from.

An important idea follows from examining these components of attractiveness. In a condition of population equilibrium, all areas must be equally attractive to any given population class, otherwise net migration would occur. If one component of attractiveness is increased in an area, other components must necessarily fall to establish a new equilibrium. Compensating changes in the components of attractiveness explain many past failures in our cities wherein we attempt to improve one aspect of the city only to discover that other aspects have become worse.

In making a laboratory model of a social system one should not attempt straightaway to solve a problem. Instead one should generate a model that will create the trouble symptoms. Only if one fully understands the processes whereby difficulties are created can he hope to correct the causes. This means that we want a model of an urban area that can start with empty land, grow a city, and show the processes whereby economic health falters into stagnation and decay.

As another guide to modeling, one should start, not by building a model of a particular situation, but instead by modeling the general class of systems under study. This may seem surprising, but the general model is simpler and initially is more informative than a model of a special case. Here we wish to model the general process of urban growth and stagnation. It should be a model that, with proper changes in parameters, is good 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 that describe their urban processes. There are fewer concepts common to all than are to be found in any one. The general model can strip away the multitude of detail that confuses any one special situation. The general model identifies the central processes and is a statement of the theory for the entire class of systems.

Figure 3 shows the behavior of the laboratory model of an urban area. It presents the nine system level variables over 250 years. The first 100 years is a period of exponential growth, but then the land area becomes filled, growth ceases, and the aging process begins. At year 100 near the end of the growth phase the labor population is almost double the underemployed population. But by year 150, the labor population has fallen and the underemployed population has risen until these two groups are almost equal. Business activity has declined and the area has taken on the characteristics of a depressed city. This has occurred because of the way that the industry, housing, and populations in Fig. 1 have interacted with each other.

Figure 4 shows other variables during the same 250 years. Notice especially the underemployed/job ratio and the underemployed/housing ratio. During most of the first 100 years of growth these two ratios were almost constant. The underemployed/housing ratio was high

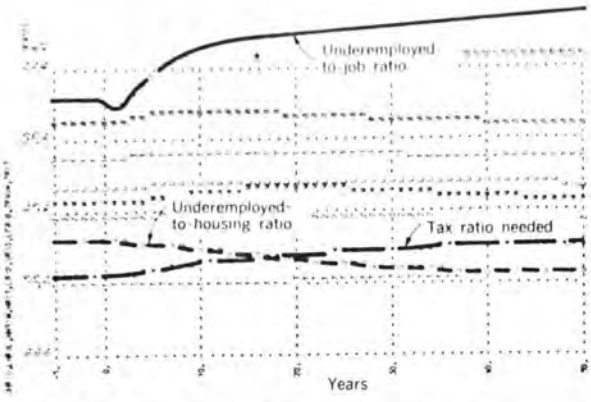
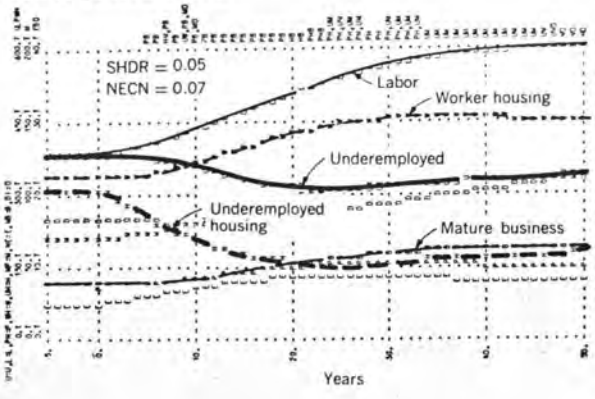


FIGURE 6. Rising unemployment and falling occupancy.

FIGURE 7. Revival caused by removing 5 percent of underemployed each year and encouraging business construction to generate jobs.



(above the center of the figure), meaning that the population is large compared with the housing. In other words, during the first 100 years there was a housing shortage for the underemployed population. On the other hand, the underemployed/job ratio was low, meaning that the population was below the job opportunities, jobs were readily available, economic opportunity was good, and upward economic mobility was high. During this early period of growth and high economic activity, the underemployed population was being effectively adjusted in relation to other activity by balancing good economic opportunity against a housing shortage.

But between 90 and 140 years, notice the sharp reversal of the curves for underemployed/job ratio and underemployed/housing ratio. Within this fifty-year span, the underemployed have increased while available jobs decreased; the result is a precipitous rise in unemployment. But in this same period, the housing that is aging and becoming available to the underemployed is rising even more rapidly than the underemployed population. Jobs have become scarce while housing has become surplus. The model is behaving the way our cities do.

Many people do not seem to realize that the depressed areas of our cities are areas of excess housing. The economy of the area is not able to maintain all of the available housing. Because of low incomes, people crowd into some dwelling units while other buildings are abandoned, stand idle, and decay.

Recall the earlier comments about compensating movements in the components of attractiveness. Here, as housing becomes more available, jobs become more scarce. The stagnating urban area has become a social trap. Excess housing beckons people and causes inward migration until the rising population drives down the standard of living far enough to stop the population inflow. Anything that tends to raise the standard of living is defeated by a rise of population into the empty housing.

Figure 5 shows fifty years beginning with the conditions found at the end of Fig. 3. At time zero, a low-cost-housing program is introduced which each year builds low-cost housing for two and one half percent of the underemployed population. Observe what happens. Underemployed housing, which is being actively constructed, rises forty-five percent, but premium housing falls thirty-five percent, and worker housing falls thirty percent. New enterprise declines fifty percent and mature business declines forty-five percent, all in the fifty-year period. Economic conditions become sufficiently worse so that even the underemployed population, although it rises initially, eventually falls to slightly less than its beginning value. *These changes are a result of the low-cost housing program.*

In Fig. 6, the corresponding underemployed/job ratio has risen thirty percent, indicating substantially higher unemployment, while the underemployed/housing ratio has fallen thirty percent, indicating a still higher excess of housing. Again, the two components of attractiveness compensate for one another with better housing and a falling standard of living. In the long run, the low-cost-housing program has not served the interests of the low-income residents. Instead, it has intensified the social trapping characteristic of the area. Over the period, the tax levies rise thirty-five percent. The area has become worse from almost all viewpoints.

