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# Cities' planner prefers computer to intuition

By Janet Riddell
Globe Staff

"It takes about six hours to explain my theory," said Jay Forrester intently, rubbing his palms together, twisting his fingers, crossing and uncrossing his legs.

"The first three hours people resist," he said. "Then they begin to ask questions. And finally, they understand."

Forrester is a lean, bony professor with rimless eyeglasses who has recently thrown liberal intellectuals into an uproar with his unorthodox ideas on planning the future of America's cities.

Working in a laboratory world of computer systems, variables and rates of flow, he has come to the conclusion that many of the job training and housing programs touted as solutions to urban problems may actually make things worse.

"I have yet to see a black leader who does not become a missionary for the theory when he understands it," said the graying, crew-cut Forrester, a professor of management at Massachusetts Institute of Technology.

Ever since his latest book, "Urban Dynamics" (MIT Press), was published last year, Forrester has been busy countering hostile arguments to his concepts — which assume that a computer can help design social policy.

In fact, he is in the process of thinking out a sequel to his book just to answer the skeptics.

Lecturing last week at a New York writers' conference, he spoke with self-assurance, and bolstered his arguments with an intimidating array of slides, charts and lists of numbers.

Cities are so complicated, he explained, with so many different factors operating, that any attempt to solve any one problem will have all sorts of unexpected — and often detrimental — effects on other areas of city life. Complex systems "behave in ways that are opposite to what most people expect," he stressed.

Only by feeding the facts into a computer, he contended, can you clarify an idea and see it drawn out to its logical conclusion.

In his laboratory simulations, Forrester devised a computer model of a hypothetical city, showing it as an interacting system of industry, housing and people. Then he asked the computer to predict what would happen to that city in 50 years under the impact of various social programs.

His computer told him, for example, that if you put up more low-income housing in the city, you attract more low-income people, who in turn need jobs, which in turn become scarce. Unemployment rises. Tax rates rise since low-income families cost the city more in taxes than they can pay; new business is discouraged, living standards fall.

On the other hand, his computer said, if you annually tear down five percent of the city's slum housing (most of it vacant), and open up the land to industry, you keep down the influx of low-income families, increase the available jobs for those already in the city, reduce unemployment, increase the tax base, and provide upwards mobility for all city dwellers.

The computer concluded that it is best not to adopt a program which would attract more poor people into the city if you want to help those already there escape the trap of poverty.

The computer also reported that financial support from outside—for example from state and Federal governments — may do nothing to improve conditions in the city and may even make them worse.

The idea that a cold-blooded computer could design a social system rubs many people the wrong way. "But," Forrester asked, "what is the alternative?"

He noted that city planners and politicians, relying only on intuition and experience, are designing social systems every day—through laws, tax regulations, state and national constitutions.

Some urban economists caution that Forrester's model, despite all its appearance of rigor and scientism, omits some important facts and therefore cannot be applied to actual situations.

According to John F. Kain, associate professor of economics at Harvard, the model's most serious weakness is that the suburbs are not considered. He also contends that Forrester's computer evaluations of conventional policies are not correct.

While defending his model, Forrester agrees that its details would change as one addresses different questions or tests alternative assumptions. Right now, for example, he is working out the effects of rent control in a hypothetical city.

But he says his main hope is that the public will accept this method—applying computer science rather than intuition to the complex problems of the cities.

# Nixon Adopts Theory: Everything Affects Everything Else

By DONALD BACON
Globe-Democrat National Service

WASHINGTON — President Nixon in his first year has quietly changed the whole method by which the government looks at problems. It may be the most significant advancement in political decision-making in generations.

What the administration has done is accept a thesis known as "systemic relations" — which means, simply, that everything affects everything else.

It has also decided that "obvious solutions" are usually wrong, and sometimes disastrous.

Until 1969, White House sources point out, federal decisions were made and sweeping new legislative programs were adopted without much regard to the effect those decisions and programs would have in other areas. The result has been, in many cases, the creation of new problems that were more serious and more difficult to solve than those originally faced.

FOR INSTANCE, when the government decided in the 1950's to undertake the largest public works project in history — the interstate highway system — no one in the Eisenhower Administration or in the Democratic-controlled Congress thought to consider what effect the new roads would have on how and where people live.

Now that it is mostly built the massive highway program has caused rapid, unforseen shifts in population and industry, and serious disruption in urban and rural living.

Since the beginning of the republic, government has operated as a collection of separate, and presumably unrelated, programs. The various segments of government went about their business without much regard to other segments.

Whether Nixon will succeed in changing the present bureaucratic approach to problems — Congress looms as his biggest obstacle — remains to be seen. But he is leading a concerted administration effort to bring some more order to federal decision-making, using some interesting, though still inconclusive, innovations.

The Administration, for instance, is attempting to look at urban problems as a whole, rather than as a collection of individual problems — poverty, transportation, redevelopment, housing, unemployment and such. Instead of having each federal department or agency step forward with a program for its particular interest, the problems of the cities are being viewed for the first time as interrelated and interdependent.

AT THE Urban Affairs Council — a Cabinet committee created by Nixon — an urban "policy," rather than a haphazard collection of urban programs, is evolving.

This means, said a White House source, that the President's new concept of welfare, embodied in his minimum income-job incentive welfare reform proposal, was developed only after the effect on housing, industrial employment, rural migration, health, and all the other factors were considered.

For decades the government has been concerned about the plight of the poor and has created many programs to help alleviate poverty. Yet at the same time the government has taxed the income of those the government defined as poor. Such contradictions exist throughout the federal system. One of Nixon's first messages to Congress called for elimination of income taxes for persons whose income falls below a certain minimum level.

For the first time, also, an Administration is looking at defense spending in light of its effect on domestic problems.

Governmental priorities — whether money now being spent for military purposes might be better shifted to other purposes, such as alleviating poverty — has become in recent months a major political and social issue. Little consideration has been given, though, to the possible unforseen and unwanted effects of a sharp cutback in defense spending.

The Nixon policy planners have been examining the possible effects, but have not yet reached any conclusions they are willing to make public. One question on the mind of Presidential counselor Daniel P. Moynihan and other top policy planners is whether the economic disruption and unemployment that might result from abrupt cutbacks in defense contracts would more than offset the good effects — economic, social, moral and all the rest — of funneling more money into domestic programs.

ALLIED WITH the Administration's new approach to national problems, particularly on the domestic scene, is acceptance of a theory developed by Professor Jay Forrester of the Massachusettes Institute of Technology. "Forrester's law" says that in approaching the problems of complex social systems, "intuitive solutions are almost invariably wrong."

This has led the Administration, rightly or wrongly to reject some seemingly obvious, direct solutions to domestic ills. If someone on the Urban Affairs Council has a "hunch" about how to solve a given problem, the "hunch" is almost automatically rejected as being probably wrong.

Although "Forrester's Law" seems to be valid, Administration policy leaders are having difficulty convincing some politicians, whose lifelong careers have been founded on their intuitive abilities.

Implementation of the "systemic relations" and "Forrester's Law" has resulted, contend White House sources, in what appears to be backdoor approaches to seemingly simple problems. But they point out that direct, front-door approaches to such nagging problems as Negro equality, poverty, transportation and health have not produced the desired results, and quite often have produced the opposite of those intended.

# Decision-Makers Seek More Scope

By JAY W. FORRESTER
Special to The New York Times

CAMBRIDGE, Mass. — As our business organization and social systems have grown, they have become too complex for human judgment and intuition. Management scientists and economists have tried to analyze the systems to establish rules for making more effective decisions. So far, these efforts have been embryonic.

During the last two decades, management education and research have focused on mathematical aids to decision-making. Volumes of professional papers have discussed decision-making in business. But the impact on actual operation has been slight. Many companies have established management-science departments, but these groups are usually isolated and have little influence on the future of their organizations.

Likewise in economics, research has emphasized model-making to find guiding rules for national decisions, but the results have been inconclusive. Why? Why so much promise, so much work, and so little effect?

### Approach at Fault

The answer to past ineffectiveness lies primarily in the perspective and objectives of those in management and economic research. Their focus is more mathematical than operational. Most of the research on rules for decision-making originates from men with little background in management practice or political leadership. Management science and mathematical economics have become closed academic societies, where teachers teach students to become teachers with little intrusion by outside reality.

Professional papers are written for a "public" that will read for the display of mathematical skill, rather than for practical utility. Such researchers have sought security in those tasks where results can be proved to follow from the assumptions.

But mathematics is so weak when faced with the complexity and nonlinearity of real situations that the simplifying assumptions have forced the work outside the realm of major problems. The search for professional security has held the field to trivial objectives. To escape the limitations of mathematical solutions, many decision-rule investigations have moved to computer simulation, but much of the simulation work lacks an adequate philosophical and theoretical base and still is addressed to narrow and unimportant questions.

### Reorientation Beginning

But a reorientation is beginning. The interconnections and interactions between the parts of our social systems are becoming recognized as more important than the parts taken separately. The improvement of the parts does not guarantee improvement of the whole. In fact, the reverse is often true. As discussed in my books, Industrial Dynamics and Urban Dynamics, the very policies adopted in a company or a larger social system to improve local situations can often be essential links in the dynamic reactions that produce over-all trouble.

Our social systems, corporate and economic, belong to a class known as "complex, multiple-loop, nonlinear, feedback systems." Such systems have important and little understood characteristics. They are not governed by simple cause-and-effect relationships. Instead, the fundamental structure is "closed loop," wherein cause determines effect, which reacts to govern cause. There is no beginning nor end. The behavior depends, not on isolated decisions, but on the structure of the system and the policies that govern the multiple decision making points.

In such systems, interrelationships between parts are usually more significant than characteristics of the parts separately. Complex systems seem counterintuitive, because they tend to react contrary to the lessons learned from a lifetime of experience with simple systems. Complex systems interact treacherously with human psychology because they often initially react to a policy change in the direction opposite to the ultimate long-term response.

### Short-Term Goals Bad

Short-term improvement is likely to be followed by long-term degradation. Because the near future is more visible and compelling than a more distant time horizon, and because managers and political leaders have short tenures in their positions, the psychological environment favors policies with short-term advantage at the expense of long-term satisfaction. A succession of policy changes aimed at immediate improvement drives a social system to ever-worsening performance and underlies the demise of corporations and civilizations.

To design improved social systems, we must come to understand such systems. We must learn how they evolve and how the structure and policies produce growth, stagnation and collapse.

Such better understanding is now in sight. Enough is known about the structure and feedback-loop dynamics of such systems that effective models can be built to permit laboratory experimentation. We can foresee a far better understanding of corporate management, urban behavior, national economic policy and changes in ecology and environment.

Any proposition about the technology, economics, organization, or psychology of a system that can be described can be included. We find that the major modes of behavior of our complex systems are being created by the interactions of well-known policies and components. The essential parts of our social systems are highly visible, but the consequent behavior cannot be deduced by mental reasoning. However, computer simulation experiments with properly conceived laboratory models of such systems can show how the parts interact to produce the evolution of the system.

### Person Plus Computer

The investigation process combines the strengths of the person and the computer. Contrary to common assertions in the social sciences, people perceive correctly and are aware of the major forces around them. They have a good understanding of their reactions, and how the individual components of a social system respond to the immediate environment.

This perception of the parts of a system is totally beyond the computer. But given the selected components and interrelationships within a system, the human mind, even when trained in dynamics of systems, is unable to anticipate the time-varying consequences. Fortunately, to trace the consequences of a stated structure and policies is the kind of tedious chore with multitudinous detail that best fits a computer. In Urban Dynamics I illustrated this process applied to the growth and decline of a city. It demonstrates the counterintuitive nature of complex systems by showing how the major proposed national solutions to the urban crisis all lie between neutral and detrimental in their ultimate effect.

Except for the shortage of men trained in structuring and interpreting complex system models, all our social systems lie within reach of these methods. For example, the kind of examination in reference for urban areas has been applied repeatedly in corporate policy situations. It could be used to examine how fiscal and monetary policies are interacting with inflation, economic growth and unemployment.

The barrier is the shortage of the necessary skills. Only a few now have the required experience and training.

To become proficient in dealing with the dynamics of complex social systems requires training at least as demanding as the major professions. As in learning medicine, a man needs theory, case studies, laboratory experience and an internship. But as yet there is no adequate professional school. Educational materials are being developed. Some men are learning by trial-and-error and by apprenticeship, and on them a professional education can be built. The need is great, the path is visible, but progress with present resources will be slow.

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*Mr. Forrester is professor of management at the Massachusetts Institute of Technology.*

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Books & Ideas

by Jay W. Forrester

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# Overlooked Reasons for Our Social Troubles

*In this department last month, Professor John F. Kain of Harvard presented a critical commentary on an unusual and controversial book:* Urban Dynamics *(M.I.T. Press), which reports strikingly unconventional conclusions derived from a computer study of a hypothetical urban area. This month the author of* Urban Dynamics, *a professor of management at M.I.T.'s Sloan School of Management, presents his own account of what his book has to tell us.*

From the city, the economy, and the environment come rising pressures on our social systems. Citizens, corporate executives, mayors, and national leaders strive to solve the problems, only to see matters worsen. Obviously, we do not understand how the structures and policies of our systems interact to *create* the troubles that surround us. In *Urban Dynamics*, using computer methods developed in my *Industrial Dynamics* (M.I.T. Press, 1961), I undertook to show how the structures and policies of an urban area turn growth into decline. Several popular proposals for remedying urban troubles (job training, financial subsidy to a city, and low-cost-housing programs) proved to lie somewhere between neutral and detrimental in their effects on a declining urban area. But policies directed to rebalancing population categories and jobs can start an internal revival, with increased upward mobility for low-income groups. This approach to policy design is applicable to any of our social systems.

Many people recoil at the thought of anyone's designing social systems. But we have no choice. We already live in social systems that have been designed—by national and state constitutions, laws, tax regulations, and traditions. If we lament the decline of our cities, the pace of inflation, or the increases in environmental pollution, we are asserting a preference for a different design. Corporate executives and legislative bodies design our systems by establishing policies and laws, but with only intuition and experience to guide their choices. Intuition and experience are demonstrably unreliable in efforts to cope with the complex systems that surround us.

## New potential for enlightened choices

It is inhumane to go on trying to achieve humane objectives by means of policies that worsen the conditions they are meant to improve. In *Urban Dynamics*, I try to indicate ways of improving the functioning of social systems, which means improving the living conditions of human beings and making it possible for them to realize their potentialities more fully. The point that a cold-blooded computer model can have humane uses has escaped some readers of my book, but not all. Erich Jantsch, a scientist who specializes in long-range forecasting and planning, wrote in the British journal *Futures:* "In reality, Urban Dynamics —or Social Dynamics, as the method might be called even more generally—enhances the role of human creativity and inventiveness in an unprecedented way. By studying the consequences of alternative courses of action for entire social systems, man acquires a new potential for making enlightened choices . . ."

> *"We must, and can, anticipate changes that will evolve from presently known structures and processes, but that have no historical precedents."*

As everyone sees, our present social systems exhibit disturbing trends and stresses. Grave doubts surround the management of corporations, the environment, and the economy. For example, we need better to interrelate taxation, government expenditure, fiscal and monetary policy, economic output, unemployment, and inflation. Past failures in economic analysis and economic policy recommendations have been blamed on inadequate data, but a much more likely explanation lies in the inappropriate structures of the models used, the timid and fragmentary approaches to analysis, and the willingness merely to explain the past rather than try to understand the future.

Likewise, the possibilities for sudden and irreversible changes in the ecological relationships of man to nature can be effectively explored neither by discussion nor by analysis of historical data. We must use the more powerful approaches that are now becoming available for dealing with our complex systems. We must, and can, anticipate changes that will evolve from presently known structures and processes, but that have no historical precedents.

## Consequences burst forth

The pressures on our society will continue to rise until the fundamental questions can no longer be ignored. Through all of recorded history, our traditions, laws, and aspirations have been based on the dynamics of growth—growth in geographical frontiers, scientific knowledge, standard of living, population, and pollution. Our social systems contain the positive-feedback processes that generate exponential growth. Exponential growth has the characteristic that in its early stages it seems unimportant, appears to be getting nowhere, and is largely ignored. But then, in the last two or three doublings in growth, the process passes from insignificance to domination. The consequences of a long history of exponential growth suddenly appear to burst forth on an unprepared society.

Exponential growth cannot continue indefinitely, otherwise it would engulf the earth. *Urban Dynamics* shows the precipitous fall in standard of living and the changes in population mix that occur in the conventional urban area as it moves out of its growth stage into equilibrium. Similar prospects for major change and stress lie before our larger social systems. Growth will cease. Geographical frontiers have been exhausted. Natural resources are being used far faster than nature is recreating them. Ecological considerations probably exclude the possibility of even the present world population rising to the standard of living of the Western industrialized nations, so rising economic expectations will inevitably be frustrated, either in local stagnation or in a worldwide ecological disaster.

The present social malaise at all organizational levels is the first evidence of far greater pressures that will be generated by the worldwide suppression of growth processes. As with the urban area, there are many routes into the inevitable equilibrium. As we move toward that condition, we must, for our preservation, make wise choices about the kind of static earth we want, and adopt wise policies for attaining it.

## The deceptiveness of systems

*Urban Dynamics* describes various characteristics of complex systems that lead us into self-defeating policies. These characteristics were first identified to explain, in management systems, the recurring choice of corporate policies that worsen the very troubles they are intended to correct. The same kinds of influences were rediscovered on the urban scene. They appear to be common to all our social systems.

▶ Complex systems are counterintuitive. They respond to policy changes in directions opposite to what most people expect. We develop experience and intuition almost entirely from contact with simple systems, where cause and effect are closely related in space and time. Complex systems behave very differently.

▶ Complex systems actively resist most policy changes. A new policy warps the entire system slightly, and so it presents a new ensemble of perceived information; the new information is processed through the new policy to produce nearly the old result.

▶ But influence points exist, often where least expected and often with a direction of influence opposite to that anticipated. These pressure points radiate new information streams that, when processed even

through old attitudes and policies, produce new results.

▶ Complex systems tend to counteract programs that attempt to supplement and add to an action stream already in the system. For example, in *Urban Dynamics* a job-training program fails because the reactions within the system reduce the natural upward economic mobility, increase downward mobility, attract the unskilled, and in the end slightly enlarge the underemployed population.

▶ In a complex system the short-term response to a policy change is often opposite to the long-term effect. This treacherous behavior beguiles the executive and the politician into a series of steps, each appearing beneficial and each leading to deeper long-term difficulty.

▶ A system contains internal dynamic mechanisms that *produce* the undesirable behavior. If we ignore fundamental causes and simply try to overwhelm the symptoms, we pit great forces against one another, expending our energy to no avail.

▶ In a complex system, certain pressures go with each mode of behavior. To sustain a particular mode we must accept the corresponding pressures. The common tendency to alleviate one squeaky wheel after another constitutes incremental redesign that can move the system toward an undesirable and nearly irreversible mode of behavior.

In his review of *Urban Dynamics*, Professor Kain concentrates on another aspect of the book, its model, or theory, of system behavior in an urban area. Details of such a model change continuously as one addresses different questions or tests alternative assumptions. Although model details are of less long-term significance than method or the general character of systems, Kain worries details. If his doubts were justified, that might affect the particular conclusions of the book, but not the method.

Almost the only concrete, testable statement Kain offers has to do with his doubtful premise that outside financial subsidy to a city would be used to reduce taxes rather than increase expenditure. He says: "If instead Forrester had used the outside support to reduce city taxes, the net effects would have been favorable to the hypothetical city." Here he is speaking explicitly of what the model will do. Only minutes are needed to make the suggested change in the model and test his assertion. This was done. There is no significant improvement. So even this unlikely use of a subsidy—to reduce taxes—is a waste of resources in the hypothetical city.

### Regrettable perhaps, but inescapable

Even here where he has complete knowledge about the laboratory system and its governing policies, Kain should not be criticized for being unable, on the basis of intuition and judgment, to anticipate the effect of a policy change. But Kain and the social scientists he represents can be criticized for asserting with assurance the consequences of policy recommendations in our real-life systems when it has been repeatedly shown that intuition and judgment cannot yield such certainty even in the laboratory and with perfect information. Only after trying the policy change in a properly constructed, dynamic simulation model should one speak confidently about the consequences.

From his economist's viewpoint, Professor Kain primarily saw tax considerations in the book. As a test of his assertion that tax rates powerfully influence employment and population behavior in the model, the tax rate was changed to be constant and equal to the average outside tax rate. This change makes only a small improvement in the depressed condition of the city, an improvement not at all comparable to what results from the revival policies discussed in the book. Furthermore, the constant tax levy does not reduce the efficacy of the suggested revival policies, so no conclusions in the book would be altered.

Again we see the danger of continuing to base political decisions on intuitive judgments and "conventional wisdom." As I noted above, complex systems are counter-intuitive. This perhaps regrettable but nonetheless inescapable fact is a main source of our present discontents. END

FORTUNE

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# A Computer Version of How a City Works

*by John F. Kain*

The intense interest in the problems of the cities in recent years has produced a great outpouring of books diagnosing and proposing remedies for the "urban crisis." The majority of these works are hardly noticed, being undistinguished and rather pallid imitations of one another. Jay W. Forrester's *Urban Dynamics* (M.I.T. Press) stands out in all this verbiage. The book has attracted attention because of the unorthodoxy of Forrester's recommendations, the self-assured manner in which he presents them, and his prominent use of the prestigious tools of systems analysis. With so many insistent voices saying that cities need more financial help from state and federal government, readers are likely to be impressed with Forrester's conclusion that help from the outside may "worsen conditions" in cities. Forrester, moreover, makes it difficult for readers to argue with him. With its appearance of rigor and scientism, its charts and diagrams, its arrays of numbers printed out by a computer, *Urban Dynamics* is rather intimidating.

Forrester, a professor at M.I.T.'s Sloan School of Management, relies on a computer model he developed to simulate the growth, decline, and stagnation of a hypothetical city (or "urban area") from birth to old age (250 years). Such methods have a great deal of potential for the analysis of urban problems and have already demonstrated their value in a number of specific, though limited applications. However, the development of truly useful and trustworthy urban simulation models remains a distant objective and will require much greater resources than have yet been devoted to the task. Before adequate models become available, many inadequate ones will be put forward. Forrester's model is a conspicuous example. In his first chapter Forrester warns the reader that caution should be exercised in applying the model to actual situations. Subsequently, however, he expresses few reservations about the model's validity and freely uses it as a basis for prescribing public policy.

*John F. Kain, an associate professor of economics at Harvard, specializes in the new field of urban economics.*

## A goal of minimum taxes

The hypothetical city in *Urban Dynamics* is, in Forrester's words, "a system of interacting industries, housing, and people." At the start of the simulations there is only new industry in the city, but as time passes enterprises mature and then decline. The speed of this aging process depends on conditions in the city. As businesses pass through these successive stages, they employ fewer workers and a smaller proportion of skilled workers.

There are similarly three kinds of people in the city: "managerial-professional," "labor" (skilled or high-income workers), and "underemployed" (including unemployed and unskilled workers). And there are three kinds of housing, corresponding to the three kinds of people: premium housing, worker housing, and underemployed housing.

The criteria used in evaluating the performance of the hypothetical city and the efficacy of alternative public policies are never explicitly set forth. However, minimization of taxes per capita would be a fair rendering of the underlying criteria. Forrester seems to think that the objective of the city is to produce the lowest possible tax rate.

The fiscal relationships in Forrester's urban system are intricate, but can be reduced to three fairly simple propositions: (1) Low-income households cost the city more in taxes than they pay, whereas the city makes a profit on high-income households. (2) Growing business enterprises are an unqualified good because they pay taxes and, by assumption, cost the city nothing in services. (3) Increases in local taxes and increases in local government expenditures produce "adverse" changes in the city's population and employment structure. It follows from these propositions that "urban-management policies" should be designed to encourage new enterprises and managerial-professional people to locate in the city and discourage low-skilled people from living there.

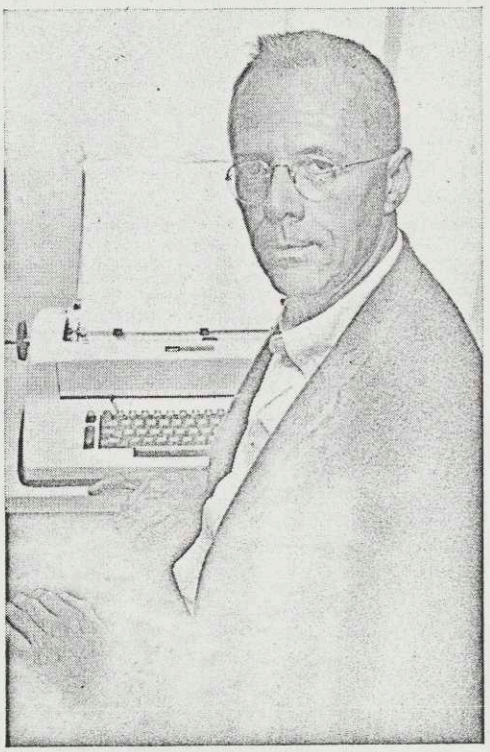
The influence of tax rates on employment and population structure in Forrester's city is powerful and pervasive. "Managerial-professional" and "labor" families are assumed to be repelled by high tax rates, whereas the "underemployed" are indifferent to them. High tax rates, moreover, discourage the formation of new enterprises and accelerate the aging of existing ones. There are still other adverse effects: high taxes retard construction of both premium and worker housing, which in turn discourages the kinds of people who live in these kinds of housing from moving to the city or remaining there.

Increases in public expenditures, the other half of the local fiscal equation, also have disastrous effects on the system. It is assumed that increases in expenditures per capita make the city no more attractive to high-income people and new enterprises, but make it substantially more attractive to low-income people. There are some small offsets in the positive effects of higher expenditures per capita on upward mobility from the underemployed class into the labor class; but these are overwhelmed by the direct and indirect effects on the size of the underemployed population.

These examples are only a few of the "adverse" consequences of higher taxes and increased public expenditures in Forrester's model. Since the model is so constructed that a development in one sector affects other sectors, these adverse effects cumulate throughout the system.

## Help from an induced shortage

Forrester uses his simulation model to evaluate several "urban-management programs" that have been tried or proposed, and he concludes that they "may actually worsen the conditions they are intended to improve." For example, he finds that "financial support from the outside"—presumably including revenue sharing by the federal government—"may do nothing to improve fundamental conditions within the city and may even worsen conditions in the long run." But this conclusion is not at all surprising in view of what he does with the outside funds. Rather than using them to reduce or hold down city taxes, as proponents of such intergovernment transfers envision, Forrester uses them to increase city expenditures. Given the framework of his model, the net effects are inevitably adverse. If instead Forrester had used the outside support to reduce city taxes, the net effects would have been favorable to the hypothetical city. Virtually all of Forrester's evaluations of "conventional" policies are similarly flawed; none is a faithful rendering of policies it supposedly represents.



Jay W. Forrester

Considering the heavy emphasis Forrester puts on tax rates, it is striking that he fails to consider the costs of his principal recommendation: each year demolish 5

percent of the low-income housing. The costs of acquiring and demolishing the properties would increase city taxes, and, within the framework of the model, any increase in city taxes has adverse effects. But Forrester considers only the favorable effects of the demolition program. Given his model, these are considerable. The induced shortage of low-income housing makes the city less attractive to low-income people; fewer come and more leave. (Where they go is a question the model is not designed to consider.) As before, a decline in the ratio of "underemployed" to total population makes the city more attractive to high-income people, encourages formation of new enterprises and construction of premium and worker housing, and impedes deterioration of dwelling units and businesses. In addition, the land cleared by increased demolition of low-income housing provides space for new enterprises and for premium and worker housing.

The supply of vacant land is a critical variable in Forrester's urban model. When more than half the land is still vacant, using additional land produces increasingly favorable effects. But once half the land in the city has been put to use—which in the simulations occurs at about 100 years—further depletions produce increasingly adverse effects. The city's growth is retarded, and stagnation and decline begin. As more land is used up, the scarcity of vacant land slows formation of new enterprises and construction of premium and worker housing, and speeds obsolescence of both enterprises and housing. Given the critical role of land availability in the model, it would appear that these adverse effects could be staved off if the city could simply extend its boundaries so as to absorb additional vacant land; but Forrester does not deal with this possibility.

## Where the solution lies

Simplification is essential in computer simulation models, and neither Forrester's nor any other model can be criticized merely because it omits detail. But Forrester omits some basic behavioral relationships. The model's most serious weakness is that the suburbs never explicitly appear in it. For some simulation purposes, it might be permissible to disregard temporarily the interrelations between, say, the city and the rest of the nation beyond the metropolitan area. But what happens in a city strongly influences its suburbs, and vice versa. If the central city reduced its low-income population by 100,000, the low-income population of the suburbs would have to increase by roughly the same amount. Although Forrester's model reflects no awareness of this aspect of metropolitan interdependence, suburban governments are all too aware of it. Indeed, much of the urban problem today is a result of suburban governments' successfully pursuing precisely the kind of beggar-thy-neighbor policies Forrester advocates for the central city.

Upon scrutiny, *Urban Dynamics* amounts to an intricate attempt to justify the responses of big-city mayors to a harsh fiscal environment. Existing intergovernmental arrangements saddled them with awesome responsibilities for the nation's social problems, but failed to provide them with commensurate financial resources. Much of the mayors' enthusiasm for now much-criticized urban-renewal programs is traceable to their desperate need for cash. In *Urban Dynamics*, pragmatic responses to an unbalanced allocation of responsibilities and tax resources are elevated to the status of rational and efficient policies for dealing with the complex web of problems popularly referred to as the "urban crisis."

The solution is not, as Forrester indicates, the pursuance of narrow self-interest by each local government. Instead we need to develop a more appropriate division of responsibilities and functions among governments, and thereby remove the fiscal incentives for local governments to follow policies that, while perhaps efficient from the viewpoint of narrow self-interest, are inefficient from the viewpoint of society as a whole. END

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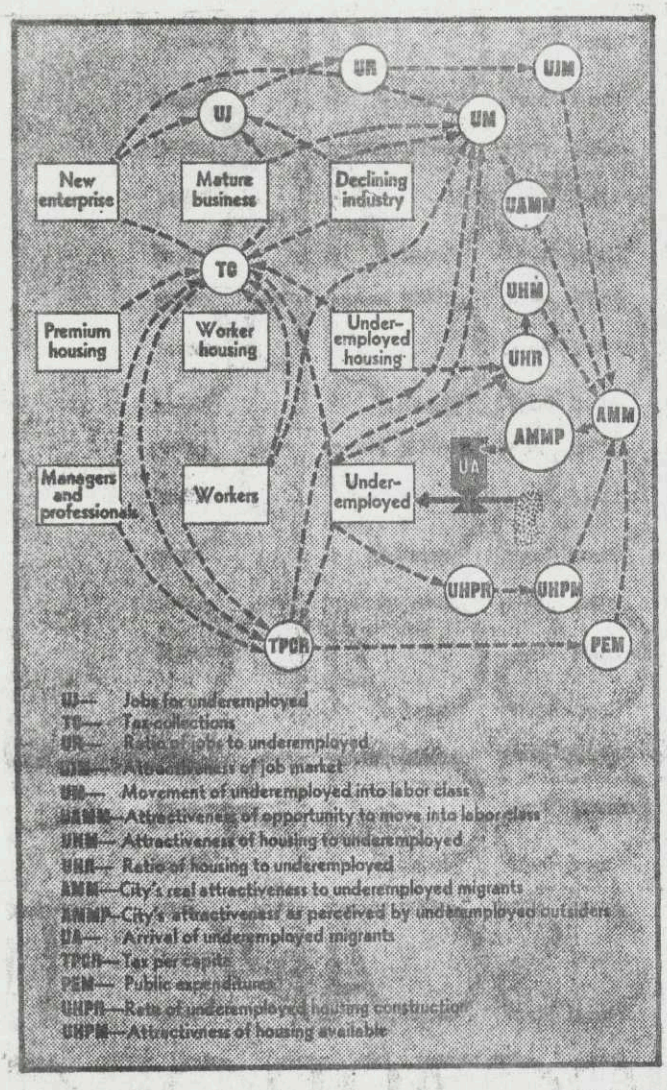
# Computer Is Used as Guide for Expert Seeking

# Way Out of Labyrinth of Urban Problems




The New York Times Oct. 31, 1969

**This Forrester chart shows how urban relationships influence arrival of underemployed migrants. Complex as it is, chart is only part of his model of a typical city.**

By WILLIAM K. STEVENS

To Jay W. Forrester, whose specialty is grappling with complexity, the modern city is a diabolically complicated system that not only hides its real nature but even sets up decoys for those who want to learn how it functions.

So he has tried to cut through the urban tangle and evade the decoys by using a computer to keep track of and simulate the interaction of what he believes to be the major factors that cause a city to rise, flourish and then decay.

This model of a functioning metropolis, expressed in mathematical equations, is a general, theoretical one that is not designed to apply to any particular city. But Mr. Forrester, a professor at the Massachusetts Institute of Technology, has used it to test the efficacy of such traditional urban "cure" policies as job training and housing construction for the poor.

Having done so, Mr. Forrester has concluded that "with a high degree of confidence, we can say that the intuitive solution to the problems of complex social systems will be wrong most of the time."

### Engineering to Sociology

His conclusions are contained in "Urban Dynamics," published last May by the M.I.T. Press. The book resulted from a gradual shift in Mr. Forrester's interests from electrical engineering to economics to sociology. Out of this metamorphosis, he has gathered patents on basic computer systems, helped design air defenses for the nuclear age, and produced a basic reference book on how industrial corporations function internally.

Mr. Forrester's tentative findings about cities suggest that the long-term effects of traditional cure measures on a city's health range from "neutral to detrimental."

For example, his model showed that the net long-term result of creating new jobs for 10 per cent of the "underemployed" (the unemployed plus those with mar-

**IN the social sciences failure to understand systems is often blamed on inadequate data. The barrier to progress in social systems is not lack of data. We have vastly more information than we use in an orderly and organized way. The barrier is deficiency in the existing theories of structure. The conventional forms of data-gathering will seldom produce new insights into the details of system structure. Those insights come from an intimate working knowledge of the actual systems. Furthermore, the structuring of a proper system theory must be done without regard to the boundaries of conventional intellectual disciplines. One must interrelate within a single system the economic, the psychological, and the physical. When this is properly done, the resulting structure provides nooks and corners to receive fragments of our fabulous store of knowledge, experience and observations.**
*—Jay Forrester, in "Urban Dynamics, M.I.T. Press.*

ginal jobs) was to draw more of the poor to the city, creating more crowded slums.

The model showed that a program aimed at building low-cost housing for 5 per cent of the underemployed each year resulted at the end of 50 years in a drop of 30 per cent in the population of skilled workers, denser slums, fewer jobs for the underemployed, a 32 per cent drop in housing for the underemployed, a drop of 49 per cent in new business and of 45 per cent in mature business.

Mr. Forrester's findings further suggest that the best means of adjusting an urban system for long-term revival would be the gradual demolition of slum housing, coupled with incentives for certain types of new business.

### Urges Tests and Criticism

"If the process works the way we see it," Mr. Forrester says, "the income of the underemployed would go up and the middle-income housing market would increase to accommodate them."

The professor himself warns that his findings should not be taken as a basis for action until the computer model has been thoroughly criticized and tested. Many who are familiar with the model are indeed criticizing some of its features.

But few deny the value of the general analytical approach to urban problems that Mr. Forrester has pioneered. And at least two cities, Minneapolis and Dallas, are planning to put the Forrester approach to practical tests.

Ted Polumbaum for The New York Times

**Jay W. Forrester, a professor at M.I.T., in his home office**

Mr. Forrester outlined his thinking on the city-as-a-system at a recent symposium of the National Academy of Engineering in Washington and elaborated on it in interviews later.

### Deluding Intuition

As he sees it, the problem in dealing with urban complexity is that the influences operating within a city are so subtly and intricately interconnected that the human brain—whose response is conditioned by exposure to simple systems—finds it all but impossible to trace cause and effect.

Worse, Mr. Forrester maintains, an urban system throws to the surface what seem to be cause-and-effect relationships, but really are only coincidences, thereby deluding the intuitive, common-sense analyst into a false appraisal.

For example, he says, a housing shortage is often blamed for the overcrowding of slums, but in fact it is caused by a whole series of related circumstances that have conspired to produce a stagnant area and populate it with poor people. Building low-income housing in that area only increases the inward flow of the poor; the immediate benefits evaporate quickly, and in the long run slum congestion is worse than before.

The internal dynamics of a city, Mr. Forrester postulates, are governed by principles of action-response-and-feedback that control the behavior of all complex systems, be they in cociology, engineering, biology, economics,ecology or business management.

The computer manipulates the elements of such a system with a speed, facility and accuracy that a human brain cannot, and thereby simulates in a few moments how an entire city will develop over a 250-year period. Likewise, it calculates how a policy change at one point in the system rebounds to affect and modify all the other parts 10, 20 and 50 years in the future.

### History Recreated

Mr. Forrester's model was designed to recreate the generally observed history of cities in the United States, ending with the well-documented symptoms of present-day stagnation — decaying buildings, poverty, and declining economic and fiscal health. In attempting to match the model to reality, he was aided by a number of politicians, city administrators and academic specialists in urban problems.

One of the most recent criticisms of the model's specifics came from John F. Kain, an economic professor at Harvard University, who writes in the November issue of Fortune magazine that "the model's most serious weakness is that the suburbs never explicitly appear in it."

Paul N. Ylvisaker, Commissioner of Community Affairs for the state of New Jersey, who advised Mr. Forrester in his work, says he believes the model accounts too little for influences outside the city that affect it, and that Mr. Forrester's view of economics "is rather simplistic, at this stage."

Mr. Ylvisaker, who sometimes teaches graduate seminars on urban problems at Harvard, said a Forrester lecture at one such seminar stirred the students, pro and con, as do few presentations. "One student was almost

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# Computer Is Used as a Guide to Urban Ills

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emotionally distraught about what he thought was an attempt to put humans into an intellectual Procrustean bed," Mr. Ylvisaker said.

Nevertheless, he said, "I like the rigorous thinking" in the Forrester approach. "The model ought to be on a national basis," he added.