In this same manner job training programs, job creation programs, and financial subsidies were examined. All lie between ineffective and harmful. The low-cost-housing program was the most powerful in depressing the condition of a stagnant urban area.

The depressed areas of our cities seem to be characterized by excess housing compared with jobs and by excessive concentration of low-income population. These conditions, created by aging industrial and dwelling buildings, interact to drive out the upper-income population and business activity, and to reduce the tax base. Once the decline starts, it tends to accelerate. Unless one can devise urban management policies that produce continuous renewal, difficulties are inherent.

Figure 7 shows an urban condition that begins with stagnation and then changes toward revival. Here five percent of the slum housing is removed each year and the incentives for new enterprise construction are increased somewhat. The result is a cascading of mutual interactions that raise the economic activity of the area, increase upward economic mobility for the underemployed population, and shift the population internally from the underemployed to the labor class. This is done without driving the existing low-income population out of the area. Underemployed housing is reduced. Initially this reduction comes largely from the empty housing. The resulting housing shortage restrains the population inflow that would otherwise defeat the revival of the area.

Figure 8 shows the same fifty-year span as in the preceding figure. Here again, employment and housing move in opposite directions. The underemployed/job ratio falls, which means more jobs and lower unemploy-

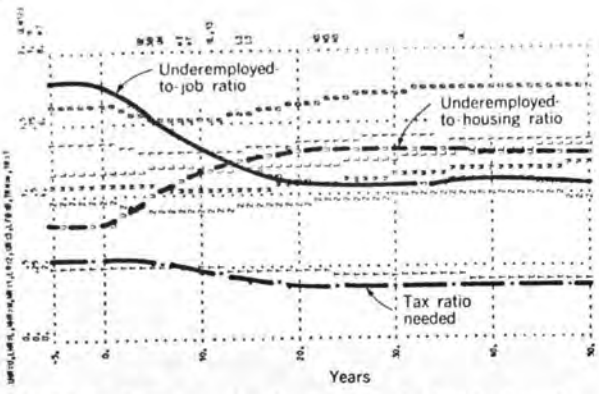


FIGURE 8. Falling unemployment and rise in housing occupancy for the same 50 years of Fig. 7.

ment. On the other hand, the underemployed/housing ratio rises, which means a tighter housing situation. If the economic circumstances are to be improved, we must accept some compensating change in other components of attractiveness. Here it is the increased tightness of housing that allows job opportunities to increase faster than population until a good economic balance is reached. I stress economic revival as the first stage of rebuilding a depressed area because it appears that an economic base must precede social and cultural development.

It is simply not possible to increase all of the attractiveness components of an area simultaneously. Attractiveness is here defined in a very broad sense. For example, legal restrictions like an immigration barrier into a country can produce enough "unattractiveness" to inward migration so that components might be maintained at a high level. But wherever one component of attractiveness is high others will be found low. Engineers, especially, should consider the compensating changes that will occur in the attractiveness components of an area because engineers tend to deal with economic considerations and technology. Economic and technical factors are more concrete than the intangible *quality of life* variables. The economic and technical aspects of a city are the ones we most easily see how to improve. Our technological society tends, therefore, to observe, react to, and improve the economic and technical aspects of a city. Such improvements increase the technical and economic components of urban attractiveness. But as a result, population density rises until the urban area once again reaches attractiveness equilibrium with its environment. The burden of forced reduction in other components of attractiveness falls on the quality of life variables—crowding, pollution, and psychological stress. These less tangible variables have been weak and hard to measure, and have been defenseless against the persuasiveness and the certainty of improvement shown by the technical and economic considerations. But we are entering a time when a reversal will occur between the formerly weak and strong variables. For a substantial fraction of our population, the standard of living is already high enough so that more gain in the economic and technical areas will come at too high a price in the quality-of-life components of our environment. The engineer, if he continues to serve society, must balance a greater number of social needs against one another. At one time his task was simply to balance financial cost against economic performance of his technology. Now the product and also the medium of payment are both expanding. Social value and quality of life become part of the product. Psychological stress, ugliness, and crowding become part of the cost. Engineers who fail to recognize this broadened role will be vilified and castigated by a society that perceives them as narrow and insensitive to the demands of the times.

When a system misbehaves, we should ask ourselves what policies within that system cause the undesirable characteristics. If we examine the laws under which a city operates, we see a structure of regulations that could hardly be designed better to create stagnation and decline. The aging and decay of buildings is central to the urban decline process, yet we see throughout our tax laws and regulations numerous incentives to keep old buildings in place. As the value of a building decreases, so do the assessed taxes. The reduced expense makes it possible to retain the old building longer. Under some circumstances the value of a building can be depreciated several times for income tax purposes. This produces incentives to keep an old building in place. This is not the place for detail, but it seems clear that a different set of tax laws and city regulations could be devised to produce the individual incentives necessary for continuous renewal. As an example, I recently saw a suggestion 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 if he demolishes the building and clears the land. This, you see, 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.

These studies of managerial, urban, and other social systems have uncovered complex systems characteristics that serve to identify potential detrimental modes of behavior. First, complex systems are counterintuitive. They behave in ways that are opposite to what most people expect. They are counterintuitive because our experience and intuition have been developed almost entirely from contact with simple systems. But 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.

Second, complex systems are strongly resistant to most policy changes. A new policy tends to warp the system so that slightly changed levels present new information to the policy points in the system. The new information, as processed through the new policies, tends to give the old results. There are inherent reasons within complex systems why so many of our attempts at correcting a city, a company, or an economy are destined to fail.

But third, the converse is also true. There are points in systems from which favorable influence will radiate. Often these points are difficult to perceive, and the required action is the opposite of what is expected. But when these points are found, they tend to radiate new information streams in such a way that the new circumstances, when processed through the old attitudes and policies, produce a new result.