"One of the great intellectual tasks of the next decade is going to be working out ways to deal quantitatively, in exact, accurate terms, with [urban] interactions," says Peter Szanton, president of the New York City Rand Institute, which is using computer-aided techniques to help New York sort out some of its day-to-day governmental problems. "This [Mr. Forrester's] model is a very important start," he said.

"Urban Dynamics" was a logical result of Mr. Forrester's intellectual development.

During his 30 years at M.I.T., the 51-year-old professor — tall, angular, thin-faced and crew cut, with eyes that sparkle behind rimless glasses — has undergone a professional evolution that many enginers talk about undergoing these days but relatively few achieve.

### Memory Bank Developed

Beginning as an electrical engineer, he developed the system of magnetic ferrite cores used as a memory bank in most computers today. He guided the design of the SAGE continental air defense system.

His growing interest in complex systems led him to shift to economics and produce, in 1961, a book called "Industrial Dynamics," now regarded as a basic work on the internal functioning of businesses.

When former Mayor John F. Collins of Boston became an M.I.T. professor in early 1968, he moved into an office suite he still shares with Mr. Forrester. "Urban Dynamics" grew out of conversations between them.

As set out in the book, the basic building block of an urban system, or any other complex system, is the feedback loop. This is composed of four elements: a "level" variable, analogous to a glass that is being filled with water from a faucet; a "rate" variable, analogous to the rate at which water is flowing from the faucet; a feedback of information from the "level" to the controller of the "rate," analogous to the housewife's watching the glass fill so she can adjust the flow; and a means of controlling the rate, analogous to the housewife herself.

In automatic feedback loops, such as a thermostat, the process of flow, feedback and control is continuous. The same is true of the interlocking feedback loops that make up an urban system, Mr. Forrester says.

The Forrester model assumes that changes in popuation, housing and industry are the central processes involved in growth and stagnation. In it, the "level" variables include quantities of new enterprise, mature business, declining industry, premium housing, housing for the underemployed, managerial and professional people, workers, and the underemployed.

The model also incorporates 22 "rate" variables, including such factors as the flow of people into and out of the city, the rate of housing construction and decay, and of the starting of new businesses.

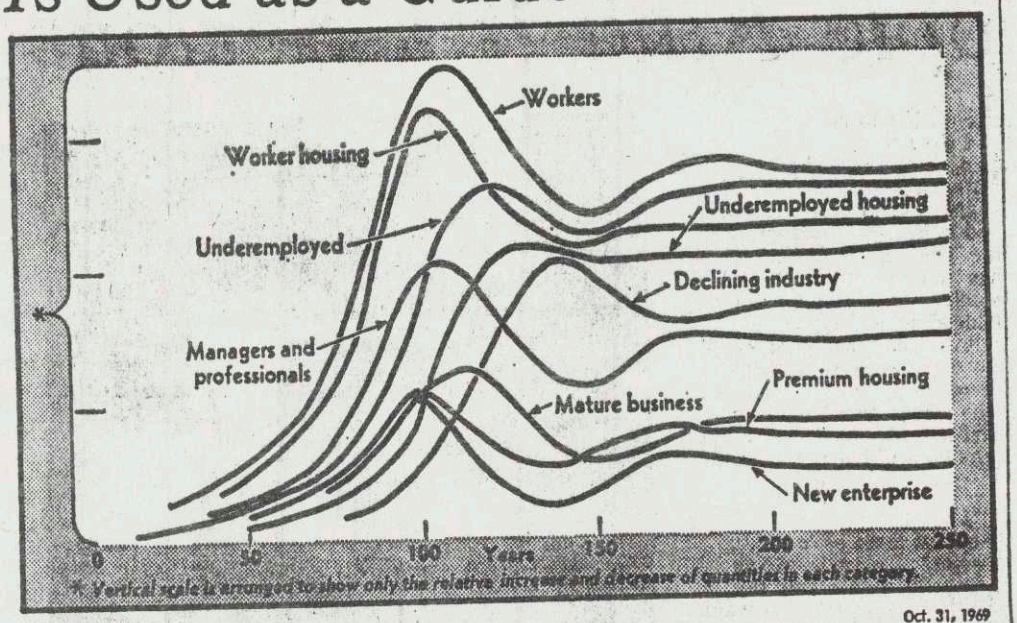
Rates are controlled by how people react to conditions in the city over the long term: New business, for example, is reluctant to move into dilapidated buildings; and unemployed workers are attracted to job opportunities or high welfare payments. Their perception of condtions constitutes information feedback.

A measure of the model's complexity and interrelatedness is that, for example, a single "rate" variable—arrival of the underemployed from outside the city—is regulated by 31 separate feedback influences.

To simulate the growth and decay of a city, each of the relationships in the interlocking system of feedback loops is expressed in a mathematical equation. Using relative "level" and "rate" values assumed to be present at the birth of a typical city, the computer solves all the equations. The answers then become new values to be inserted in the equations, which are then solved again. And so on, for as long as is desired.

Mr. Forrester makes no claims other than that, in a broad-brush sort of way, cities grow and decay according to his model.

As to the specific findings about cures, he says that although they are not proved, "we must examine the possibility that a lot of these traditional policies are counterproductive.




The New York Times Oct. 31, 1969

**The Forrester urban model involves mathematical equations stored in a computer. He inserted in the equations data representing the condition of a hypothetical city at its birth. The computer then produced the above chart showing the city's growth and stagnation over a 250-year period. Mr. Forrester says the general long-term relationships hold despite short-term fluctuations caused by technological innovations and world events.**

B-45
Sunday Globe
October 26, 1969

## Computerized theory:

# *Public housing harms a city*

If results of a computer study of a hypothetical city can be believed, then cities which continually adopt more public housing programs and design similar programs to help the poor are helping to lower standards of living in the city while at the same time speeding up the deterioration of the cities.

This is the conclusion drawn by Dr. Jay W. Forrester, professor of Massachusetts Institute of Technology's Sloan School of Management and a pioneer in the development of the computer.

The reason for the detrimental affects to the city, according to Forrester, lies in the "attractiveness" principal.

"As (low income) housing becomes more available, jobs become more scarce," said Dr. Forrester.

"The stagnating urban area has become a social trap. Excess housing beckons people from other areas and causes inward migration until the rising population drives down the standards of living far enough to stop the population inflow."

The implication, said Dr. Forrester, is that if one element of attractiveness increases, others in the area must be decreased to maintain an equilibrium which would discourage "in-migration."

"If my results are right," he said, "they show that most of the traditional steps taken to alleviate the conditions of our cities may actually make matters worse."

Dr. Forrester's theory was presented last week in Washington at a National Academy of Engineering symposium on "The Engineer and the City."

His conclusions were obtained through analytical techniques he developed to study any complex social or physical system and how it performs or changes over long periods of times. His book, "Urban Dynamics," published earlier this year by the M.I.T. press, contains a detailed description of how these techniques can be applied to urban problems.

At the Washington meeting he described a "computer model" of a city in which industrialization, housing availability and population migration are the principal factors in determining economic health and the general quality of life. Dr. Forrester experimented with various policies controlling these factors and noted their effects over a simulated 50-year period.

At the beginning of the 50-year period, he instituted a hypothetical housing program which produced low-cost dwellings for 2.5 percent of the underemployed population each year.

"Underemployed housing which is being actively constructed, rises 45 percent," he said, "but premium housing falls in quantity by 35 percent and worker housing falls 30 percent over the half-century period. New industrial enterprises decline 50 percent and mature business by 45 percent.

He said other effects were a general drop in the standard of living, an increase in tax levies and higher unemployment due to a 30 percent increase in population over jobs available.

He said he then tested a different housing policy on his "computer model of a city," obtaining far more positive results.

FORRESTER

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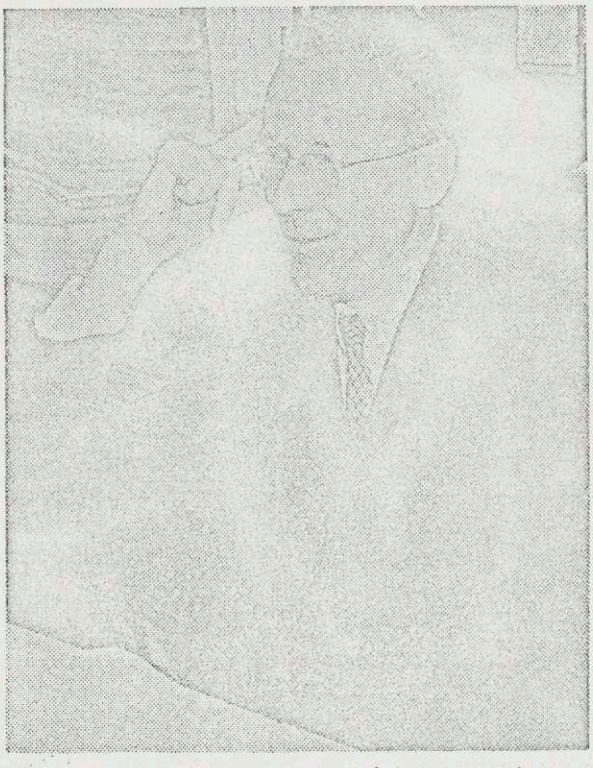

CITIES STUDIED BY COMPUTERS bring interesting conclusions for Dr. Jay W. Forrester of M.I.T.

# A different system to overcome problems

## ★ *FORRESTER*

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"Slum housing is removed over the half-century period at the rate of 5 percent annually—accomplished either by direct governmental intervention or by tax incentives for property owners. Instead of replacing it exclusively with public housing projects, a mixture of high-employment industries and unsubsidized housing for workers and executives was encouraged.

"The result," according to Dr. Forrester, "is a cascading of mutual interactions which raise the economic activity of the area, increases upward economic mobility for the underemployed population, and shifts the population internally from the underemployed to the labor class. This is done without driving the existing low-income population out of the area. The resulting housing shortage restrains the population inflow which would otherwise defeat the revival of the area."

Since his book was published, he noted, there has been at least one major dispute over his controversial theories.

He sees systems analysis techniques as capable of making significant contributions to the design of social and urban systems.

"Some people recoil at the thought of designing social systems," he said, "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."

He noted that there is a major shortage of persons qualified to use such analytical techniques in the design of urban systems, that it takes extensive professional training.

Boston Sunday Globe, March 22, 1970

## Dilemma of the inner city

# It's urban renewal vs. revival

By Fred Pillsbury, Globe Staff

Boston Redevelopment Director John D. Warner sketched out the "dilemma of the inner city" in a speech at Simmons College recently. Twenty-nine percent of Boston's households, he pointed out, have incomes of less than $5000. "In other words, they are poor."

These poor people, he said, produce little tax revenue because they live in inferior housing and generate only small amounts of commerce. At the same time they require disproportionately high tax expenditures because of special health needs, low educational levels and similar factors.

The property tax, Warner said, is relied upon for 60 percent of the city's income — the next highest ratio in the country in Newark, at 40 percent.

The property tax, he said, is regressive — it costs the poor a larger percent of their income, since they pay proportionately more for housing.

Furthermore, the property tax benefits the competing suburbs more than the cities because it favors homeowners more than renters, and only 28 percent of Boston's households own their own homes.

The fact that 50 percent of the land in Boston is tax-exempt doesn't help matters at all.

The concentration of the poor and elderly, and their low tax yields with high costs, Warner said, raises the tax rate, forcing middle income persons to the suburbs, which lowers the tax base of the city and increases the rates, while reducing the services that can be provided.

In the short run, Warner said, it might be better to build office towers and luxury housing to raise the tax base and attract people to the city. But this would not help the poor to find jobs or housing.

In the long run, he said that a stable city must have decent housing and job opportunities for all of its citizens, including the poor.

That conclusion seems acceptable enough, although Warner said that neither was completely right by itself.

But Jay W. Forrester, professor of management at M.I.T. and author of a book called "Urban Dynamics," appears to think that something like Warner's short-term solution might be, in fact, the best long-term solution for the city.

Forrester suggests that urban renewal programs, far from helping the cities, actually have hastened their decay. Using computer models, Forrester has found that, especially in the field of low-income housing, the city has been cutting its own throat.

"The natural condition of the aging city tends toward too much housing and too few jobs for the underemployed population," he writes. "in such condition an urban area fails to operate effectively. It attracts an unskilled population but then offers little opportunity. It traps the underemployed in a low economic condition from which few escape."

The city, he says, cannot "out-run the needs of the underemployed by providing ever more low cost housing and welfare. The city that attemmpts this will inundate itself with the less fortunate of the world in a cycle where effort does not improve conditions but only increases population without in fact improving the lot of that population."

Forrester's conception of the tax problem is a little different from Warner's.

"The tax structure," he writes, "tends to penalize those who can contribute most to the well-being of the city while favoring those who generate costs to the city. . . . In the short run the conventional tax policies seem humanitarian and appear to be a desirable social force. But in the long run the policies produce economic decline and trap in poverty the very people they are designed to serve . . ."

Forrester's proposals for "urban revival" seem a bit brutal in this day and age. Instead of demolishing slums and then putting up better housing for the people who lived in those slums, he thinks we should demolish slums and then replace them with "new business enterprise." One means of doing this — he is opposed to Federal aid, incidentaly — would be to end the practice of reducing assessments on old buildings and, instead, to have a flat tax per dwelling unit. He thinks this would create incentives for new construction.

But Prof. Forrester does not suggets that his solution would work in every city.

"If the city has already reached the point where the underemployed are numerous and politically powerful," he writes, "these programs for restoring the economic health of a city may not be open for political considerations."

Perhaps John Warner might say that he was describnig Boston in that sentence.

# PLANNING AND DESIGNING FOR THE FUTURE

## The Breakthrough of the System Approach

René Dubos' *So Human an Animal*[1] and Jay Forrester's *Urban Dynamics*[2] together with Aurelio Peccei's *The Chasm Ahead*[3] (reviewed in the March 1969 issue of FUTURES), although widely different in subject, complete a troika of books published this year which take the same system approach and show the way for futures research. They measure out the vast problems the future holds for us and provide a platform on which to build a body of scientific knowledge that will enable us to deal actively with our own future.

AURELIO PECCEI, in *The Chasm Ahead*, deals with the macro-problems that mankind is facing in the near future, with the urgent need for re-designing the world system. At the other end of the spectrum, René Dubos explores in his book *So Human an Animal* the joint systems of man and his environment, the biological platform of the human species which is no less endangered by urbanisation and technology and needs to be built anew continuously. And Jay Forrester, in *Urban Dynamics*, presents the first full-scale simulation study of the dynamic social system which has moved to the focus of concern today, the city.

Apart from their common deep concern with the future, a certain unity of basic approach ties these three books together and may give their almost simultaneous publication enhanced significance. This basic approach is characterised by three essential notions:

- The future of man and society has to be dealt with in the context of systems which link them to the environment shaped by nature, technology, or social development—by what is now called the integrative approach, cutting across many dimensions, social, political, economic, technological, anthropological, psychological and others.
- These systems form complex dynamic systems, which implies that they are high-order, multiple-loop, non-linear, feedback structures—with particular emphasis on their feedback nature.
- Actively shaping the future, and planning for it, imply changing the structure

of these systems, not just the variables. This is done by what may be called system engineering in a broad sense (especially socio-technological system engineering); or, more suggestively, ecological engineering.

Only Forrester's book treats its theme in a technical and methodical way. However, computer simulation of complex dynamic systems which he applies to the city, and which he adapted from the original 'Industrial dynamics' concept, developed by himself and co-workers over the past decade, carries a most important general potential for dealing with complex dynamic systems at all levels—at the level of the individual, of social systems, and of the world system. It constitutes at present the only fully-developed means to study outcomes of specific courses of action in the context of dynamic system behaviour. With the dramatic shift from input- to outcome-oriented planning, as it is inherent in the development of long-range planning at the policy and strategic levels, this approach will acquire universal significance.

With the books by Dubos, Forrester, and Peccei, research into and planning for the problems of the future will have to abandon their fixation on goals, scenarios, and anticipations of possible futures to the extent that they are all usually conceived in more or less static and piecemeal terms. They will focus on system dynamics, in particular the dynamics of complex feedback systems. Their guiding images will consequently be formulated in dynamic terms, and their dominant criterion will be dynamic system stability—a concept quite distinct from equilibrium and the variety of hedonistic constructs filling the literature so far.

The intellectual games played today with possible and desirable futures have little to do with planning and design leading to real action. The sudden recognition that it may become possible to shape the future actively, and the lack of understanding of evolutionary processes—which are characterised by complex system dynamics—led to some sort of intoxication with unrestrained freedom and even anarchy, and to blindness towards the growing complexity of the systems of human living which, in turn, makes the tasks of planning and design so much more complex. We may now begin to discard these naive attempts to dream up or extrapolate the future. We are led to a profound concern about the basic structures and boundaries of systems whose uncontrolled development we have to get into our hands before we may allow ourselves some extravagance. Here is a basis of rationality for setting priorities, planning, and making decisions—a basis for exerting human freedom in a responsible way.

"Design, rather than anarchy, characterises life", states René Dubos in his book. "In human life, design implies the acceptance and even the deliberate choice of certain constraints which are deterministic to the extent that they incorporate the influences of the past and of the environment. But design is also the expression of free will because it always involves value judgements and anticipates the future."

*So Human an Animal* sums up the conclusions which the famous French micro-biologist, working at Rockefeller University in New York, reached during his life-long concern about man's place in a rapidly changing environment. It is Dubos' finest book to date, and the Pulitzer Prize it has been awarded, is due both to its high motivation and competence and to the simplicity, transparence and elegance of its style.

The basic aim of the book is to bring to light the complex feedback interactions between human and environmental development, and to grasp their implications for the future of mankind. Whereas classical Darwinism and other evolutionary theories focused on particular aspects, and thus failed to explain the development of the integral man-environment system, Dubos recognises a multiple-loop feedback system in which evolutionary development, experiential development, and human free-will interact with each other. "In the course of human evolution, the brain, the body, and culture developed simultaneously under one another's influence, through the operation of complex feedback processes. Integrated inter-relationships of biological constitution and of function necessarily result from this evolutionary inter-dependence of body, brain, and culture."

A change in environment brings new parts of man's genetic endowment into play, only a fraction of which is actually used. This is the cause for man's astounding propensity to adapt himself, especially to the rapidly changing environments affected by urbanisation and technology. But our confidence in an almost infinite capability to adapt ourselves lacks any sound basis of knowledge about the limitations of our genetic endowment on the one hand, and the effects of man-made environments on human life on the other. Here lies the danger of self-destruction through rapid and uncontrolled developments in the man-environment systems, brought about by actions of human free-will.

"Man makes himself through enlightened choices that enhance his humanness." But the basis for making enlightened choices is essentially lacking today. We have developed 'know-how' to change the environment wilfully but we have not developed the 'science of humanity' to clarify the 'know-why', urged by Dubos, and least of all have we developed system analysis and system engineering that are applicable to the man-environment systems and provide a basis for the 'know-what' and the 'know-where-to'.

In particular, Dubos underlines that "the view that man's future is linked to technology can become dangerous if accepted uncritically. Any discussion of the future must take into account the inexorable biological limitations of *homo sapiens*. . . . The first move toward a richer and more human philosophy of life should be to rediscover man's partnership with nature."