Fourth, complex systems tend to counteract most active programs aimed at alleviating symptoms. For example, Chapter 4 in *Urban Dynamics* shows how a job training program can increase the number of underemployed in a city. When outside action tries to alter the condition of a system, the system relaxes its own internal processes aimed at the same result and throws the burden ever more onto

the outside force that is attempting to produce a correction. The internal need for action is reduced and the external supplier of action must work ever harder.

Fifth, 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 that 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 that produce results quickly. These are often the very actions that eventually drive the system to ever-worsening performance. Short-run versus long-run reversal processes are all around us. If an agricultural country is to industrialize, it must accumulate railroads, factories, and steel mills. This capital accumulation can only be done by foregoing consumption and reducing the standard of living first in order that the standard of living may rise at a later time. If a company faces declining earnings because its products are obsolete, it must invest more heavily in product research and incur even deeper short-term losses if it is to recover in the more distant future to a profitable product stream. A student forgoes short-term earning opportunities by attending college to increase his longer-term earning capability. This reversal between the short run and the long run occurs repeatedly.

Sixth, a system contains internal dynamic mechanisms that *produce* the observed undesirable behavior. If we ignore the fundamental causes and simply try to overwhelm the symptoms, we pit two great sets of forces against one another. 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. The causes will outlast our persistence in overwhelming the symptoms. Furthermore, the internal pressures usually rise to counteract a corrective force from the outside. We can expend all 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 spontaneously moves to a new mode of behavior.

As the last of these characteristics of complex systems, we must recognize that a certain ensemble of conditions goes with each possible mode of a system. More specifically, each mode of a system is accompanied by a set of pressures characteristic of that mode. We cannot sustain a particular mode unless we are willing to accept the corresponding pressures. For example, contrast the depressed mode of a city in Figs. 5 and 6 with the revived mode in Figs. 7 and 8. The depressed mode is one characterized by the pressures that come from decaying buildings, low incomes, and social disorientation. But the revived mode also contains pressures. The revived mode is sustained by the housing shortage and the legal and tax pressures that generate a steady demolition and replacement of old buildings. But everyone in the system will want to alleviate the pressures. Active industry will want more employees; residents will want more floor space; and outsiders will want housing so they can move to the attractive job opportunities. Rents will be high. These pressures are easy to relieve by increasing the fraction of the land area permissible for housing, by keeping old buildings in place longer, and by allowing taller apartment buildings. But such moves will start the area back toward the depressed mode. We must decide the kind of system we want with knowledge of and acceptance of the accompanying pressures. Instead, much of our social legislation of the last several decades has consisted of trying to relieve one set of pressures after another. The result is a system mode characterized by inflexibility, conformity, crowding, frustration, supremacy of the organization over the individual, and a choking of the environment. And the resulting pressures, acting through the counterintuitive and short versus long-term reversal characteristics of complex systems, may well move us further in the same direction.

I am suggesting that the time is approaching when we can design social systems to obtain far better behavior. Different policies could change our urban areas from ones that are designed to deteriorate into ones that are designed for self-renewal. One can foresee a time when we will understand far better the relationships between monetary policy, interest rates, unemployment, and foreign exchange. Already such studies have thrown new light on the processes of corporate growth, on the reasons for product stagnation and loss of market share, and on the growth and decline of cities.

To design new policies for social systems requires a level of skill that is rare. The kind of system modeling and policy design I have been describing requires a professional training at least as extensive as that in any of the established professions. The proper training requires theory, laboratory, case studies, apprenticeship, and practicing experience.

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REFERENCES

1. Forrester, J. W., *Urban Dynamics*. Cambridge, Mass.: The M.I.T. Press, 1969.

2. Forrester, J. W., *Industrial Dynamics*. Cambridge, Mass.: The M.I.T. Press, 1961.

3. Forrester, J. W., *Principles of Systems*. Cambridge, Mass.: Wright-Allen Press, Inc., preliminary printing of first ten chapters.

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In 1967 Dr. Forrester was elected to the National Academy of Engineering. He is a Fellow of both the American Academy of Arts and Sciences and the Academy of Management. In 1969 he received the honorary doctor of science degree from Boston University in recognition of contributions to computer technology, air defense, and urban dynamics. Also in 1969, the Danish Academy of Technical Sciences awarded him the Valdemar Poulsen Gold Medal. Dr. Forrester is a director of the ALZA Corporation. He is also a member of the American Physical Society, the American Economic Association, and ACM.

MODULAR SIZED INTEGRATED UTILITY SYSTEMS
PROGRAM SUMMARY FOR
BLUE RIBBON PANEL

PREPARED BY

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

IN COOPERATION WITH

ENVIRONMENTAL PROTECTION AGENCY
NATIONAL SCIENCE FOUNDATION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ATOMIC ENERGY COMMISSION

OCTOBER 6, 1971

PRESENTATION OUTLINE

1. PROGRAM DESCRIPTION
2. URGENT NATIONAL PROBLEM
3. RANGE OF APPLICATION
4. PROGRAM GOALS
5. PROGRAM PLAN
6. MANAGEMENT AND PARTICIPANTS
7. FEDERAL BUDGET IMPACT
8. NON-FEDERAL SUPPORT - UTILITY INDUSTRIES

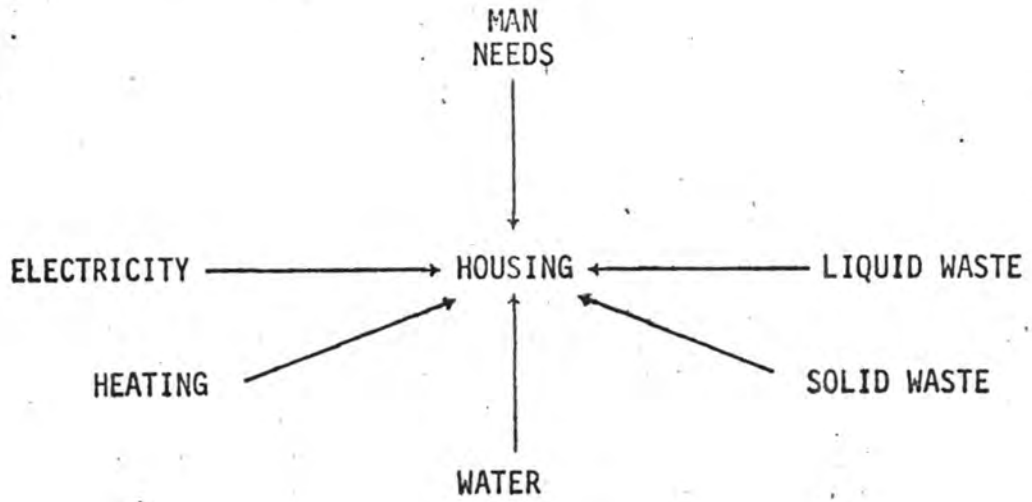
PROGRAM DESCRIPTION

THE PROGRAM WILL DEVELOP, DEMONSTRATE, EVALUATE AND IMPLEMENT WIDESPREAD USAGE OF MODULAR SIZED INTEGRATED UTILITY SYSTEMS.