Dubos' book comes at the right time to question some of the narrower concepts developing today that focus almost exclusively on joint systems between society and technology. The systems, of which man as an individual is one of the constituents, are in danger of becoming neglected. But it is here that the most stringent requirements and limitations for further development probably become effective, as superficial economic and social criteria lead us to shaping an ever more artificial environment. At present, our actions are more characteristic of anarchy than of design. Dubos' book gives science, including systems science, a new and powerful challenge, the response to which may well decide the fate of the human species.

*Urban Dynamics* had become the subject of heated debate even prior to publication. It has captured the imagination of politicians and managers in the public domain, and it has been furiously attacked and rejected by social scientists. It is a safe prediction to state that it will become one of the most

provocative and stimulating books of our time in a climate which, at least in the United States, is conditioned by a wide recognition of the plight of the cities.

This book constitutes the imaginative application of the 'Industrial Dynamics' concept, looking at systems as feedback processes having a specific and orderly structure, to the problems of the city. It considers the city as a living, self-regulating system of complex nature, exhibiting the same counter-intuitive dynamic characteristics found in other complex dynamic feedback systems (of which the business corporation is the best studied system to date).

The basic approach is simple. The system is described in the form of a structural model with the essential relationships of the real system built into it, including those which give rise to undesirable system behaviour. To build such models is not an easy task. The proof of correctness lies in the dynamic characteristics revealed by computer simulation, matching experience as far as possible.

However, once a model has been adopted, computer simulation permits study of the outcomes of structural changes made in the model. Thus, simulation of this type becomes a most important method for planning at the policy and strategy levels and in the context of complex systems. It permits study of the consequences of alternative courses of action in ways which enhance the potential of human imagination and inventiveness, for example:

- The outcomes of interactions of cause-effect relationships with long time-constants may be studied (for the city of the order of decades); these are usually counter-intuitive
- Complex feedback interactions and their effect on overall system behaviour may be simulated
- Causes (structural relationships), instead of mere symptoms, may be dealt with
- Dominant relationships, determining the overall system behaviour, may be discovered and the effect of changing them may be studied. This may lead to effective and inexpensive ways to restructure systems (if, as Forrester believes and demonstrates, a relatively small number of relationships dominates in this way)
- Simulation of alternative changes may reveal possibilities to build systems with a greater capability of self-regulation and self-stabilisation.

All of these studies could not be made without the help of the computer; outcomes in dynamic system behaviour could not be grasped intuitively. However, the nature of changes introduced and tested by simulation depends on the creative human mind.

To demonstrate the application of the method, the book uses a specific model, built from 153 equations and described in full detail in an appendix. Two types of simulation are carried out, a growth simulation over a 250-year time span from the beginnings of a city to its stagnation, and variations starting with the equilibrium (stagnation) conditions derived from the last stage of the growth simulation. These variations constitute the most significant part of the book, because here real social system engineering—restructuring stagnant

social systems—is tested through simulation to explore how various changes in policy would cause the conditions of the urban area to be altered over the following fifty years.

The counter-intuitive nature of social system behaviour is demonstrated drastically. Measures, which intuitively would be chosen to improve the under-employed: job ratio, one of the crucial variables, turn out to act in the desired direction only in the short run, but to worsen the situation in the long run. This is shown, for example, for measures such as low-cost housing programmes and under-employed job-training programmes (which, as a matter of fact, explains some of the recent failures in intuitive USA urban policies). On the other hand, a slum demolition programme contributes substantially to an improvement of the situation in the long run, because it does not give rise to increased inflow of under-employed into the city, and it furthers gradual and lasting improvements in the economic conditions of the city—in other words, it acts on causes, not on symptoms.

Urban Dynamics is not the only approach to long-range planning and it is not perfect. In its present form, it deals with specific system structures, which are kept unchanged over the time span of the simulation. The introduction of structural changes is reserved for human interference, where, in reality, these structures may also have to be looked at as dynamically changing parts of a living system. These inherent dynamics may ultimately also be simulated in more sophisticated models.

However, Urban Dynamics already constitutes a giant step forward in long-range planning for systems, opening up entirely new potentialities of social system engineering. Without doubt, it will give new food to the naive myths about the computer gaining control over society, as they flourish particularly in Europe in such an indiscriminate way. In reality, Urban Dynamics—or Social Dynamics, as the method might be called even more generally—enhances the role of human creativity and inventiveness in an unprecedented way. By studying the consequences of alternative courses of action for entire social systems, man acquires a new potential for making enlightened choices in a long-range and complex system framework which is impenetrable to mere intuition and simpler techniques.

"Human freedom", states Dubos, "includes the power to express innate potentialities, the ability to select among different options, and the willingness to accept responsibilities." The books by Dubos, Forrester, and Peccei all show us ways to exert this human freedom.

*Erich Jantsch*

References

1. René J. Dubos, *So Human an Animal* (New York, Charles Scribner's Sons, 1968) 267 pages, $6.95
2. Jay W. Forrester, *Urban Dynamics* (Cambridge, The MIT Press) 285 pages, $12.50
3. Aurelio Peccei, *The Chasm Ahead* (New York, Macmillan; London, Collier Macmillan) 297 pages, $7.50

# A daring look at city ills

## New books by men trained to work with computers fuel the controversy over the systems approach to urban problems

**Imagine a candidate** for mayor of New York, Chicago, Los Angeles or any tension-ridden city today who ran for office pledging to:

- Tear down 5% of its already-scarce low-income housing every year.
- Clear away an equal volume of aging business enterprises.
- Spurn programs for housing, job training and outside financial assistance.

He would probably get as many votes as Richard Daley at an SDS convention. But just such policies are what a distinguished expert on industrial management thinks city officials should be following.

Jay W. Forrester

In his Urban Dynamics, an unsettling, complex and ground-breaking new book about our cities and the decay that afflicts them, Jay W. Forrester, professor at the Massachusetts Institute of Technology and holder of some basic patents in the computer field, offers findings that shatter established notions about curing urban ills.

Forrester insists that only by restoring the proper dynamic equilibrium between housing and jobs can cities be returned to economic and social health. For most cities today this means more emphasis on premium housing and managerial-professional jobs rather than on low-income housing and low-skill jobs. He draws upon an array of head-spinning equations, fed through a computer, to show that as things stand now most of the programs aimed at helping cities will make things worse. In fact, he asserts that no outside help in the form of housing, job training programs, or financial assistance really comes to grip with a basic cause of a city's unemployment, bad housing, or economic decline.

Forrester says, in brief, that our cities will sink even deeper into decay unless the people who run them apply some of the things he has been teaching business about the management process.

**Applied systems.** What he wants them to apply comes under the heading "industrial dynamics," a term for his version of the "systems approach;" a bundle of techniques for analyzing highly complex situations by treating them as a system of interacting parts. A year or so ago, enthusiasm for turning trouble-plagued cities into modern Utopias by using these aerospace-derived techniques reached near faddish proportions. But actual experience in the hurly-burly of city politics, and the vastly complex task of identifying and reducing to numbers the countless variables that impinge upon the city threw a dash of cold realism on the subject.

Some cities have achieved modest success in using these valuable tools. In New York, for example, Rand Corp. has helped improve decision-making in very specific jobs, such as how best to deploy fire engines. The city's Bureau of the Budget is busy installing a so-called planning, programming, budgeting system for more purposeful control over city spending. But by and large, efforts to bring very broad problems, such as poverty, under a systems analysis approach has failed to deliver the benefits that enthusiasts hoped for. A speaker at a recent meeting of the National Conference on Public Administration, which was devoted entirely to urban systems, summed up talks on the present state of the art as "a report on different degrees of disillusionment."

**Not quitting.** But as Forrester's book demonstrates, the experts aren't giving up. Much of the earlier enthusiasm, in fact, shines through in a second new book on the subject, Simon Ramo's Cure for Chaos. Ramo, vice-chairman of TRW, Inc., is a businessman-scientist-engineer. Unlike Forrester's technical and detailed exposition, Ramo's readable book is avowedly a primer for the nonprofessional, a broad-brush description of what the systems approach is all about. Compared to Forrester's ambitious effort, some think Ramo's book is so broad-brushed it falls into the earlier excesses.

Simon Ramo

Harold Wolf, management consultant and student of systems, feels that way. Ramo's book, he says, "does not present the kind of documentation or detail that will give the uninitiated much feel for the potentialities of systems techniques." He calls it "a translation into homilies and over-simplified analogies of the systems approach to social problems," that confirms that "the most ardent proponents of the application of new systems techniques to social problems are, by their over-enthusiasm and under-explicitness, often its worse enemies." On the other hand, Wolf believes Forrester makes "a clinching case for its usefulness and its limitations."

**Redefinition.** Forrester's starting point is the now commonplace observation that the city is a system. According to Wolf, "Prior efforts to apply systems analysis to social problems, have been verbal and quantitative. Therefore, they weren't precise enough to disclose the true dynamics of the urban system. Forrester is the first to analyze the city as a closed system in which all the significant cause and effect factors are accounted for and are linked together to show how a change in any one will reverberate throughout the system. This is what Forrester means by the term 'urban dynamics' and it is what he believes the management of the city, or any other complex organization such as a business, is all about."

Trying to understand this closed system through intuition or logic, Forrester asserts, leads to the kind of mistakes he finds officials enmeshed in today. His major contribution has been to put numbers on the factors and interactions at work in the city, and to write equations that describe statistically how changes in any one factor will affect every other. His equations enable him to simulate a hypothetical city in his computer in order to study the impact of given policies and programs and record their effects in quantitative terms.

**A landmark.** It's this process rather than conclusions about

city problems, that Wolf believes gives Forrester's book outstanding value. Forrester calls it "a method of analysis," offered as a "contribution" to understanding "the growth and aging processes of a city."

Forrester's reputation insures that his contribution will receive sober attention from other experts trying to construct computer models of urban problems. But his approach, involving long-range, macroeconomic data, will churn up the running controversy with model builders who lean toward other techniques, especially short-range, microeconomic models.

The factors that Forrester decides should go into his model, of course, determine the results. To identify and evaluate what is crucial to the city, Forrester worked with people experienced in city affairs, such as former mayor John F. Collins of Boston, who wrote the introduction to the book. Forrester copes with a lengthy list of factors, but focuses primarily on the interaction of different kinds of employment and housing, and the different kinds of people they attract to the city.

His figures indicate that a city must maintain a balance between the sorts of jobs and housing it offers people. Left alone, the city's business and housing ages. But corrective policies that draw in and overload the city with unskilled people who fill up the aging housing lead to inevitable decline of the city. And this is what he says is happening today.

**Housing cycle.** To cite one example, Forrester asks his computer what happens when the federal or state government gives the city new housing for low-income people. In the short run, it means an increase in housing and jobs. But over the years, both will decline.

This occurs because as such housing takes over available building sites, it discourages others in the neighborhood, including housing for skilled workers, higher-income tenants, and new business. As job opportunities decline in relation to the increase in unskilled people, unemployment rises. Business and skilled people leave in greater numbers, the tax base narrows, the city raises taxes, and more business is driven away. The process of decay steps up.

Forrester sees a similar cycle of decay in federal financial assistance to cities to provide an increase in services to poor groups, which are then drawn into the cities in greater numbers.

Forrester isn't arguing that the city should draw no poor or unskilled people. He is simply saying the city can handle only a given volume. As conditions stand today, he feels, the major plague of the city is an out-of-balance relationship between employment opportunities and living space.

A third and very different kind of new book about cities reaches somewhat the same conclusion as Forrester. In The Economy of Cities, Jane Jacobs, the planners' bête noire, also contends that the vitality of the city depends heavily on stimulating a diversity of new business enterprises.

**What to do?** What, then, should the city do? To Forrester, the answer is obvious. The city should pursue policies that make it more attractive to new enterprises and managerial-professional people, and less attractive to aging business and unskilled people. Specifically, Forrester says the city should stimulate the growth of new business enterprise. Equally important, it should use its tax, zoning, and other powers to cause the demolition of at least 5% of low-income housing a year. The land thus freed, he believes, will enable the "natural dynamics" of the city to take over and restore healthy balance.

With his general policy findings, Forrester comments on specific city functions. Three examples:

- He feels taxes should openly favor high-employment industries that pay high wages. He wants reduction of commercial tax rates relative to residential and possibly even a tax credit based on salary levels of high-skilled people.
- He wants to reverse present zoning policies that tend to restrict industry and favor residences.
- He thinks urban transportation should connect industrial areas with one another rather than industry to housing. This would help business and cut down on long home to job commuting.

**Social answers.** Forrester is sensitive to the social implications of his prescriptions. To the question "Would they work a hardship on the city's poor?" he admits that "policies that lend to urban revival will give the superficial appearance of favoring upper-income groups and industry at the expense of the underemployed." But he points out, "the number of underemployed people living in a city is not a measure of the city's social value."

Reducing the volume of low-cost housing, he insists, won't drive the poor from the city, but it will discourage more from coming, and this will enable the city to perform more efficiently its traditional role of upgrading its existing inhabitants. Forrester's answer to potential social critics: "No purpose is served by operating a city so that it is a drain on the economy of the country and a disappointment and frustration to its occupants."

About the politics of his ideas, Forrester admits that "if the city has already reached the point where the underemployed are numerous and politically powerful, these programs may not be open for practical political consideration." But he believes he has shown the high price that pressure groups exact when they press for programs that "trap in poverty the very people they are designed to serve."

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Memo to Prof. Forrester Room Ext.

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MURAN BOSTON

Boston Sunday Globe May 31, 1970

# Cities' planner prefers computer to intuition

By Janet Riddell
Globe Staff

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"The first three hours people resist," he said. "Then they begin to ask questions. And finally, they understand."

Forrester is a lean, bony professor with rimless eyeglasses who has recently thrown liberal intellectuals into an uproar with his unorthodox ideas on planning the future of America's cities.

Working in a laboratory world of computer systems, variables and rates of flow, he has come to the conclusion that many of the job training and housing programs touted as solutions to urban problems may actually make things worse.

"I have yet to see a black leader who does not become a missionary for the theory when he understands it," said the graying, crew-cut Forrester, a professor of management at Massachusetts Institute of Technology.

Ever since his latest book, "Urban Dynamics" (MIT Press), was published last year, Forrester has been busy countering hostile arguments to his concepts — which assume that a computer can help design social policy.

In fact, he is in the process of thinking out a sequel to his book just to answer the skeptics.

Lecturing last week at a New York writers' conference, he spoke with self-assurance, and bolstered his arguments with an intimidating array of slides, charts and lists of numbers.

Cities are so complicated, he explained, with so many different factors operating, that any attempt to solve any one problem will have all sorts of unexpected — and often detrimental — effects on other areas of city life. Complex systems "behave in ways that are opposite to what most people expect," he stressed.

Only by feeding the facts into a computer, he contended, can you clarify an idea and see it drawn out to its logical conclusion.

In his laboratory simulations, Forrester devised a computer model of a hypothetical city, showing it as an interacting system of industry, housing and people. Then he asked the computer to predict what would happen to that city in 50 years under the impact of various social programs.

His computer told him, for example, that if you put up more low-income housing in the city, you attract more low-income people, who in turn need jobs, which in turn become scarce. Unemployment rises. Tax rates rise since low-income families cost the city more in taxes than they can pay; new business is discouraged, living standards fall.

On the other hand, his computer said, if you annually tear down five percent of the city's slum housing (most of it vacant), and open up the land to industry, you keep down the influx of low-income families, increase the available jobs for those already in the city, reduce unemployment, increase the tax base, and provide upwards mobility for all city dwellers.

The computer concluded that it is best not to adopt a program which would attract more poor people into the city if you want to help those already there escape the trap of poverty.

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The idea that a cold-blooded computer could design a social system rubs many people the wrong way. "But," Forrester asked, "what is the alternative?"

He noted that city planners and politicians, relying only on intuition and experience, are designing social systems every day—through laws, tax regulations, state and national constitutions.

Some urban economists caution that Forrester's model, despite all its appearance of rigor and scientism, omits some important facts and therefore cannot be applied to actual situations.

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# Book Notes

URBAN DYNAMICS

*by Jay W. Forrester*

The MIT Press, Cambridge, Massachusetts and London, England, 1968. 285 pp. $12.50

Here is genuine systems analysis, and it is quite different from so much of the talky and marginal stuff. This is substantive, understandable, complete, cohesive, and directly instructive to what we are trying to do as planners. The remarkable scope of the work will make it interesting to everyone from politician to historian, not simply to other modelmakers. The book describes the construction, operation, and results of a real systems model of a city, simulating development and policy interventions over a 250-year period. The city is not real; nonetheless, the findings may be true.

The model is composed of three major sectors, each containing three elements (status variables). The business sector contains new enterprises, mature businesses, and declining industries; the housing sector holds premium housing, worker housing, and underemployed housing; and the population sector holds managerial-professionals, laborers, and the underemployed. These nine elements are combined with twenty-two modes of interaction (rate variables), then linked to the rest of the world through many complex multiplier functions. The city is a closed dynamic system. A 250-year scenario is computed. It begins with vacant land, fills it up, readjusts, equilibrates, and then stagnates with unemployment, dying industry, and increased taxes. The sequence of fluctuating variables is plotted in detailed graphs.

Given this cycle of growth and decay, Forrester then tests several sets of policies. The first set includes job programs, training programs, outside financial aid to the city, and low-cost housing construction. They are tested over a fifty-year period. In the short run, each program tends to make some things better while making other things worse. In the longer run the programs have either no effects or clearly undesirable effects throughout the system, demonstrating what Forrester calls the "counterintuitive" nature of complex systems. He also tests programs for worker housing and premium housing construction, new enterprise construction, declining industry and slum demolition, discouraging housing construction, and encouraging industry. One of Forrester's conclusions is that externally imposed housing construction programs, of any class, are detrimental.

A separate chapter is devoted to notes on the general nature of complex systems. The assumptions of the work and the results are interpreted in a final chapter. There are several substantial appendices. One details the complete model in flow charts, equations, and graphs. Another discusses political power, the negative income tax, sensitivity of the model's parameters, population densities, effects of improving the external environment, and mechanization of agriculture. Others contain lists of terms and equations and a complete listing of the nearly 400 statements of the computer program. The program is written in an algebraic language for the DYNAMO compiler in the DYNAMO II version.

There are numerous assumptions and implications in the work that require fuller treatment than can be offered in a note such as this. One such assumption is that essentially the city competes with the rest of the world for jobs while trying not to attract to urban life people who are poorly skilled. Such a position closely resembles the feelings of many city administrators and policymakers. The author is willing to assume that this competitive structure need not be violated in order to solve urban problems. He claims that the policies necessary to control "population balance" are not antisocial, even though they "will give the superficial appearance of favoring upper-income groups and industry at the expense of the underemployed." The computational model directly implements the assumption, revealing, more fully than any before it, that planners must be concerned with political strategy and structure of analytic models.

This book is going to be debated, modified, and reworked. It is bound to be politically influential, the author's words of caution notwithstanding. Here is a challenge. The sooner we get started the better.

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Vol. II, No. 2, Apr. 1970

*Urban Dynamics*, by JAY W. FORRESTER. Cambridge: M.I.T. Press, 1969. 285 pp. + xiii, figs., tables. $12.50.