A NECESSARY PREREQUISITE FOR URBAN/SUBURBAN DEVELOPMENT IS THE PROVISIONING OF FIVE SERVICES PROVIDED BY THESE INTEGRATED SYSTEMS. THEY ARE:

- ELECTRICITY
- HEATING, AIR CONDITIONING, HOT WATER, ETC.
- SOLID WASTE
- LIQUID WASTE
- DOMESTIC WATER

URGENT NATIONAL PROBLEMS



URGENT NATIONAL PROBLEMS (ALL $ 1971)

RESIDENTIAL PRESSURE FOR CAPITAL EXPENDITURES (1971 TO 1986)

$50 BILLION/YEAR FOR HOUSING	$750 BILLION
7% ANNUAL INCREASE IN RESIDENTIAL ELECTRICAL DEMAND (@ $300/KW)	$255 BILLION
OTHER COSTS SMALL BY COMPARISON (BUT INCREASING RAPIDLY)	
TOTAL LOWER BOUND 15-YEAR CAPITAL COSTS	$1,005 BILLION

RESIDENTIAL OPERATING COST COMPARISONS (1971 $ IN BILLIONS)

	1971	1986
7% ANNUAL INCREASE IN ELECTRICAL DEMAND (@ $.02/KWH)	8.8	24.2
4% ANNUAL INCREASE IN SPACE HEATING (GAS @ .003¢/KWH)	12.5	22.5
5% ANNUAL INCREASE IN SOLID WASTE (@ $22/TON)	4.2	8.6
2 1/2% ANNUAL INCREASE IN POTABLE WATER (@ $0.24/$10^3$ GALLON)	1.7	2.5
2 1/2% ANNUAL INCREASE IN LIQUID WASTE (@ $0.20/$10^3$ GALLON)	1.4	2.0
TOTAL ANNUAL OPERATING COSTS	$28.6B	$59.8B

RANGE OF APPLICATION - MARKET

. MULTI-FAMILY ANNUAL HOUSING STARTS HAVE INCREASED FROM 19% OF THE TOTAL IN 1959 TO OVER 50% IN 1970.

. ALL MULTI-FAMILY DWELLING UNITS ARE A POTENTIAL MARKET FOR INTEGRATED UTILITY SYSTEMS (ABOUT 13 MILLION UNITS BETWEEN 1976 AND 1986).

. IN ADDITION, COMMERCIAL, SCHOOLS AND OTHER LIKE UNITS PLUS MANY INDUSTRIAL APPLICATIONS ARE ALSO SIGNIFICANT POTENTIAL MARKETS.

. SUBSEQUENT ESTIMATES PRESENTED HEREIN OF CAPITAL AND OPERATING COST AND OTHER BENEFICIAL IMPACTS ARE CONSERVATIVE. ONLY THE 50% RESIDENTIAL MARKET IS ASSUMED (EVEN THOUGH IT PROBABLY WILL BE GREATER) AND NO CREDIT IS TAKEN FOR COMMERCIAL AND INDUSTRIAL APPLICATIONS.

PROGRAM GOALS - TOP LEVEL

CATEGORIES OF TOP LEVEL PROGRAM GOALS ARE:

- PROVIDE OPTIONS IN UTILITY SERVICES NEEDED FOR URBAN/SUBURBAN DEVELOPMENT, HAVING ADVANTAGES OVER EXISTING APPROACHES.

- MORE EFFICIENT ENERGY AND OTHER RESOURCE UTILIZATION.

- IMPROVE QUALITY AND ENVIRONMENT OF AMERICAN LIFE.

- REDUCE "TOTAL" COSTS.

- EXPAND PRIVATE INSTITUTIONAL PARTICIPATION, RESPONSIBILITY AND PERSPECTIVE IN PROVIDING UTILITY SERVICES.

- ESTABLISH U.S. TECHNICAL LEADERSHIP.

- BALANCE OF TRADE.

- NATIONAL PRODUCTIVITY AND EMPLOYMENT.

PROGRAM GOALS - SPECIFICS

"PROVIDE OPTIONS IN UTILITY SERVICES NEEDED FOR URBAN/SUBURBAN DEVELOPMENT, HAVING ADVANTAGES OVER EXISTING APPROACHES:"

- UTILITY SERVICES ARE "ON LINE FASTER" - REDUCED PLANNING TO OPERATION TIME SPAN BY OVER 75% (FROM 8+ YEARS TO 2 YEARS).

- REDUCE RISK, FINANCING QUESTIONS AND EARLY OPERATING COSTS THROUGH ADDING CAPACITY IN PHASE WITH ACTUAL DEMAND.

- MORE FLEXIBLE AND ECONOMICAL URBAN/SUBURBAN GROWTH PATTERNS POSSIBLE THROUGH SELF-CONTAINED UTILITY SYSTEMS THAT ARE INDEPENDENT OF EXISTING INFRASTRUCTURE.

PROGRAM GOALS - SPECIFICS

"MORE EFFICIENT ENERGY AND OTHER RESOURCE UTILIZATION."

- IMPROVE UTILITY SYSTEMS FUEL USEAGE EFFICIENCY FROM 35% TO 70%.
- RECYCLE 65% OF THE SOLID WASTES FROM URBAN/SUBURBAN SOURCES.
- IMPROVE EFFICIENCY OF DOMESTIC WATER USEAGE BY 80%.