This is a difficult, dangerous, important book. It attempts to model the dynamics of "The Urban Problem." Stylistically it has much in common with the author's earlier *Industrial Dynamics*, and this is one of the difficulties for he eschews both mathematics and references. In many ways the book is a description of a single complicated computer program in a rather obscure, though not impossible, language called DYNAMO. Descriptions of canned programs are usually not very enlightening; the importance in the present instance is that this program proports to capture the essence of the cities. Non-linear difference equations would presumably only serve to frighten concerned city officials, whereas computer code in bold print must be unassailably true. There is one reference to a work not by the author; apparently Forrester feels that the reader is better left ignorant of the rather vast competing literature on urbanism. Computer modelling of urban systems, expecially transportation and urban growth as well as economic development, has now been a multimillion dollar business for over a decade. On the whole, the approach is that of an engineer rather than a scientist.

The specific model consists of business, housing, and employment sectors—each at three levels: premium, worker, and underemployed. The cartesian product yields the nine state variables of the model. These are related to each other and to the exogenous, non-city environment by a complex of flow variables. In other words, it is a classical non-linear deterministic equilibrium model, but of great complexity. Herein lies its importance for it is rather grandiosely conceived. One simulation, for example, is run for 250 (model) years, proceeding through "urban development, maturity, and stagnation." Chapter Two and the Appendices—which are half the book and especially Appendix A, "A Theory of Urban Interactions"—describe the specific model and all the interrelations. There are about 300 parameters, interacting nonlinearly and with lags. Forrester makes the point that the model is not sensitive to specific values of many of the parameters, and indeed has many perceptive comments on the "counter-intuitive behavior" of complex systems. Policy implications of the model, deduced through computer simulations, constitute an important part of the book.

But the consequences are a result of the premises. Not only the values of the parameters, but also which variables are chosen for consideration and how they are interconnected, are critical. When slums are called "underemployed housing" and when so many of the conclusions are what one imagines would please clients of the Harvard Business School, one begins to wonder whether the model represents a real city or someone's perception of a city. An appropriate local policy may also be disastrous if adopted nationally because the dynamics of a system of cities are not the same as the dynamics of a single city. Forrester is quite aware of this difficulty; the danger is that his model has not really been tested empirically, thus the policy implications may be wrong, and the model—because of its complexity—is extremely difficult to test. A very careful study of the many assumptions of the model are required. Also required are more competing models, thus the book's greatest achievement may be the competition which it stimulates. It would be unfortunate if others took Forrester's attitude and developed their own models, completely ignoring his.

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# SYSTEMS ANALYSIS

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Professor Ludwig von Bertalanffy (1968), assaying the subject with which he is identified, writes that "[systems theory] heralds a new world view of considerable importance." By standards of self-congratulation common to the field, this ranks as understatement. Kenneth Boulding (1968: 3), in discussing the itches for which systems theory is to act as unguent, identifies them with nothing less than the desire "for a body of systematic theoretical constructs which will discuss the general relationships of the empirical world." And Professor J. Forrester, not content to serve as a mere surveyor of the slums, often sees in his researches clues to the very cosmos itself. The "loop structure" that systems analysis studies, he (1969a: 107) remarks, "surrounds all decisions public or private, conscious or unconscious. The processes of man and nature, of psychology and physics, of medicine and engineering all fall within this structure."

Despite its air of modernity, systems analysts assure us that the discipline sports a distinguished pedigree. C. W. Churchman, in a survey of readings, claims Plato, Aristotle, Thomas Aquinas, Descartes, Spinoza, Hobbes, Kant, John Stuart Mill, and Jeremy Bentham as early practitioners of the systems analytic arts. The *Republic*, he (1968: 239) adds, is actually a "famous systems science book."

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AUTHOR'S NOTE: *A special note of gratitude is due Annabelle Devine for her skillful reconstruction of this text.*





Enthusiasm of such undignity is itself a challenge. Is systems analysis in fact an advance of galactic proportions or is it rather a brother to scientology, homeopathy, and the doctrine of the humors? Distressingly, one discovers little save ambiguity in the brace of terms themselves. 'Systems analysis' suggests a discipline engaged in the analysis of systems. Yet this might be too narrow a reading: pushing 'systems' toward the adjectival would render 'systems' analysis a variant of 'systematic analysis.' Thus, systems analysis major as the analysis of systems and systems analysis minor as systematic analysis. On this axis we may split the discipline, at least at first.

## SYSTEMS ANALYSIS MINOR ($SA_m$)

Systems analysis minor apparently was first admired at the Department of Defense, a circumstance that might presently suggest a certain diffidence in appreciation. In its purest form, as expounded, say, by Charles Hitch (1955: 1), it appears as a whole determined by five parts:

(1) An objective or objectives which we desire to accomplish.
(2) Alternative techniques or instrumentalities by which the objective may be accomplished.
(3) The costs of resources required by each system.
(4) A mathematical model or models, i.e., the mathematical or logical framework or set of equations showing the interdependence of the objective, the technique and instrumentalities, environment, and the resources.
(5) The criterion, relating objectives and costs of resources, for choosing the perferred or optimal alternative.

The technique thus described has by no means been limited to the Department of Defense. E. S. Quade (1966: 28), in writing on the theory of PPB (Planning, Programming, and Budgeting), characterizes systems analysis in congruent terms:

> A systems analysis is an analytic study designed to help the decision maker identify a preferred choice of possible alternatives. It is characterized by systematic and rational approach,[1] with assumptions made explicit, objectives and criteria clearly defined, and alternative courses of action compared in the light of the possible consequences. An effort is made to use quantitative methods, but computers are not essential. What is essential is a model that enables expert intuition and judgment to be applied efficiently.

Construed simply as schemata for a normative theory of decision making, both the Hitch and Quade summaries evince a Polonial uncontroversiality that puts one promptly in mind of a baked potato.[2] Nonetheless, the theory of rationality, which both authors implicitly invoke, is by no means in so satisfactory a state as their summaries suggest. The problems can be located quickly. What is needed—in the rough—is an explication of the schemata:

(1) $\Phi$ is a rational decision,

especially when the instances of $\Phi$ denote decisions taken under varying degrees of certainty.

We can express all possible conditions of uncertainty as *states of nature*, and collect them as the set $S = (s_1, s_2, \ldots, s_n)$. Further, we can represent possible decisions as $D = (d_1, d_2, \ldots, d_n)$. And further still we can define a function F from SxD to a set of consequences $C = (c_1, c_2, \ldots, c_n)$ whose value of a particular state of nature $s_i$ and a particular decision $d_j$ is some consequence $c_k$. Explicating (1) is then achieved in two steps. First, a utility function $\mu$ on C that indicates *preferences* among consequences must be defined, and then a rule of rational choice that selects decisions in the light of the values associated with C must be described. If the situation is one in which there is no uncertainty whatsoever, the problem is tractable. All that is needed is an ordinal preference ranking $\mu$ defined on C. A rational rule of choice would enjoin simply that $\mu$ be maximized: given the certainty of S, agents should survey D with the aim solely of assuring that the value of F be some $c_j$ such that $\mu(c_j) \geqslant \mu(c)$ for all c in C. Any numerical representation $\mu'$ of such an ordinal preference ranking will be as satisfactory as any other just so long as it faithfully mirrors preferences: all functions are monotone transforms of each other.[3] Once, however, uncertainties are admitted, the problem becomes more difficult. Not only must consequences be ranked on varying assumptions of probability, numerical or cardinal utilities must be fixed so that utility differences can be measured. The real trouble commences, however, in the choosing of a rational rule. It is not at all clear, for example, that under circumstances of uncertainty, an agent ought to act so as to maximize his expected utility. Von Neuman and Morgenstern proposed instead that he adopt the more prudent minimax principle: act so as to minimize expected loss. The technical literature of decision and game theory is in effect an extended exploration of various principles of rationality, especially with respect to situations in which agents have imperfect information about the consequences of their actions.



But neither utility theory, nor game theory, nor statistical decision theory for that matter, has produced a body of principles that explicate the notion of rationality in an utterly clear, unambiguous, and intuitively attractive fashion. In fact, the situation is worse. John Milnor (1954), in developing an axiomatic theory of rationality, proposed nine criteria that any acceptable rule of rational choice should satisfy. He went on to show that for a wide variety of decision theoretic principles, none satisfied all nine. This result, together with such well-known impossibility theorems as Arrows', suggests that the concept of rationality is not only unkempt, but intractable as well. The theory to which ($SA_m$) is grappled is rather more unfinished than the enthusiastic, confident, and untroubled descriptions cited above suggest.

## SYSTEMS ANALYSIS MAJOR ($SAM_j$)

To learn more of the general theory of systems one turns first and naturally to the discipline of General Systems Theory. GST is nothing if not ambitious. In the opening chapters of his text on the subject, entitled "Systems Everywhere," Professor von Bertalanffy claims information theory, set theory, graph theory, game theory, decision theory, the theory of automata, and cybernetics as parts of GST. The sense of motley abandon is reinforced both by reading the text of *General Systems Theory*, and by thumbing through the Society for General Systems Research yearbooks, *General Systems*. The latter especially contains papers on an astonishingly diverse number of subjects. But Professor von Bertalanffy (1968), by his own argument, does not preside over a zoo: The discipline has a purpose:

> Its subject matter is the formulation and derivation of those principles which are valid for systems in general.
>
> The meaning of this discipline can be circumscribed as follows. . . . We can ask for principles applying to systems in general, irrespective of whether they are of physical, biological or sociological nature. If we pose this question and conveniently define the concept of system, we find that models, principles, and laws exist which apply to generalized systems irrespective of their particular kind, elements, and the forces involved.
>
> A consequence of the existence of general system properties is the appearance of structural similarities or isomorphisms in different fields. There are

correspondences in the principles that govern the behavior of entities that are, intrinsically, widely different.

A discipline so ambitiously, even gigantically, construed suggests at least three questions: (1) what are systems? (2) what are some of their interesting laws? (3) what interesting isomorphisms between systems does GST illuminate?

A. D. Hall and R. E. Fagen (1968), in a paper entitled "Definition of System," have thoughtfully addressed first matters first. A system is "A set of objects together with relationships between the objects and between their attributes."

"Objects," the definition continues, are simply "the parts or components of the system." Attributes are "properties of objects." Relationships are those things that "tie the system together."

Just so.

These citations, plucked as they are from a more discursive article, illuminate at low wattages. But Fagen and Hall, wobbled though they be by the definitional arts, have suggested something that mathematicians would recognize as an elephantine approximation to the notion of a model. The term 'model' of course, enjoys almost the same high status as the term 'system'; and, one might add, is employed with just the same deft precision.[4] Happily, greater clarity is possible if we hew to the more or less standard notion of a model employed in modern model theory or semantics. I excerpt from "Quines' Definition of Logical Truth," which sets the details out with elegance. (My excerption is free form. See Berlinski and Gallin, 1969.)

> Suppose, as a beginning, we make explicit a choice of language L, by first fixing its vocabulary as comprising an infinite list of individual variables, standard sentential connectives, quantifiers, and at most denumerably many predicate variables of various finite ranks. A model can then be defined as an ordered pair M = [D, F], where D is a nonempty set (the domain of M), and F is a function assigning to the predicate variables of L relations of corresponding rank on D. The values of F are called the relations of M. Given this much it is possible to define important semantic relationships between L and M. An assignment $\alpha$ is a function that maps the individual variables of L onto individuals in the domain D. The notion
>
> $\alpha$ satisfies S (x, . . .) in M
>
> can then be defined by recursion on the length of the formula S (x, . . .). The intuitive idea behind the definition is that an assignment $\alpha$ satisfies a formula if the formula holds in M, when its predicate variables are interpreted by F, its free individual variables are interpreted by $\alpha$, and its bound variables range over the domain D. A sentence, which is formula with no free individual variable, will either be satisfied by every assignment in M, or else by none. In the first case the sentence is *true* in M, otherwise *false* in M. Given the definition of truth, we may identify the *theory* T of M, as the set of sentences satisfied in M.



The usage thus employed sharply distinguishes between a model, which is a set theoretical entity, and the language that is used to talk of the model, which, of course, is not. This distinction is frequently blurred in discussions of systems analysis and often, in what amounts to a systematic confusion of use and mention, the passage from model to theory and back to model again is made with an almost oleaginous ease.

So systems are models, at least on this utterly unsolicited reconstrual of GST. That takes care of (1). What of (2)? The notion of a law is unclear, but for purposes at hand, noting simply that the laws of L displace a certain space within its *truths* should suffice. In view of the proposed generality of GST, then, it would seem natural to require that S be true in all systems if it is to be among the truths of GST. Thus, tentatively:

(2) S is a truth of GST if and if only S is true in all systems.

S will so count if given a certain class of particles that do not change their interpretation come what may, the remainder of the particles in S can have their interpretation varied at will without changing the truth of S. But distressingly, (2) above boils down to the definition of *logical* truth commonly associated with Tarski (see Berlinski and Gallin, 1969: 3). The laws then of GST turn out to be a subset of the *purely logical truths.* Worse still, in view of the completeness of elementary quantification theory, there is little left for GST to discover, since we more or less have all the logical truths at hand in one fell swoop.[5]

All this is rather disagreeable from the GST point of view. And certainly unintended. Nonetheless the point thus reached seems joyfully reaffirmed not only in principle, which I admit is often expressed with a vanishing degree of intelligibility, but in boldly offered examples. I turn to von Bertalanffy's text (1968: ch. 3):

> A system can be defined mathematically in various ways. For illustration, we choose a system of simultaneous differential equations. Denoting some measure of elements, $P_i$ (i = 1, 2, . . .n), by $Q_j$, these, for a finite number of elements and in the simplest case, will be of the form:

$$\frac{dQ_1}{dt} = f_1 (Q_1, Q_2, \ldots, Q_n) \qquad [1]$$

$$\frac{dQ_2}{dt} = f_2 (Q_1, Q_2, \ldots, Q_n)$$

. . . . . .

$$\frac{dQ_n}{dt} = f_n (Q_1, Q_2, \ldots, Q_n)$$

By Taylor's theorem, such a system of equations can, given suitable restrictions, be developed into a Taylor series. In the simplest case:

$$\frac{dQ}{dt} = f(Q) \qquad [2]$$

which may be expanded thus:

$$\frac{dQ}{dt} = A_1 Q^1 + A_{11} Q^2 + \ldots \qquad [3]$$

Retaining only the first term:

$$\frac{dQ}{dt} = A Q \qquad [4]$$

Whence by integration:

$$\frac{dQ}{Q} = Adt \qquad [5]$$

Thus:

$$\int_{Q_o}^{Q(T)} \frac{dQ}{Q} = \int_{O}^{T} AdT \qquad [6]$$



Evaluating both integrals:

$$LQ \left[\frac{Q(T)}{Q_o}\right] = AT \qquad [7]$$

Hence:

$$\frac{Q(T)}{Q_o} = e^{AT} \qquad [8]$$

Equation [8] is, of course, the familiar exponential law of growth. All this seems unremarkable—yet what conclusions it engenders.

> Mathematically trivial as these examples are, they illustrate a point of interest for the present consideration, namely the fact that certain laws of nature can be arrived at not only on the basis of experience, but also in a purely formal way. The equations discussed signify no more than that the rather general system of equation, its development into a Taylor series and suitable conditions have been applied. In this sense such laws are "a priori" independent from their fiscal, chemical, biological, sociological, etc., interpretation. In other words, this shows the existence of a general systems theory which deals with formal characteristics of systems, concrete facts appearing as their special applications by defining variables and parameters. In still other terms, such examples show a formal uniformity of nature [von Bertalanffy, 1968].

The abundance of confusion here is alarming. The very first sentence seems to suggest that *being based in experience* and *being formally derivable* are alternative but symmetrical procedures whereby a sentence may be counted as a law of nature. This is a grave error. If S is based in experience, then S is *confirmed* or *inductively supported;* if S is formally derivable from other sentences, then S is *entailed* or *deductively implied.* As it happens, any sentence S admits of other sentences $A_1, A_2, \ldots, A_n$ from which it is formally derivable: simply set $S=A_i$, a procedure of great ease and perfect triviality. But no matter how S is derived, it will not follow simply on the strength of the derivation, that S is a law of nature.

With distinctions thus fixed, scan again the equations numbered above. Taylor's theorem and its corollary, which sanctions the expansion of [2] into [3], are, of course, theorems of analysis; similarly the conditional whose antecedent is [4] and whose consequent is [8]. That these

sentences turn out to be true in models other than the primary models of analysis is hardly surprising: if a complex theory T, developed to discuss population growth, invokes the powers of the calculus, then models of T must *also* be rich enough to satisfy portions of analysis thus developed.

But, my more clamorous readers will insist, von Bertalanffy is not arguing merely that the theorems of the calculus turn out to be true wherever they *are* true: when properly reinterpreted, some hold of a variety of nonmathematical entities as well—[8] is an example. It is wonderful that one statement holds of physical entities when we measure population growth, of bank balances when we compound interest, and of bacteria when we cultivate *pyogenes staphlococci var. aureus.*

Notice, however, that though the entailment of [8] by [4] ranks as a theorem of the calculus, or would were relevant portions formalized, the [8] does not *thereby* count as a truth of, say, genetics, or theory of population growth. In fact, there are obvious models in which it turns out false, even though all but parameters retain their standard interpretations. To register it as prize of genetics on the strength of its heritage in the calculus, one must confirm it to be true in its reregistered interpretation by proving certain satisfying models of analysis isomorphic to models of the theory in question, be it concerned with genetics, population growth, or the development of compound interest.

No doubt it is still wonderful that [8] and its crowd happen, as it were, to be confirmed in so many different domains. So long as my readers hew to the cited distinctions and urge no truths electrifyingly discovered by unaided reason, I find no fault and plan to content myself with the murmuring of a few academic "hear, hear's."

But then why scruple with such exotica as the entailment of [8] from [4] and way points? If extended reinterpretability is what is wanted, why not count as truths (and hence as laws) of GST only statements true *everywhere* and not merely in some parched or distant model? I suggest the following as properly in the spirit of GST:

(3) The truths of GST are that set of sentences satisfied in the *largest* set of models.

But the largest class of models is the class of *all* models. And the set of sentences so satisfied is the logical truths. Thus, with very few refinements, one is driven back to the view of page 109 which, after all, was my claim of page 109.



Isomorphisms are the third of the three pledged usufructs of GST. The master's own discussion of these matters, with its notion of analogies, homologies, and explanations, remains more or less incomprehensible to me. However, the concept and the program to which von Bertalanffy alludes are well known. Isomorphism or structural identity is set theoretical but not general: no single definition applies indifferently to *any* set theoretical entity: we must speak of isomorphism between *groups,* or *models,* or *rings,* or the like. Thus restricted, its utility in mathematics is well known and widely understood. Certain mathematical endeavors, for example, can best be seen as searches for *representation* theorems: proofs that a class of models exists such that every model of a given theory is isomorphic to some member of this class. Cayley's theorem in group theory asserts, for example, that every group is isomorphic to a group of transformations.

The concept of isomorphism is useful not only within a given discipline but between disciplines.

> When a branch of empirical science is stated in exact form, that is, when the theory is axiomatized within a standard set theoretical framework, the familiar question raised about models of the theory in pure mathematics may also be raised for models of precisely formulated empirical theory.
>
> . . . many of the discussions of reductionism in the philosophy of science may best be formulated as a series of problems using the notion of a representation theorem. For example, the thesis that biology may be reduced to physics would be in many people's minds appropriately established if one could show for any model of a biological theory it was possible to construct an isomorphic model within the physical theory [Suppes, 1969: 18].[6]

Certainly important work has been done under this rubric. The reduction of thermodynamics to statistical mechanics is an acknowledged triumph of mathematical physics. But what remains in all this of GST? To discover that one model is isomorphic to another is only to diminish the stock of what was thought to be novel: isomorphism is an indicator of indifference. More to the point, discovering a significant representation theorem is hardly a task *external* to a given discipline. The reduction of thermodynamics to statistical mechanics was after all a triumph of mathematical physics; Cayley's theorem is a theorem in group theory. GST seems to be in the faintly embarrassing position of having rendered its aims precise, only to discover the various sciences doing what it claims requires to be done.[7]

## SYSTEMS ANALYSIS MAJOR$_2$ (SAM$_2$)

Systems theorists by their own admission suffer from an uncontrolled appetite for the general. Not all programs, however, are quite so grandly conceived as von Bertalanffy's. Some writers, uninterested in systems generally, have turned to various disciplines with the hope of seeing there, concepts general enough to count as parts of GST. I am thinking now of GST variously construed as information theory, cybernetics, and the theory of automata.

These separate pursuits are unified by more than a common if promiscuous identification with GST. Under certain lights, they all seem to share a concept in the notion of a machine. Here Ashby (1968: 110) strikes something of the right note:

> Here we are obviously encroaching on what has been called General Systems Theory, but this last discipline always seemed to me to be uncertain whether it was dealing with physical systems, and therefore tied to whatever the real world provides, or with mathematical systems, in which the sole demand is that the work shall be free from internal contradictions. It is, I think, one of the substantial advances of the last decade that we have at last identified the *essentials* of the machine in general.

Fixing the concept of a machine as central was a process that in bulk took place from 1947 to the present–at least in these social sciences. Psychologists had long seen opportunities for exploitation in the general notion, but not until the development of cybernetics, information theory, and the theory of automata did they feel secure in passing from exploitation to expropriation. The theory of automata for the first time made the mathematical notion of a machine explicit by linking it both to the theory of recursive functions and to the actual development of the digital computer. In information, information theorists hit on a powerful notion that was supposed to apply indifferently to a multitude of systems, and cybernetics, finally, seemed to provide a schema whereby machine behavior could be perceived as purposive and human behavior explained as machinelike. If not completely captivated by a single concept, the various disciplines did appear to be converging upon a series of common concepts.

The notion of a machine to which Ashby (1968) alludes, he also defines:

> The machine with input or the finite automata is today defined by a set of internal states I, a set of input or surrounding states, and a mapping, f say, of the product set I x S into S. Here, in my opinion, we have the very essence of the machine; all known types of machines are to be found here; and all interesting deviations from the concept are to be found by the corresponding deviation from the definition.



As it happens the definition of a machine is not all that helpful. The apparent restriction to finite deterministic automata seems cramping. But no matter–in the concept of a *Turing Machine,* there does exist a deeply investigated, utterly idealized general notion.

A Turing Machine consists of a set of states $q_1, q_2, q_3, \ldots$; a doubly infinite two-way tape scanned by a reading head and segregated into squares; and a series of symbols $S_0, S_1, S_2, \ldots$ that the machine is capable of printing. At any given time, $t_i$, the machine is in a certain internal state $q_i$. At the same time, the reading head scans a given square on the tape. In moving from $t_n$ to $t_{n+1}$ the machine can either halt operations entirely, erase the scanned symbol and change it for another, or shift the reading head from the given square to one adjacent, while changing its internal state. Instructions governing the change from $t_n$ to $t_{n+1}$, then, can be expressed as ordered quadruples:

$$[q_i S_j R_{q_1}],$$

where $q_i$ and $S_j$ represent initial states and scanned symbols respectively, R represents a move to the right on the tape; and $q_1$ represents the resulting change in internal configuration. A Turing Machine itself, can then be *defined* as a finite nonempty set of such quadruples.

A Turing Machine can not only calculate but can calculate anything calculable. The proof invokes Church's thesis that calculability or computability collapses into recursiveness, and then shows Turing Machines capable of computing all and only the recursive functions. Nor do we need a clumsy plethora of such devices. The *Universal* Turing Machine can produce as output, sequences imbedded by any particular machine, thus achieving hypothetical universal computing capacity.

The utility of the abstraction thus described is hardly at issue. Automata theory generally, despite a somewhat uncertain and inelegant formulation, remains an exciting area of recursive function theory. But what of the larger hopes for the abstract concept of a machine touched on by Ashby and touted in GST? Roughly they were three in number. First, the development of an abstract theory of machines was to provide a sophisticated way of construing complex human *cognitive* abilities. Machines would simulate human behavior: the *theory* of machines would

explain the analogous human capacities. Some theorists were emboldened to suggest that only the details were missing. Second, the development of cybernetics was to permit the perception of *purposive* behavior in machines, and thence to explain it *as* purposive so that human behavior formerly unreached by the machine analogy could finally be accommodated. Finally, the concept of information was to provide scholars with a tool of stunning generality sufficient at the least for yoking together the various sciences. There were such obvious connections between information theoretic and physical concepts of entropy, between information and probability.

John von Neumann had doubts about automata theory in 1951, chiefly because the theory could not deal with continuous properties. His spirit of skepticism has survived; it waxes rather than wanes. Machine translation is an acknowledged failure. Very serious and detailed work in linguistics has indicated human abilities that are unexplained in simple automata theory or related disciplines. The entire automata theoretic enterprise of simulating human intelligence has swerved sharply from its curve of ascending optimism. Even in relatively trivial areas such as the construction of chess-playing programs, an impression of failure is hard to avoid.

Something of the same thing has taken place in cybernetics and information theory. Both subjects are shaped about real theories, but their *extensions* have taken place in the paraplegic disciplines: sociology, psychology, political science, management science—a sure sign of debility. Cybernetics caused dispute from the beginning. Richard Taylor argued that early formulations were philosophically objectionable, especially since they construed *purpose* as a behavioral concept. One wonders now, some twenty years after the first popular accounts, whether concepts borrowed from the uninteresting theory of servomechanisms have the force generally required to sustain cybernetics. Certainly, the positive results have not been terribly impressive. Information theory is a much richer discipline than cybernetics, but much the same limitations are now felt when it is pressed beyond the narrow problems of communication channels for which it was designed.

All this is nothing new. Scholars have been expressing various sorrows with these disciplines for at least a decade. But news travels with uneven speed: the fine edge of skepticism that now characterizes linguistics has not yet cut its way to various dark corners of the intellectual community. Worse, one sees a dismaying vulgarization of the theories as they are stretched beyond limits of natural elasticity.



## EVIL DAYS FOR SYSTEMS ANALYSIS: THE FORRESTER MODEL

But all this cannot possibly be appreciated in the abstract. The delight as always is in the details and for these I turn to J. Forrester's *Urban Dynamics* (1969a). Here is a fat book covering 250 pages in length and crammed with computer theoretic arcana. Half the work is delivered unto the reader in the form of a computer printout: recondite charts dance across the pages; there are learned references to the Dynamo Compiler; pages and pages of densely printed input-output charts; and finally, flow charts featuring intricately drawn arrows in numbers approaching the transcendental.

*Urban Dynamics* carries the ordinary systems analytic hunger for the general to a point of virtually Baroque splendor; for in it, Professor Forrester has assayed to explain the growth and decline not of any particular city, not even of a group of particular cities, but of urban areas *überhaupt*. Progress on this order has been formerly unobtainable, primarily because, in the words of *The New York Times* (1969), "the problem in dealing with urban complexity is that the influences operating within a city are so subtly and intricately interconnected that the human brain—whose response is conditioned by exposure to simple systems—finds it all but impossible to trace cause and effect." Professor Forrester (1969a: 1), whose own brain has presumably smashed through the barrier of simple systems, has been sustained in his analysis by communion with the powers of Systems Theory:

> The concepts of structure and dynamic behavior apply to all systems that change through time. Such dynamic systems include the processes of engineering systems, biology, social systems, psychology, ecology, and all those where positive and negative feedback processes manifest themselves in growth and regulator action.

Although Professor Forrester's model is of the twentieth order of complexity, the details can be summarized compactly. There is first of all the theory proper: a series of numbered[8] equations that describe relationships between three economic[9] classes; three classes of housing; and three kinds of business enterprises, all within a given and fixed area of land. The theory is segregated into what Professor Forrester calls *level* and *rate* equations. The former describe some magnitude associated with each sector at a point in time; the latter describe the rates of change associated with given levels. In addition, *Urban Dynamics* contains a simulation run

of the theory that fixes initial values for parameters and then traces predicted consequences over a period of 250 years.

Forrester's model is a hypothetical entity, whose idealized features are presumed comparable, at least in major respects, with the features of virtually any urban area.[10] Given some fixed and empty plot of land at an initial date, various attractions and tugs first act to create a healthy urban area, and then over time and quite unmolested by outside influences, push the plot toward a state of stagnant equilibrium characterized by excessive underemployment, declining industry, and wretched housing. The dejecting shape of an urban area, of course, is completely determined by the theory—so the actual simulation run provides little in the way of surprises. The inevitable descent toward decrepitude is primarily, although not exclusively, a function of the ever-swelling poor (quaintly called underemployed), who come to the city first tentatively, and then in larger numbers, as public policies exacerbate the very conditions they were meant to alleviate. As the poor come, the middle class goes, antagonized by high per capita tax rates and frightened by their growing political impotence. As the middle class leaves, housing decays and industry wobbles. The completion of the process sees the city shuttered, stagnant, and slumly.

Naturally Professor Forrester derives from his theory grave lessons for the conduct of government. Succoring the lower classes, attractive though it be in a narrow swatch of time, is ultimately disastrous. Job programs, training programs, financial aid, tax subsidies, low-cost housing construction all bulk large but weigh little. What is needed instead are techniques for grappling the middle and upper classes to the city's core, extruding the poor into the limitless environment beyond the city and encouraging the growth of labor-intensive industries.

All this is advanced very tentatively at the beginning of the book, but with increasing confidence and assertiveness toward its end. Professor Forrester is undismayed by the absolute lack of evidence adduced in support of his theory: he dismisses the matter with untroubled dispatch. But despite its air of confident *brie*, faith in both the accuracy and intelligibility of Forrester's theory, and the remarkable and astonishing claims that it entails, is morbidly affected by even a moderately close reading of the text.

Consider for example the first equations:

$$UA \cdot KL = (U\,K+L \cdot K)\,(UAN)\,(AMMP \cdot K) \qquad [1.R]$$
$$UAN = .05$$



UA = Underemployed Arrivals (Men/Year)
U = Underemployed (Men)
L = Labor (Men)
K = Current Year
KL = Period from K to L - 1 year
UAN = Underemployed Arrivals Normal
AMMP = Attractiveness for Migration (of Underemployed) Multiplier Perceived

Equation 1.R "is the rate equation describing the arrival of underemployed into the area" (Forrester, 1969a: 135).[11] Between any two given times, the number of underemployed attracted to an urban area is equal to the product of the present underemployed and labor population of the city construed as a fixed percentage of the total labor and underemployed population, and an attractiveness multiplier, computed at a given time, and evaluated by a separate function.

That function is given in Equation 3.A.

$$AMM\,K = (UAMM \cdot K)\,(UMM \cdot K)\,(PEM \cdot K)\,(UJM \cdot K)\,(UHPM \cdot K)\,(AMF) \qquad [3.A]$$

AMF = 1
J = Previous year
UAMM = Underemployed/arrivals mobility multiplier
PEM = Public expenditure multiplier
UHM = Underemployed/housing multiplier
UJM = Underemployed/job multiplier
UMPM = Underemployed/housing program multiplier
AMF = Attractiveness for migration factor

[3. A] states that the attractiveness of a given urban area for a given class (in this case the underemployed), can be computed as a product of six terms, each dealing with a different dimension of attractiveness, and each receiving a value from a separate multiplier or function. For example, the UHM function is suggested in the curve in Figure 1.

In essence these multipliers seem something like utility functions defined not only to reflect preference but *degrees of preference* between alternatives. In each case, the arguments are indicators of relative difference between the city and its environments; the value of the function, ranging from o to n, represents cardinal weights assigned to the various arguments. Arguments that represent no relative differences are fixed as normal and consequently receive the value of one in the multiplier.

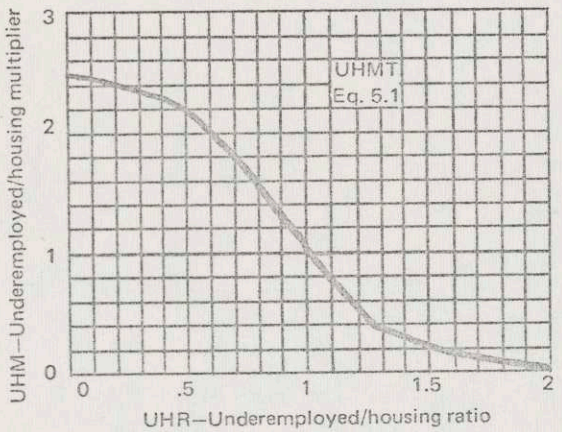



Figure 1. UHM FUNCTION

Equations 1.R and 3.A, then, represent the main factors that account for the number of underemployed attracted to a given area.[12] Together they constitue an explanation or partial explanation of what might be called *net propensity to migrate.* But even at first cut, much of this small theory is odd. The mathematics, such as it is, is ornamental merely. There is no more reason to assume that attractions are aggregated by the product function, as in [3.A], than to assume them aggregated by a function that extracts the cube root of the product multiplied by itself.[13] And then ought not net propensity to migrate be expressed probabilistically? Aggregate behavior is notoriously insusceptible to deterministic analysis. Surely a more sophisticated version would have it that variations in attractiveness affect the *probability* that the poor will choose to migrate. Additionally, and still *en passant,* one wants to know why the total numerical expression set equal to UAN is in its turn a function of the *size* of already existing labor and underemployed classes. This feature is repeated throughout the equations that predict and explain propensities to migrate, and seems equally arbitrary everywhere.

Forrester's equations account for no changes in arrival rates without the tacit assumption that men move toward urban areas they perceive as relatively attractive. So far so good. But Forrester also assumes that agents only perceive as attractive those areas that *are* attractive, thereby leaving untreated the important case of false belief concerning relative attractiveness.[14] More importantly, Equation 1.R defines attractiveness itself



along dimensions narrow enough to destroy the theory's psychological plausability. Only factors of employment, housing, public expenditure, and occupational mobility get reflected. But urban migration in this century involves chiefly factors of land use—the decline of the agricultural way of life. Myriad other causes go uncited in the model. Consider such simple parameters as *distance.* On Forrester's theory, two urban areas A and B should evince comparable rates of UAN arrivals just so long as the right-hand side of their respective model equations are equal. But if the only available supply of underemployed agents resides five miles from A and ten thousand from B. . . . You see the point, surely.

The model is quantitatively but not qualitatively sensitive to variations in the mix of attractiveness.[15] This means that an urban area verging on chaos, but with a large number of labor and underemployed, might well be as attractive to the UAN class generally as one better managed but with a relatively smaller number of labor and underemployed. The total weighing construes identical products identically, a policy that wipes out differences in the *way* the products are determined. Nor do interactions between dimensions of attractiveness get reflected in computation of aggregate attractiveness. But attractions are not generally independent: the total value of a plate of ham and eggs depends heavily on whether the ham and eggs or the plate is served first.

The theory yields additional puzzles. Take, for example, the concept of normality. Multipliers translate relative attractiveness into numerical values that enter into the computation of total attractiveness at Equation 3.A. The functions are arbitrarily pegged so that each multiplier has a value of one when the argument reflects an equilibrium with the outside environment. Thus one represents no net gain or loss in attractiveness. The curves described by the various multipliers are not linear, so there is ample room in each curve to reflect the fact that strictly equal increments in arguments do not necessarily produce equal increments in values. And this is as one would expect, for a ten percent increase in public expenditures would have different attractive powers depending on whether it were added to a financial structure just comparable to the environment or one vastly wealthier than it. But paradoxically, various AMM multipliers fixed at *different* equilibrium points all seem to be identical: their shape never changes. Thus suppose that there are two urban areas A and B interacting with two environments $A'$ and $B'$. Imagine that equilibrium points at A are taken as $\Phi$ and at B as $\beta\Phi$, such that $\beta\Phi > \Phi$. If the arguments of the multipliers $\xi$ and $\xi'$, are such that $\xi - \Phi = \xi' - \beta\Phi$, then, all other things being equal, the value both of the multipliers and hence of the rates of

migration turn out to be the same. More generally, any two cities with comparable degrees of relative attractiveness attract the same number of people. But this is silly. The behavior of people moving from misery to mere wretchedness is quite different from the behavior of people moving from luxury to absolute ravening opulence.

Naturally in a theory covering almost 120 equations one cannot exhaust the possibilities for criticism in so short a space, but I would not want to utterly ignore the rest. There is, for example, on page 144, a record of the curious decision to fix departure rates as the *reciprocal* of inward migration rates, making the explosive migration of management and middle-class groups to the suburbs inexplicable. There is, on page 166, the hypothesis that managerial unwillingness to stay within a city is almost a linear function of rising tax rates—an assumption that makes the movement of managers toward the suburbs and higher per capita taxes hard to explain. On page 175, a strange connection is drawn between high tax rates and premium housing construction, one that leaves undiscussed the documented relationship between mortgage funds, labor costs, zoning restrictions, and depressed premium housing construction. Page 184 presents the astonishing assertion that the "history of successful housing construction, and the building industry organized to provide the construction, tends to *maintain* the construction rate." On page 192 we read that "increasing managers in proportion to managerial jobs increases the likelihood of establishing new enterprise": a claim that suggests a peak of business dynamism during periods of mass unemployemnt. The very next page describes "the inclination to build new enterprise in terms of the availability of labor" and implies that a low labor-job ratio depresses while an excessive ratio encourages new construction. On page 218 we learn that as the underemployed population grows larger, it becomes politically more influential, consequently congratulating itself with higher tax expenditures while paying a disproportionately smaller share of the taxes.

There is all this and much, much more.

## HAILS AND FAREWELLS

The influence of systems analysis, both minor and the two majors, is palpable here. ($SA_m$) makes at least a partial appearance in Forrester's multipliers, for construed conveniently, they turn out to be utility functions defined for classes rather than individuals. Forrester, of course,



must describe the fixing of the function, and his proposals for verifying their shape.

But this is a quibble. The theory is really dominated by assumptions that belong quintessentially to ($SAM_j$) and ($SAM_2$). Virtually all important properties of an urban area, Forrester assumes, can be *explained* by describing processes and structures occurring within the urban area itself. Thus the environment collapses to an abstract point functioning solely as the source of men and relata for the relative inequalities that power the theories' multipliers; agents appear or disappear on the city's tape only when levels (or *internal states*) sink or rise. This thesis immediately puts one in mind of ($SAM_2$), especially in its automata theoretic guises: cities are systems, systems are machines. More particularly cities are *goal directed* systems, so ($SAM_2$) gets reflected in its cybernetic roles as well.