PROGRAM GOALS - SPECIFICS

"REDUCE TOTAL COSTS"

- SAVE $62 BILLION BY 1986 IN POWER GENERATION FACILITY CAPITAL COSTS.

- USE 37% LESS FUEL IN GENERATION OF ELECTRICITY AND HEATING FOR DOMESTIC USE (FOR UNIT SERVED BY INTEGRATED UTILITY SYSTEMS).

- BY 1986 SAVE DOMESTIC USERS OF ELECTRICITY $3.8 BILLION ANNUALLY.

- BY 1986 SAVE 8.5% ($2.7 BILLION) OF THE TOTAL ANNUAL FUEL NEEDED FOR GENERATION OF ELECTRICITY AND HEATING FOR DOMESTIC PURPOSES.

PROGRAM GOALS - SPECIFICS

"IMPROVE QUALITY AND ENVIRONMENT OF AMERICAN LIFE."

- REDUCE THERMAL POLLUTION
  - 50% REDUCTION IN WASTE HEAT FROM INTEGRATED UTILITY SYSTEMS WITH NONE WASTED IN RIVERS OR LAKES.
  - COOLING WATER REQUIREMENTS REDUCED FROM 175 X 10^9 gpd TO 96X 10^9 gpd (IN 1986 WITH 50% MARKET CAPTURE IN 1976 TO 1986, INDUSTRY NOT INCLUDED)
- AIR POLLUTION
  - REDUCE COMBUSTION PRODUCTS BY 40% FROM ELECTRICAL POWER GENERATION AND HEATING FOR DOMESTIC PURPOSES (IN THOSE CASES USING INTEGRATED SYSTEMS).
  - REDUCE TOTAL COMBUSTION PRODUCTS BY 10% IN 1986 FROM SOURCES SUPPLYING ELECTRICITY AND HEATING FOR DOMESTIC PURPOSES.

- SOLID WASTE POLLUTION
  - RECYCLE 65% OF SOLID WASTES FROM DOMESTIC SOURCES (FOR THOSE USING INTEGRATED UTILITY SYSTEMS).

- LIQUID WASTES
  - REDUCE SEWER WATER VOLUME BY 80% (FOR THOSE UNITS SERVICED BY INTEGRATED UTILITY SYSTEMS).

  - BY 1986 REDUCE TOTAL SEWER WATER VOLUME FROM ALL DOMESTIC SOURCES BY 11%.

- SOLID WASTE POLLUTION
  - RECYCLE 65% OF SOLID WASTES FROM DOMESTIC SOURCES (FOR THOSE USING INTEGRATED UTILITY SYSTEMS).

- LIQUID WASTES
  - REDUCE SEWER WATER VOLUME BY 80% (FOR THOSE UNITS SERVICED BY INTEGRATED UTILITY SYSTEMS).

  - BY 1986 REDUCE TOTAL SEWER WATER VOLUME FROM ALL DOMESTIC SOURCES BY 11%.

PROGRAM GOALS - SPECIFICS

"EXPAND PRIVATE INSTITUTIONAL PARTICIPATION, RESPONSIBILITY AND PERSPECTIVE IN PROVIDING UTILITY SERVICES."

- PROVIDE THE OPPORTUNITY TO PRIVATE INSTITUTIONS TO BECOME OWNERS AND OPERATORS OF UTILITY SYSTEMS THAT PROVIDE FIVE SERVICES RATHER THAN ONE AS IS CURRENTLY THE CASE.

"ESTABLISH U.S. TECHNICAL LEADERSHIP"

- CONDUCT A PROGRAM THAT WILL DIRECT AND INTEGRATE THE TECHNICAL CAPABILITIES OF THE U.S. TOWARD BETTER SOLUTIONS OF ENERGY USEAGE, WATER AND HANDLING OF WASTES - PROBLEMS FACED BY ALL COMMUNITIES OF THE WORLD.

"BALANCE OF TRADE"

- REDUCE FUEL IMPORTS BY $2.7 BILLION ANNUALLY BY 1986.

- EXPORT OF MODULAR SIZED INTEGRATED UTILITY SYSTEMS HAS A POTENTIAL MANY TIMES GREATER THAN THE U.S. MARKET.

"NATIONAL PRODUCTIVITY AND EMPLOYMENT"

- BETWEEN 1976 AND 1986 INTEGRATED UTILITY SYSTEMS REPRESENT AN $80 BILLION STIMULUS TO BOTH PRODUCTIVITY AND EMPLOYMENT.

FEDERAL BUDGET IMPACT (ESTIMATED FUNDING)

DIRECT PROGRAM COSTS
($ IN MILLIONS)

	FY 1972	1973	1974	1975	1976
HUD	2.7	8.9*	15	15	15
NSF	0.25	0.40	0.20	0.20	0.10

DIRECT GOVERNMENT MANPOWER
(IN MAN YEARS)

NASA	15	25	25	25	25
EPA	2	4	4	4	4
AEC	10	15	15	15	15

RELATED RESEARCH ACTIVITY FUNDING
($ IN MILLIONS)

NASA	1.0	5.0	5.0	5.0	5.0
NSF	2.4	3.5	3.5	3.5	3.5
EPA	1.5	1.5	2.5	2.5	2.5

* 3.0 CURRENTLY PROPOSED

NON-FEDERAL SUPPORT

- IN THE 1973 TO 1974 TIME PERIOD, THE GOVERNMENT-SUPPORTED PROGRAM WILL HAVE PRODUCED RESULTS SUFFICIENT TO ENCOURAGE THE MORE FORWARD LOOKING PRIVATE UTILITY INSTITUTIONS TO ENTER THE INTEGRATED UTILITY SYSTEMS BUSINESS.

- INCENTIVES FOR THEM ARE:

  - INCREASED UTILITY FUNCTION RESPONSIBILITY.

  - INTEREST IN ENVIRONMENTAL CONCERNS AND ENERGY CONSERVATION.