Not only are cities systems, they are amenable to study by *general principles* of systems good everywhere and for all systems. Thus, in one master stroke, Forrester has brought urban dynamics under the aegis of both ($SAM_j$) and ($SAM_2$). Those principles are hinted at in *Urban Dynamics* and expounded more fully in a separate text entitled *Principles of Systems* (1969b: 4.1). The theory gets plotted out in Chapter 4, devoted exclusively to the *structure* of systems:

> concepts of structure organize into the following hierarchy of major and subordinate components:
>
> 1. The closed system generating behavior that is created within a boundary and not dependent on outside inputs
>
> a. The feedback loop as the basic element from which systems are assembled
>
> –Levels as one fundamental variable type within a feedback loop
>
> –Rates (or policies) as the other fundamental variable type within a feedback loop
>
> –The goal as one component of a rate
>
> –The apparent condition against which the goal is compared
>
> –The discrepancy between goal and apparent condition
>
> –The action resulting from the discrepancy.

However, when one attends closely to details one finds little in the way of explication. The notion of *feedback* itself, which occurs with prodigious frequency in all of Forrester's writings, is never fully explained. Evidently, positive feedback is simply a barbarism denoting growth, while negative

feedback has something mainly to do with servomechanisms. But one cannot be sure. Terms like *decision* and *decision process* get dragged in without much explanation:

> As used here the decision process is one that controls any systems action. It can be a clear explicit human decision. It can be a subconscious decision. It can be a governing process in biological development. It may be the valve and actuator in the chemical plant. It can be the natural consequences of the physical structure of the system. Whatever the nature of the decision process, it is always imbedded in a feedback loop. The decision is based on the available information; the decision controls an action that influences the system level; the new information arises to modify the decision stream [Forrester, 1969b: 4.4].

Connoisseurs will want to read this paragraph backward as well as forward.[16]

After siphoning off the merk we are left with something rather traditional. Forrester is chiefly interested in behavior that changes over time. His level equations simply are recordings of magnitudes associated with some or another physical quantity. The rate equations reflect changes in magnitude: the apparatus that is actually developed is nothing more than the traditional method of handling changes through time by means of differential equations. The principles of systems that were to hold universally turn out to be nothing more than the mechanics of the calculus clumsily applied to a fairly limited range of behavior. But regrettably, experience in the last half century or so seems to show that the range of social phenomena thus explicable is distressingly small. And one can see in Forrester's theory itself how extraordinarily inflexible these tools really are, how little behavior gets explained.

All this might leave untouched the central thesis that cities are systems. And there is a point of abstraction in which this view can be rendered trivially true. If all laws needed to explain the city turn out recursive, then one can always concoct a Turing Machine to compute all and only the functions associated with those laws. But this is a mere flight of fancy. Further there is no assurance that the internal states so uncovered will correspond in any way to states of the city itself.

More prosaically, the notion that laws that explain urban dynamics can only *refer* to urban dynamics (which is another way of stating the cities-systems identity) seems intuitively unattractive.

But making that case complete would require another argument.



## NOTES

1. Very few authors, one should note, characterize *their* approach to decision-making as haphazard and irrational.

2. This has not prevented riotous and full-blown debates on the programmatic merits of $SA_m$. Connoisseurs of this sort of literature will find Lindblom's writing a special joy.

3. On the von Neumann, Morgenstern view, at least.

4. Killbridge et al. (1969), for example, define a model as "the symbolic representation of urban relationships," thereby transforming avowals that New York City stinks from inadvertent evaluations to model theoretic appraisals.

5. Although, in view of Church's theorem, we cannot get them mechanically.

6. Readers will find that many of my points have been gingerly lifted from Suppes' essay.

7. I make this point hesitantly. Some philosophers (Suppes, Morgenbesser et al.) would, I think, argue that technically trained philosophers ought to occupy themselves investigating the logical structure of science. So construed, GST, under [3] at least, might be viewed as part of the philosophy of science.

8. Numbering seems to exhaust the possibilities for order which Forrester has explored. There is no formal segregation of assumptions from the bulk of the theory.

9. I conjecture here; Forrester does not traffic in definitions.

10. Forrester calls his theory his model and vice versa.

11. I cannot account for the large number of capital letters that swarm over Forrester's equations. Perhaps the computer finds them easier to read.

12. I neglect Equation 2.A which indicates time lag.

13. In point of fact, *Addiction* seems more intuitive: i.e., a standard game theoretic assumption is that $U(x_1, x_2, \ldots, x_n) = U(x_1 + Ux_2, \ldots, + Ux_n)$.

14. Although provisions are made for *delayed* belief.

15. For example, a change of the UM from .05 to .15 increases the UAMM from 1 to 1.5; a change in TCPR from 1 to 1.5 results in an identical change of the PE from 1 to 1.5. The 2 changes then result in identical changes of the AMMP.

16. The sentence belongs to J. K. Galbraith.

## REFERENCES

ASHBY, W. (1968) "Principles of the self-organizing system," in N. Buckley (ed.) Modern Systems Research for the Behavioral Scientist. Chicago: Aldine.

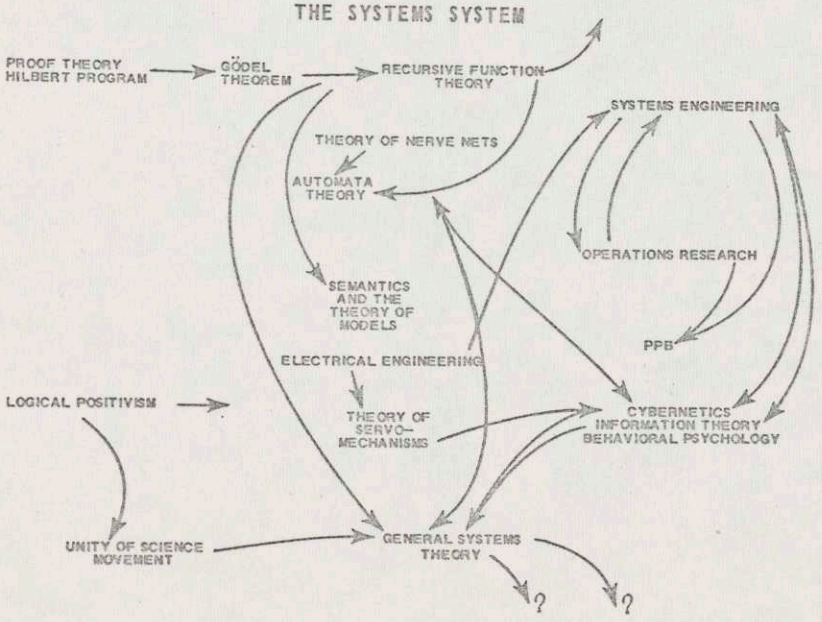
BERLINSKI, D. and D. GALLIN (1969) "Quine's definition of logical truth." Nous 3: 1-7.

BOULDING, K. (1968) "General systems theory," in N. Buckley (ed.) Modern Systems Research for the Behavioral Scientist. Chicago: Aldine.

CHURCHMAN, C. W. (1968) The Systems Approach. New York: Delacorte Press.
DAVIS, M. (1958) Computability and Undecidability. New York: McGraw-Hill.
FORRESTER, J. (1969a) Urban Dynamics. Cambridge: MIT Press.
——— (1969b) Principles of Systems. Cambridge: Wright-Allen Press.
HALL, A. D. and R. E. FAGEN (1968) "Definition of system," pp. 81-92 in N. Buckley (ed.) Modern Systems Research for the Behavioral Scientist. Chicago: Aldine.
HITCH, C. (1955) "An appreciation of systems analysis." Santa Monica: Rand.
KILLBRIDGE, M., R. O'BLOCK, and I. TEPLITZ (1969) "A conceptual framework and urban planning models." Management Sci. (February).
MILNOR, J. (1954) "Games against nature," in R. Thrall, C. Coombs, and R. David (eds.) Decision Processes. New York: John Wiley.
New York Times (1969) October 31.
QUADE, E. S. (1966) "Systems analysis techniques for PPB." Santa Monica: Rand.
SUPPES, P. (1969) "Meaning and use of models," in Studies In The Methodology And Foundations of Science. New York: Humanities Press.
VON BERTALANFFY, L. V. (1968) General Systems Theory. New York: George Braziller.

## APPENDIX

### THE SYSTEMS SYSTEM






Jules Cohn

The most characteristic feature of the burgeoning bookshelves on urban problems is the emotionalism encapsulated in their works by authors acquiescing to the impulse to intone rather than inform, lament rather than enlighten. There follows an annotated list of some current products from ideologues and apologists, but also two first-rate books from scholars determined to keep their cool and thereby contribute to knowledge rather than dialectic.

*The Unheavenly City*, by Edward C. Banfield (Boston: Little, Brown, 1970). Professor Banfield undertakes a painstaking, courageous confrontation with current faddist ideas about urban problems. This is a carefully crafted book that addresses most of the key urban issues: unemployment, race, poverty, education, crime, riots, and finally, prospects for the cities. It is informative and analytical rather than polemical, and therefore part of the solution rather than part of the problem. Banfield's works are landmarks in the field of urban politics because they add to our knowledge by providing data and to our understanding by providing theory. He has specialized in documenting examples of issues involving public and private interest groups. The case study has always been for him the vehicle, not the journey. Banfield's actors are neither heroes nor villains, and both the reformer and his object are subjected to scrutiny.

Banfield, of course, has sought to avoid ideological or self-serving rhetoric since *The Moral Basis of A Backward Society*. In *The Unheavenly City*, he raises questions about the social consequences of the morality that polarizes groups, the utopianism that justifies violence. "Surely," he says, "if it is to be morally significant, good cannot be done from motives that are contrived for the individual by people who have large organizations to maintain or foisted upon him by the mass media." We must "find ways of doing good that are relatively harmless—that do not greatly injure those to whom the good is done. . . and that do not tend to damage the consensual basis, and thus eventually the political freedom, of the society." Banfield quotes Lionel Trilling to remind the polemicists and the righteous of "the dangers of the moral life itself."

*The Unheavenly City* is rich in bibliographical lore, and for that alone is worthy of the attention of urbanists. The author leads us to literature that provides historical perspectives on the problem of the cities—as well as to an awareness that we very much need more works that throw light on the history of urban problems.

# Organization Development Council

For Immediate Release

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Harvey Sherman
Chairman, ODC Awards Committee
(212) 620-7388

"Urban Dynamics" by Jay W. Forrester has been selected for the eleventh annual Publications Award of the Organization Development Council. Mr. Forrester is Professor of Management at Massachusetts Institute of Technology. His book was published by the M.I.T. Press.

Professor Forrester's book was chosen as the best work published during 1969 on the subject of organization on the basis of four criteria: (1) Depth of insight, (2) originality, (3) persuasiveness, and (4) usefulness to practitioners. Forrester proposes a detailed, dynamic model, or theory, utilizing sophisticated computers to analyze the processes affecting the growth and decay of cities. He demonstrates that intuitive, or common sense, approaches are inadequate -- or even detrimental -- to the solution of problems involving complex social systems such as the modern city. Such problems are best examined through simulation on computers that can process the detailed interactions among parts of the system; thus, his model represents the interrelated behavior of industry, people and housing.

Professor Forrester is careful to point out that his book is preliminary and that it

more

suggests a method of attack rather than a set of answers for the urban policy-maker. While certain features of Professor Forrester's model will probably be subject to a great deal of controversy, the O.D.C. Awards Committee is convinced that there will be general acceptance of the value of his general analytical approach to the study of urban behavior.

The Awards Committee regards Professor Forrester's book as important reading for both the general top level executive and the specialist in organization planning (1) because of the potential application of his approach to large scale industrial or governmental organizations which are also complex social systems, and (2) in view of the current interest of executives in helping to solve urban problems.

The Organization Development Council, established in 1951, is composed of executives and university professors concerned with organization theory and organizational planning. The members of the O.D.C. Awards Committee are:

Hugh Estes, Consultant on Organization Planning,
General Electric Company

Dr. Denis Philipps, Director, The Management Institute,
New York University

Harvey Sherman, Director of Terminals,
The Port of New York Authority (Chairman)

Previous O.D.C. Publication Awards were made for books by Ernest Dale, Melville Dalton, Robert Guest, Paul Lawrence, Rensis Likert, Joseph Litterer, Douglas McGregor, Leonard Sayles, Harvey Sherman, and Alfred P. Sloan, Jr.

end

thing is clear: if the contributors to these sections are correct in their assessment of the character of white institutional and individual reaction to the riots, one cannot expect a significant reduction in racial tensions in the near future. A sense of relative deprivation among urban blacks is likely to continue, and a sense of impotent frustration with the major institutional structures of white society may very well increase.

Poor relations between Negroes and big city police departments illustrate the kind of frustration with institutional structures that is likely to continue despite the best efforts of well-meaning reformers. Articles by Lohman and by Levy contend that improvements in police-ghetto relations can come about only through major systemic changes within police departments—changes that will affect the basic values, mores, and standards of the police rather than the attitudes of individual policemen. Changes of this kind are notoriously slow in coming, and Negro communities will continue to be plagued by what Levy describes as the "anti-black" values of big city police departments.

Harry Scoble's paper on the political reaction to the Watts Riot of 1965 again illustrates the point that the slowness of major institutional structures to respond to Negro demands is likely to continue to have potential for ghetto violence. Scoble shows that the Los Angeles riots produced a new kind of militant Negro leader, whose demands center more around bread-and-butter issues than around status or civil rights issues, which are easier to satisfy. He concludes that it is precisely because the demands of the new leadership are so much harder to satisfy through the standard political process that the development of militant leadership styles within the Negro community has potential for violence.

Any collection of twenty-six articles is bound to be uneven. This collection is no exception. Some of the papers are well-written, coherent, and informative; some are not. Overall, what is most disappointing about this book is the lack of solid empirical data. Many important issues are raised, but few are made to face an empirical test. It is perhaps inevitable that this should be the case, given the fact that the riots of the 1960's caught the sociological community, as well as the larger society, by surprise. It is lamentable that sociologists and the country as a whole should not have seen what was coming, but they did not. As a result, most of the empirical research on urban rioting has been completed only recently and has not been reported in this volume or elsewhere in final form.

This book should thus be viewed as a report on work in progress; despite its limitations, it is especially useful at a time when the confrontation between black and white has entered a new level of intensity and new ideas and approaches are needed. The book's usefulness in this regard is enhanced by an excellent topical bibliography on revolutions, rebellions, and riots.

*Urban Dynamics*, by JAY W. FORRESTER. Cambridge, Mass.: The MIT Press, 1969. 285 pp. $12.50.

ALLAN G. FELDT
*Cornell University*

Most sociologists will probably misunderstand this book and criticize it severely. A traditional urban theorist who expects a new work on urban theory will find little of interest here. Professor Forrester's proposed theory of urban dynamics is severely limited in scope. He seems to be largely unaware of the basic elements common to most attempts to formulate urban theory. Furthermore, he does not provide empirical proofs for his assumptions, show the origins of the values assigned to various parameters, or document the particular kinds of interrelationships asserted to exist among his principal theoretical components.

The important contribution of this work lies elsewhere—in an area that is somewhat difficult to evaluate. In essence, Forrester has provided a brief and highly readable account of the *manner* in which an urban theory might best be examined and employed. Thus the work is more on the methodology of theory utilization than on theory itself, although his simple and lucid commentary on the basic characteristics of theory construction are not to be taken lightly. The method proposed and explained in some detail in this work is that of mathematical computer simulation. Following this procedure with a very limited number of principal components and interrelationships, Forrester succeeds in creating a limited representation of the growth process of an hypothesized urban area through its first 250 years of life. At the end of this period the city has reached a point of relatively stable equilibrium that might be called stagnation, in view of the housing deterioration, unemployment, etc. that characterize it at this point.

Forrester clearly defines the basic attributes of this city, both at its birth and in its later equilibrium stage; he also gives a number of its exogenous attributes in terms of assumptions concerning its relationship to the external en-

vironment, its available land area, and so on. The basic dynamic attributes of the model are nine principal stocks and twenty-two principal flow rates among these stocks and between them and the outside world. These nine principal stocks are New, Mature, and Declining Businesses; Premium, Worker, and Underemployed Housing; and Managerial-Professional, Labor, and Underemployed Populations. Transitions among them are provided by certain rates of flow, with most stocks having a notable tendency to decline over time. Examples of rates of flow include such items as the rate of Worker-Housing Obsolescence, the rate of New-Enterprise Decline, the rate of Labor Arrivals from the external environment, the rate of Labor to Managerial Transition, and so on. The definition of these flow rates and the basis for their modification in successive interactions of the model provide the principal basis on which the model operates, and in most respects determine the outcome of the model under various sets of constraints or experimental manipulations.

Forrester next provides a series of very readable computer-printed graphs and tables showing the manner in which various stocks and flows have changed during the 250-year hypothetical history of his city. It is at this point that the important and truly stimulating results of Forrester's work begin to emerge. Accepting the validity of his model at face value, Forrester systematically introduces a series of policy innovations. The city is made to grow again and again during a period from year 250 to year 300, with various policy decisions in effect. The impact of these policies on various elements of the city is shown and explained fully and carefully. Time and again, Forrester's city exhibits what he calls "counterintuitive behavior," which in his view is a property of most complex systems. The long-run impact of a new program is often found to be totally unrelated to its original intention, or it may even worsen the condition it was designed to ameliorate. The manner in which such unexpected effects occur is traced out in a number of fairly realistic examples.

Unfortunately, both Forrester and his publisher overplay the possible significance of these findings, and open themselves to criticism regarding their conclusions concerning the relative efficacy of low-income housing programs, etc. Forrester's conclusions are justifiable and well proven with respect to his model, but unless his model is proven to have high validity, both in its components and assumptions as well as in its behavior, the applicability of these findings to situations in the real world is highly questionable. The model itself is sufficiently vulnerable to criticism to render meaningless the specific policy implications derived from Forrester's experimentation. At best, his conclusions about policy are premature and irresponsible. At the same time, the means by which he has arrived at these conclusions is extremely important and should be closely examined by all serious urban theorists.

In a later chapter entitled "Notes on Complex Systems," Forrester offers a number of insightful and provocative comments on some of the major problems encountered in understanding high-order complex systems. He argues convincingly for the potential significance of simulation modelling as a means of theory construction, and contrasts it with traditional methods of theory construction and testing, but he might have given this approach even more emphasis.

Following the basic text is a series of technical appendices giving detailed descriptions and interpretations of the principal equations and other items necessary to fully understand the manner in which the model operates. Although these sections are written in DYNAMO II computer language, a rudimentary knowledge of FORTRAN should enable a diligent reader to follow them. Also included in the appendices are (1) a brief examination of some additional policy alternatives and (2) a very brief but important discussion of sensitivity testing.