  - $80 BILLION MARKET BETWEEN 1976 AND 1986.

  - RESULTS OF GOVERNMENTS INTEGRATED UTILITY SYSTEMS EXPERIENCE MADE AVAILABLE.

PROGRAM PLAN

- PHASE I - (PAST SEVERAL YEARS TO MID 1972)
  - DEVELOPMENT, DEMONSTRATION AND EVALUATION OF INDIVIDUAL TECHNOLOGY,
  - DETAILED ANALYSIS (PERFORMANCE, COST, ETC.), CONCEPTUAL DESIGN SELECTION, PRELIMINARY DESIGN AND PLANNING FOR PHASE II DEMONSTRATIONS AND EVALUATIONS.
- PHASE II (1972 TO 1976)
  - FOUR GOVERNMENT FUNDED INTEGRATED UTILITY SYSTEMS DEMONSTRATED AND EVALUATED IN REAL-LIFE SITUATIONS.
  - IN PARALLEL ENCOURAGE PRIVATE UTILITY INSTITUTIONS TO ENTER INTEGRATED UTILITY SYSTEMS BUSINESS.
- PHASE III (1976 ON)
  - BASED ON TECHNOLOGY ADVANCES FROM RELATED RESEARCH ACTIVITIES PROVIDE FURTHER IMPROVEMENTS IN UTILITY SYSTEMS.

MANAGEMENT AND PARTICIPANTS

- PROGRAM TO BE MANAGED BY HUD UTILIZING EXISTING GOVERNMENT ORGANIZATIONS AND CAPABILITIES.

- MAJOR GOVERNMENT PARTICIPANTS ARE:
  - EPA
  - NASA
  - AEC
  - NSF

THE

HOUSING

ALLOWANCE

EXPERIMENTAL

PROGRAM

OFFICE OF RESEARCH AND TECHNOLOGY
U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

OCTOBER 6, 1971

The Problem

It has been established that in 1969 there were between 12.8 and 16.8 million households that could not afford adequate housing at a reasonable percentage of income. In addition, although roughly 25 million families are currently legally eligible for our major subsidy programs, it is projected that only 2 million or 8% of them will be served by the end of fiscal year 1972. Our current subsidies are tied to buildings. They are, therefore, available only in certain locations and for certain designated units. If a needy family moves out of a subsidized unit, it loses its subsidy. While new construction and to some limited extent existing housing is being subsidized, in many large cities, the existing sound rental housing stock is undergoing rapid deterioration and abandonment largely because owners are curtailing maintenance in response to rising costs without the prospect of corresponding increases in revenue.

Housing allowances have been suggested as an alternative subsidy approach that would provide housing purchasing power for those in need, encourage free market competition in the new and used housing market, provide freedom of housing and locational choice, encourage maintenance of existing units, and minimize inequities.

Previous Work

Four of the papers submitted to the House Subcommittee on Housing Panels, based on six HUD-funded studies by the Urban Institute, as well as work by the New York City Rand Institute and researchers at M.I.T., deal with housing allowances. From this work, it appears that housing allowances would be more cost-effective than present subsidy programs, that they would be more equitable than present programs -- both to those who would be eligible for subsidies and to builders who produce housing for subsidy programs, that they could help prevent the rapid deterioration and abandonment of sound housing, and that residential options for low-income households would be expanded to include the entire metropolitan area. A study by the Urban Institute of costs of the leased housing program and a thesis written at Harvard University covering costs of Federal housing programs show that in the leased housing program, which comes closest to a housing allowance of all Federal housing programs, the costs to the government per family served are substantially less than those of all other Federal housing programs.

But questions were raised about any secondary negative affects of housing allowances. These questions concern issues of whether a large scale housing allowance program, implemented all at once, might result in inflated rents and sales prices and whether such a program, by itself, would stimulate the level of new construction required to meet the nation's expanding needs. Although little analysis has been done in these issues, work by the Urban Institute indicates that there might not be major inflation. The thoroughness of investigation on housing allowances is indicated by the fact that such questions are being examined; they were not examined in establishing our present subsidies.

The consensus of the work on housing allowances is that a housing allowance experiment should be carried out to evaluate the major primary and secondary affects.

In addition to the above, the San Francisco Development Fund carried out a successful experiment which provided short-term subsidies and family counseling of an advocacy nature to low-income families, designed to make them homeowners. Lower income families, when supported by a well conceived and executed counseling program, were more likely to be successful homeowners than those families not receiving the counseling support. This experiment has served as important background to the development of consumer oriented homeownership programs.

WHY

A HOUSING ALLOWANCE?

ARGUMENTS IN FAVOR:

- .FREEDOM OF CHOICE
- .FREE MARKET OPERATION
- .HELP PREVENT DETERIORATION & ABANDONMENT OF HOUSING STOCK
- .MORE EQUITABLE TO RECIPIENTS & TO BUILDERS
- .MORE EFFICIENT THAN CURRENT PROGRAMS
- .AVOID CURRENT CONTROVERSIES OVER LOW-INCOME HOUSING DEVELOPMENTS IN SUBURBS

WARNINGS:

- .MAY INCREASE HOUSING RENTS & PRICES
- .MAY NOT STIMULATE ADEQUATE PRODUCTION OF HOUSING
- .MAY NOT BE SPENT BY RECIPIENTS ON HOUSING
- .TOTAL COSTS
- .MAY NOT LEAD TO DISPERSAL OF POPULATION

PROGRAM DESCRIPTION

EXPERIMENT DESIGN

- DEMAND EXPERIMENT
- MARKET EXPERIMENT
- DURATION OF EXPERIMENT
- NATIONAL SURVEY
- TRANSITIONAL PROCEDURES

SELECT FIELD OPERATORS (ADMINISTER AREAS, CONDUCT SURVEYS)

SELECT AREAS & INITIATE ON A STAGGERED SCHEDULE

SELECT APPROX. 1,000 PARTICIPANTS FOR EACH AREA
(600 RECIPIENTS AND 400 CONTROLS)

TARGET DATE FOR FIRST AREA: EARLY CALENDAR 1972

FY 72:	3 AREAS	APPROX. 3,000 PARTICIPANTS
FY 73:	6 AREAS	6,000 PARTICIPANTS

ANALYSIS

RECOMMENDATIONS

EXPERIMENT OBJECTIVES

MARKET ISSUES

1. ARE RENTS DRIVEN UP?
2. DOES EXISTING STOCK IMPROVE?
3. DOES NEW CONSTRUCTION RESULT?

PEOPLE ISSUES

1. WHAT DO HOUSEHOLDS BUY WITH THEIR ALLOWANCES?
2. DOES DISPERSAL OCCUR?

ADMINISTRATIVE ISSUES

1. WHAT ADMINISTRATIVE MECHANISM IS BEST?
2. WHAT ARE PROGRAM COSTS?
3. WHAT IS THE BEST ALLOWANCE PROGRAM?
4. HOW DO ALLOWANCES COMPARE IN COST WITH EXISTING HUD PROGRAMS?
5. HOW DO ALLOWANCES COMPARE WITH INCOME MAINTENANCE?

POLICY VARIABLES

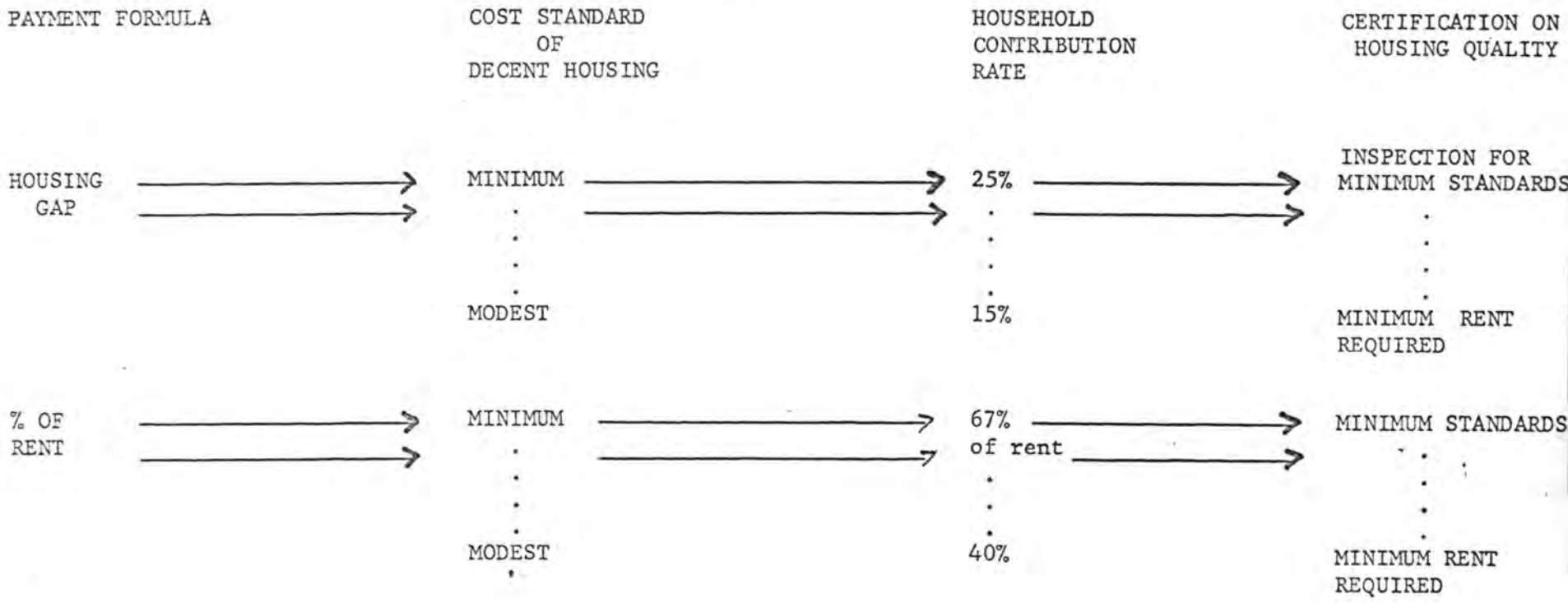
-PAYMENT FORMULA	(ALLOWANCE BASED ON FAMILY SIZE, INCOME, OTHER FAMILY CHARACTERISTICS, RENT PAID)
-COST OF DECENT HOUSING	(BASED ON COST OF ADEQUATE HOUSING FOR HOUSEHOLD OF A GIVEN SIZE)
-HOUSEHOLD CONTRIBUTION RATE	(PERCENTAGE OF INCOME, PERCENTAGE OF RENT)
-ELIGIBILITY	(BELOW CERTAIN INCOME, UNABLE TO AFFORD DECENT HOUSING)
-OWNER/RENTER	(SEPARATE PROGRAMS, SAME PROGRAM)
-FORM OF PAYMENT	(CASH, VOUCHER)
-CONDITIONS	(MINIMUM STANDARDS, NO STANDARDS, CERTIFICATION OF RENT)
-COUNSELING	(GROUP, INDIVIDUAL: BUDGETING & SAVING, CREDIT PRACTICES, EMPLOYMENT, LEGAL, REAL ESTATE TRANSACTIONS, FAMILY PROBLEMS, HOMEMAKING, OTHER)

MAJOR HOUSING ALLOWANCE

PLANS TO BE TESTED

	HOUSING GAP	PERCENT OF RENT
COST STANDARD OF ADEQUATE HOUSING	MINIMUM (Based on structural standards; central city housing)	MINIMUM
HOUSEHOLD CONTRIBUTION RATE	25% OF INCOME	HIGH % OF RENT
CONDITIONS ON ELIGIBLE HOUSING	INSPECTION	INSPECTION
COUNSELING	YES	YES

SPECIFIC PROGRAM VARIATIONS
(FOR COMPARISONS)



ENVIRONMENTAL VARIABLES

PRIMARY -

VACANCY RATES
PREDOMINANT TENURE TYPE
POPULATION SIZE

] - DEFINE LOCAL HOUSING MARKETS

SECONDARY -

DEGREE OF MINORITY CONCENTRATION
COST OF HOUSING
REGION
EXISTENCE OF OTHER HUD SUBSIDY PROGRAMS

SITE SELECTION PROCESS

I. CLASSIFICATION OF SMSA'S OVER 250,000 BY:

RENTAL VACANCY RATE
OWNER/RENTER RATIO
POPULATION SIZE
} 6 CATEGORIES

II. SCREEN CATEGORIES BY:

RACIAL CONCENTRATION

REGION

COST OF RENTING

PRESENCE OF FEDERAL HOUSING PROJECTS

SITUATED IN TWO OR MORE STATES

LEGISLATION REQUIRED FOR WELFARE WAIVER

STATE INCOME TAX RULING

III. NEGOTIATION FOR:

MOST FAVORABLE EXPERIMENTAL CONDITIONS

POPULATION VARIABLES

INCOME	(LOW AND MODERATE)
RACE	(BLACK, WHITE, OTHER MINORITY)
HOUSEHOLD SIZE	(SINGLE TO FAMILIES WITH MANY CHILDREN)
HOUSEHOLD AGE	(YOUNG TO ELDERLY)
HOUSEHOLD COMPOSITION	(BOTH PARENTS PRESENT, FEMALE HEADED)
PROBLEM FAMILIES	

HOUSING ALLOWANCE EXPERIMENTAL PROGRAM BUDGET*

	$ FY 72	FY 73
DISBURSEMENTS	590,000	4,690,000
ALLOWANCE PAYMENTS CONTROL GROUP PAYMENTS INTERVIEW PAYMENTS		
ASSISTANCE	40,000	230,000
COUNSELING		
FIELD OPERATIONS	2,660,000	5,100,000
FIELD ADMINISTRATION SCREENING INTERVIEWS ADP RENT SURVEYS		
DESIGN & EVALUATION	380,000	780,000
URBAN INSTITUTE SAMPLE DESIGN MARKET EXPERIMENT DESIGN NATIONAL PANEL		
TOTAL	$3,670,000	$10,800,000

*IT IS ESTIMATED THAT FY 74, FY 75, FY 76 WILL CONTINUE TO RUN AT ABOUT THE SAME LEVEL AS FY 73.

MEMORANDUM

THE WHITE HOUSE

WASHINGTON

October 4, 1971

MEMORANDUM FOR PSAC MEMBERS

In connection with the discussion of new technological initiatives at the October PSAC meeting, the Committee is asked to identify longer-range initiatives (particularly those that have potential for major impact on our society or economy) that the Committee desires to pursue in depth at subsequent meetings.

For example, the following topics have been highlighted in the course of the current initiatives exercise, which might benefit from further PSAC examination. Please number in order of priority those items on which you would like to have briefings and discussion at future PSAC meetings, and identify other topics that should be added to the list for PSAC examination. Additionally, oral reports are requested at the October meeting on the following subjects previously agreed:

Nutritional Technology - I. Bennett
Automation and Computers - J. Truxall
Superconductivity - R. Garwin

Water Desalting

The technology of water desalting continues to advance, although at present costs are high compared with those of conventional water supply systems in areas where such systems are feasible. However, reduced costs are foreseen, and desalting is economic in special situations. There is developing industry interest both in the aerospace industry, such as Aerojet General, and in the chemical industry (DuPont and Dow). A federal push here might very well catalyze the formation of a viable industry with increased export potential as well as considerable domestic importance in critical areas in the near future, e.g., in Southern California.

Weather Modification

Experiments employing cloud seeding to modify weather continue to give encouragement, although much remains to be learned. NOAA, the Department of Agriculture, and the Department of the Interior particularly, have on-going programs aimed at increasing water supplies, decreasing

hail and lightning damage in crops and forests, and alleviating hurricane conditions. The pay-off could be billions of dollars annually. The overall federal program is coordinated through a committee of the FCST. The effort includes extensive mathematical modeling of the physics of the atmosphere to improve our understanding of the basic principles involved. The situation appears ripe for the establishment of an accelerated effort, both in the field and in the laboratory.

Modification of local weather conditions is operationally feasible under limited conditions. Advanced research will enable us to get on with more extensive modifications, possibly including climate control. Required here is a better weather measurement network in order to obtain better climatic baseline data for the determination and prediction of long-term trends.

Earthquake Prediction and Control

Experiments here and abroad suggest that with proper instrumentation of geological faults and a better understanding of earthquake mechanisms the imminence of earthquakes can be predicted. With timely warning, loss of life and property could be significantly reduced.

In addition, there appears to be the possibility for preventing earthquakes when their foci are relatively shallow. Injection of fluid through deep drilling holes has relieved strain along rock fractures in experiments carried out by the U. S. Geological Survey. It is not yet clear whether this technique would materially decrease earthquake hazards, but further experiments and semi-operational efforts appear attractive, particularly for the West Coast and perhaps Alaska. Reports indicate that both Soviet and Japanese scientists are ahead of us in this field. For example, as a result of two decades of experiments the Russians believe they can make 10-day predictions of earthquake magnitudes and locations in their Tadzhikistan province.

Unconventional Automobile Propulsion

The Ford-DoD stratified charge engine is only one of a number of possibilities for providing clean propulsion for automobiles. Others include gas turbines and vapor drive engines. Some are similar to, but far more advanced than, the old steam engines. Also, new battery technology seems promising for

economical propulsion in a longer time frame. A substantial effort in these areas would augment nicely the all-consuming industry effort to meet the 1975-76 emissions standards by modification to the current engines and provide the country with options to select a less expensive personal transit vehicle power plant.

High Power Lasers

High power lasers are beginning to open applications which were considered "science fiction" only a few years ago. Many exciting applications may now be at the verge of feasibility. Thermonuclear power generation, machine tools, and high-density, high-data-rate communications systems are near-term possibilities with continued advances in higher technology. The prospects are for dramatic further progress in the next few years, but the federal program is not organized adequately to meet that opportunity. The Soviet Union has a large, well-planned program in this field. The possibilities for ABM, a nuclear "internal-combustion" engine, and other revolutionary applications make a focused program vital.