The book as a whole is written without reference to existing knowledge, research, and theory on urban processes. As Forrester points out in his Preface, he works primarily from his own observations of urban problems, his contacts with professional urban administrators and politicians, and his lengthy background in research in industrial dynamics. The only references to literature include five citations of his own previous work and one citation to Kurt Lewin. But to attack this book on these kinds of academic grounds is trivial and meaningless. Professor Forrester has something significant to say about the processes of examining urban theory, and the social sciences will be the loser if they fail to recognize the true nature of his contribution.

*People and Plans: Essays on Urban Problems and Solutions*, by HERBERT J. GANS. New York: Basic Books, 1968. 395 pp. $10.00.

RICHARD DEWEY
*University of New Hampshire*

Of the twenty-nine essays in this book, nineteen appeared between 1956 and 1968 in some twenty different publications, including planning

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5 JWF

JWF 1/18/71

33 East End Avenue
New York, N.Y., 10028
January 14, 1971

Mr. Jay Forrester
Professor of Management
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Mr. Forrester,

I am sure that your theories on the dynamics of social change have produced sufficient critics.

Therefore, you might be interested to know that there are those who consider your work extremely provocative and stimulating.

I have no idea how many books, pamphlets and articles I've read on urban social change in more than a decade as a student, teacher and practicioner of the problems. But I have no hesitancy in saying that your work on Urban Dynamics is an Everest compared to all others.

Furthermore, contrary to some of your critics, I find it a thoroughly "practical" book. For two years I served as Assistant to the Mayor (of New York City) and emerged from that experience completely bewildered and confused. All the "solutions" proposed and adopted by me and my colleagues only seemed to worsen the problems. The theories which you proposed accord very well with the facts as I experienced them and offer the only logical basis for understanding.

Your recent article in Technology Review is extremely helpful to me in my current attempt to understand some of the problems that beset the universities. I look forward to reading your book on World Dynamics.

Sincerely,

D.F. Shaughnessy

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

January 20, 1971

Mr. D. F. Shaughnessy
33 East End Avenue
New York, New York 10028

Dear Mr. Shaughnessy:

Thank you very much for your kind letter of January 14. It comes after I have been reading critical and negative reviews of Urban Dynamics over the last month. It is good to hear from someone who understands the book and knows something about cities. I fear many of the critics show neither.

If you are so inclined it would be helpful if you were to write a commentary or a discussion of the various book reviews which have already appeared or some other message for a suitable urban journal. I believe it is now about time that we will begin hearing from those who have thought about the book and the subject more carefully than the authors of the first wave of reviews. Is this something you would be able to do?

A number of people have raised the possibility of the Urban Dynamics ideas being extended and interpreted until they could be influential in New York City. Do you know of any movement under way toward this end?

Sincerely yours,

Jay W. Forrester
Professor of Management

JWF:ie

URBAN DYNAMICS

*by Jay W. Forrester*

MIT Press, Cambridge, Mass., 1968.
285 pp. $12.50

In the area of urban studies many people have been talking about applying the techniques of systems analysis, but until now no one has done it on the same large scale and with the same unflinching confidence as Jay W. Forrester, Professor of Management at MIT. Professor Forrester has produced a detailed "urban system" model in a book that is well documented with computer print-out graphs and program listings. The text of the book outlines the workings of the model and offers evaluations of a host of simulated policy strategies.

The model grew out of Forrester's collaboration with Boston's ex-Mayor John Collins and other persons with practical experience in urban management. The behavioral relations and insights into the workings of a city were supplied by the collaborators, but Forrester constructed the model. Neither the results of the model nor the behavioral relations specified in it have been tested in the traditional way, that is, by comparing predicted with actual values. Forrester eschews the use of real world data; he feels that the main problem is structural specification, and further, that one does not learn about structure by studying data. He asserts that such knowledge comes only from those who have an intimate working knowledge of the actual system. However, he did not ask representative members of the lower economic classes how they behaved or what pressures they responded to, but rather seems to have depended on his collaborators for those insights. Thus, the model and the book take a fairly narrow "urban manager" view of the city, how it works, and what is good for it.

The model and its results are valuable in that the implications of this partial, manager's view are worked out more fully and explicitly than they ever have been before. However, the view of the beseiged group at the top is often distorted by pressures they feel, constraints they face, and objectives they hold. The danger is that this model will be accepted as an overall objective model of the city which it is not.

The organization of Forrester's model involves many tripartite classifications. There are three kinds of people: manager-professionals; skilled labor; and the underemployed. These three classes are assigned to three kinds of housing respectively: premium housing; worker housing; and underemployed housing. In addition there are three types of business: new enterprises; mature businesses; and declining industry. The employment mix for each of these types is specified. The model takes nine major level variables, defined by class over population, housing stock, and employment, and relates them recursively through twenty-two rate variables to arrive at the city's configuration in aggregate terms at each point in time.

The model conceives of the city as a location of fixed land area situated on an infinite plane that is capable of supplying population to or absorbing population from the city according to the relative attractiveness of the city vis a vis the plane. An attraction score is calculated for each population class as a function of employment opportunities, housing availability, tax rate, and other social atmosphere indicators specific to each population class. At an equilibrium position the attraction score of the city is equal to that of the supporting plane, and city growth stops. To ease the problems of the cities, Forrester sees the urban manager's role as one of changing the components of the city's attraction score while maintaining its attraction equilibrium. His recommendations involve strategies such as increasing employment opportunities while decreasing housing availability so that the city is not swamped by the underemployed.

Forrester begins with a vacant area and lets a city grow in it over a period of two hundred and fifty years until it reaches an equilibrium pattern, which he refers to as the stagnant condition. This equilibrium is characterized by high unemployment of the underemployed, a housing shortage for manager-professionals and skilled labor, a housing surplus for the underemployed, and an average per capita tax rate over twice that in the environment. He then simulates the effect of several urban management programs over a period of fifty years, starting from the phase of stagnating equilibrium, and evaluates their effects by comparing the new system levels with those of the old equilibrium. Programs traditionally felt to be helpful, such as training for the underemployed and federal aid to cities, tend to deepen the problems of the city, whereas programs now subject to question and contention, such as slum demolition and construction of industry and premium housing in cleared areas, tend to improve the city.

These results do not surprise Forrester. He maintains that systems as complex as cities often produce counter-intuitive behavior because of the unpredictable interaction of hierarchies of feedback mechanisms. In order to see if his explanation is justified, one must in effect read the model rather than the book. One can then ascertain whether or not the unexpected results can be attributed to other factors. Working through the logic of the model and its results seems to reveal that the counter-intuitive results are largely due to the implicit evaluative criteria employed to judge program results and to shortcomings in the model's structure.

Unfortunately the evaluative criteria for the programs are never explicitly stated. In a model of this magnitude, with so many output variables, it is indeed difficult to form an objective function with which to rank the various policy recommendations. One senses, however, that the underlying evaluative criteria used to identify policy failures and successes reflect the objectives of urban managers. Although Forrester speaks highly of the city's role in society as a "socio-economic converter" transforming the underemployed into skilled labor, ex post his goals seem to be to keep down the average per capita tax rate and to diminish the population share of the underemployed. Programs that move the problem out of the city tend to get higher marks than those attempting to solve it. The job training program, for instance, is classified as a

failure even though it shifts more underemployed to the skilled labor category than any other program tested.

But the important questions which must be asked regard the verisimilitude of the model as a representative of the real world. How similar is the modelled world to the real world? And if different, do the model's differences significantly affect the policy consequences suggested in the book?

There are two basic ways in which differences between the model and reality can arise: firstly, the model structure can be correct and the parameters inaccurate; and secondly, the model structure itself can be invalid. Forrester treats the first point extensively in the book. He shows that the policy conclusions are robust with respect to variation in the value of many of the parameters when these parameters are altered one at a time. Since the model contains many nonlinearities, varying several "insensitive" parameters at once still could have a significant effect on the policy conclusions. On the other hand, Forrester also shows that variations in the values of some individual parameters will affect the strength of the policy conclusions. He demonstrates that when the attraction of the city to the underemployed is only mildly influenced by housing availability, his recommended slum demolition policy is much less effective as a revival measure. He dismisses this result as not being of practical interest in the United States. However, most empirical studies of migration patterns in the United States have not found housing availability to be significant in explaining migration flows. Instead variables relating to economic opportunity are the best predictors of migration. In terms of Forrester's model, it appears that the attraction coefficients relating to housing should be much lower than those relating to jobs and advancement. In fact, the housing coefficients are more important than the job availability coefficients in the model.

Perhaps the main reason for carrying out sensitivity analysis on the parameters of a model is to identify those parameters whose values are crucial to the model results. One must then ascertain their true values through empirical estimation. The specification of "reasonable" values for other parameters is only justified when their values are found to have relatively little impact on model results. The reader of *Urban Dynamics* must be warned that neither has a complete sensitivity analysis been carried out on the model nor has an empirical estimation been done of parameters already found to be important.

But the parameter values are of secondary importance when compared to the structural specification. This is not, as Forrester seems to suggest, because model results are insensitive to variations in parameters, but because an invalid structure makes the parameter values irrelevant. Although he cautions the reader that one must investigate the model assumptions and accept them before accepting the model results, Forrester seems to think his model structure represents reality adequately enough for one to take his policy conclusions seriously. There is a good chance, however, that the world simulated by the model is so different from the real world that the model results have no carryover at all.

When considering how one might model an urban area, two possibilities come to mind: one could model the entire metropolitan area or one could model only part of it, for example, the central city. If the former approach were chosen, the immigration-attraction method used by Forrester would be a good representation of the interaction of the metropolitan area with its environment, but the modelled area would need to grow over time as the demand for space increased. Alternatively, if one chose the model city, then the assumption of a fixed area would be adequate; but the interaction between the city and the rest of the metropolitan area as well as its interaction with the rest of the world would have to be modelled. Forrester's model is caught on a cleft stick; it models interaction with the attraction specification appropriate to metropolitan areas, but assumes that the city area is fixed.

This specification leads to much confusion as to what area the model refers. In discussing this point, Forrester suggests that the area should be thought of as a sector of an older city that would be "crossed by available transportation during a rush hour in twenty minutes." The model, on the other hand, accords the area fiscal autonomy that implies that it exhausts one political subdivision, that is, the city proper; yet the model uses a metropolitan interaction approach valid for metropolitan areas. Finally, the actual simulation deals with an area of one hundred and fifty-six square miles with a population of 5.7 million during stagnating equilibrium. This corresponds to an area somewhat larger than the city of Philadelphia (one hundred and thirty square miles) with a population nearly three times as great as Philadelphia's in 1960.

If the fixed urban area of the model is a center city, the model specification implicitly assumes that there are no commuters. All classes of the population who work within the city also live within it. The economic section of the model is in turn sensitive to the resident population of the city and reacts importantly to the supply of labor and managerial talent there. Changing the model specification to allow for more interaction between the city and the surrounding metropolitan area would involve several modifications. Since some members of each class who work in the city could live outside of it, housing availability in the city would be much less important as a component of the attraction scores. The economic sector of the model would have to be reformulated to alter its dependence on the resident labor supply and to allow city residents to work outside the city. These modifications would undoubtedly change the effects of some of the policies considered in the book, but the results could be difficult to interpret. Tinkering with the model might produce a more reasonable representation of the city, but in trying to accommodate what seems to be a basic structural misspecification, one may only create confusion. Of course, there are other deficiencies in the *Urban Dynamics* model. For instance, the economic submodel ignores demand factors in determining the rate of economic growth, and the overall model assumes that tastes, income, and technology are unchanging over the three-hundred-year purview of the model. But these

shortcomings are not as striking as the one discussed above.

There is another sense in which the specification of the model could be misleading. The model deals with only one city and assumes that the rest of the country has an infinite capacity for supplying and absorbing population flows while remaining stable in all of its characteristics. Yet there is an almost irresistible urge to take the policy conclusions from this model and apply them to all cities in the nation. If one does this, the recommended policies may be fallacious. The model may be suggesting, in effect, that to see the parade better, one should stand on one's tiptoes. If everyone in the crowd does this, no one can see any better but all are less comfortable. This result is well known to students of game theory, tariff wars, and many other areas. Such a result is likely in this instance because the characterization of the environment as unchanging breaks down upon aggregation. When one considers all urban areas together, it is no longer reasonable to assume that the rest of the country approximates a stable and infinite source or sink for population flows. In 1960, for instance, 60 percent of the population lived in metropolitan areas, covering just slightly more than 10 percent of the country's total area. Major flows into and out of urban areas will change characteristics of the environment. Thus, those persons who hope to gain insights into the formulation of a national urban policy should be very careful about generalizing the results of a single city model such as Forrester's.

The model presented in *Urban Dynamics* does, however, represent an interesting step toward a comprehensive and reliable urban simulation model. The approach embodied in the book, that of using behavioral relations in the simulation context, represents the most promising means available today for analyzing the workings of urban areas. One only hopes that critics will not identify the shortcomings of the model outlines in *Urban Dynamics* with its underlying methodology.

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## PEOPLE AND PLANS

*by Herbert Gans*

Basic Books, Inc. New York, 1968.
48 pp. $10.00

*People and Plans* contains a varied collection of essays spanning Herbert Gans' career as a city planner and sociologist. The book tends—inevitably—to be somewhat disjointed, and it contains a few pieces that could better have been omitted. There are, however, several themes which unify the work, and to these Gans brings a great deal of insight. The extent to which his conclusions are open to dispute points less to his failings than to the liveliness and significance of the issues he raises and the complexity of the dilemmas that confront city planners.

Gans' basic concern is with the role of the city planner in a democracy. In the first section of the book he criticizes traditional environmental planning and in particular attacks the assumption that the physical arrangements of a community profoundly affect the lives of its residents. He blames the inadequacies of the master plan on

> . . . planners who believed that the city was a system of buildings and land uses which could be arranged and rearranged through planning, without taking account of the social, economic, and political structures and processes that determine people's behavior, including their use of land (p. 61).

Gans attributes the failures and false assumptions of planners to a reformist ideology, which justified "policies that fit the predispositions of the upper middle class, but not those of the rest of the population" (p. 21). In other words, planners sought to impose on their clients what the planners felt they should want. They presumed that after exposure to these new forms people would change their predispositions and come to embrace the new way of life presented to them. In addition to pointing out the errors in the traditional planner's theory of change, Gans rightfully shows the rationality for middle and lower class people of the kinds of life styles they have chosen and argues that for an upper middle class life style to be appropriate for most people, they must be made upper middle class.

Gans, in arguing powerfully against what has been, after all, the dominant bias in city planning throughout the century, somewhat minimizes the effects of community design on both those living outside and within its boundaries. First, planning decisions taken by any one community have external effects on other communities. To use the most obvious example: if zoning and other restrictive arrangements in suburbs effectively keep out the poor, then the central cities will bear a disproportionate share of the burden of their maintenance, and quality of life in the city will be affected. Second, the impact of a community should not be measured simply by its direct effects on the people who move into it. Its impact is also on the young who grow up within it and the range of alternatives they see while they are maturing. Moreover, while Gans is undoubtedly correct in claiming that a community's physical arrangements do not change people's predispositions, they do determine what kinds of people will be attracted to it; the extent to which people can *act out* their predispositions; and which of an individual's many unfulfilled and often contradictory desires he will be able to realize.

It might be fruitful to regard the environment as a set of channels or dikes that limit the choices of people within it without forcing them to follow any one particular path of behavior. Thus, while Levittown, in which Gans finds much of his illustrative material, does not force people to socialize or join organizations, it facilitates this behavior. Because it does not provide facilities for the consumption or production of the arts, it either discourages this form of expression by residents with proclivities toward the arts or does not attract people who desire a high level of artistic activity.

Gans substitutes for traditional "reform oriented planning" the concept of "user-oriented" planning. He defines the goals of this planning policy as permitting "the users to shape, or at least to influence, the goals and programs of the institution,

# books

2 pages

*Urban Dynamics*, by Jay W. Forrester, MIT Press, Cambridge, Mass., 1969. 285 pages, $12.50

Utilizing experience gained in modeling complex large scale industrial systems with the aid of a computer, Jay W. Forrester develops some intriguing and startling predictions of the behavior of an urban area. The purposes of the book *Urban Dynamics* are threefold; to demonstrate the ability of a man to construct a realistic model of an urban area; to exercise this model using currently existing and proposed policies to evaluate their effect on the characteristics of the urban area; and to stimulate discussion on both the method and its implied results. The book does the first two well and, with the underlying philosophy of Forrester peeking through the equations, will very likely succeed in the last.

The book is split into two major portions, the first half (chapters 1-7) being descriptive material concerning the model and policy evaluation, and the second half (appendix A) being devoted to an exhaustive, detailed description of the computer model. This description is in sufficient detail to enable any reader who so desires to reproduce the computer program and try out his own pet urban policies. The purpose of describing the model in such great detail is to enable the serious reader to understand the intricacies of formulation and evaluate the model validity. In most cases, the choice of model variables and their assumed relationships have a distinct influence on the dynamic characteristics of the model. Being aware of this fact, Forrester is careful to provide all of the relationships which comprise his urban model.

In reading the book, it is advisable to read chapters 1, 6, and 7 first since the bulk of the descriptive material lies in these chapters. Chapter 1 is entitled "Orientation" and includes both a quick preview of the contents of the book and a summary of the urban policies which Forrester considers to be the worst and the best.

Chapter 6 contains general comments on the properties of the models of complex systems. It contains a crystallization of Forrester's experience in modeling and the philosophy of modeling. The counterintuitive behavior of complex systems is a major point made in this chapter. This is the property of large-scale complex systems which makes the obvious solution the wrong one. Forrester states that the distinction must be made between symptoms and causes of the symptoms in order to alleviate the problems. Modeling the system is the way to get at the structure which is exhibiting the symptomatic disorders. It is also in this chapter that the social scientist in his never-ending quest for more data is challenged. It is stated that it is not a shortage of data which is hindering progress in solving social problems but rather deficiences in the existing theories of structure. Forrester points out that it is better to get on with the process of urban policy design on the basis of a structure which fits the available data than to wait for the next few decimal points while Rome rots. His point is driven home by the observation that parameter values must not be of primary importance since growth, stagnation and decay have occurred in cities with quite distinct economic and social environmental constraints.

Chapter 7, entitled "Interpretations," deals with social philosophy. Here are explanations of the concepts of the "limitless environment" and the "attractiveness concept." It is the words in this chapter which are put into the graphs and equations which make up the dynamic model. In addition, the summary of the results of all of the computer runs are integrated into cohesive policy statements interpreted through a political philosophy.

Chapter 2 is an example run-through of the design of the model with introductory remarks on the principles of system structure. It is a partial description of the model which is redone in greatest detail in appendix A.

At the broader level of detail, the urban model is composed of three sectors, business, labor and housing. Each sector has three categories with the rates of flow from one category into the next being determined by the values of system parameters. For example, the business sector is comprised of new enterprise, mature business and declining industry. New enterprise, in time, changes into mature business which, in turn, changes into declining industry. The rates of change are dependent on the urban environment in which the industries find themselves. Three classes of labor are employed in differing ratios by each of the three classes of industry. There are managers, labor and underemployed. Opportunities for the underemployed to become labor and for labor to become management are provided in varying degrees—depending again on the urban environment.

Housing is constructed for the managers and labor in amounts dictated by the demand. Housing for the underemployed is normally created by the labor class moving out.

Provision for the enterprise and people to move into and out of the urban area is made by the definition of the concept of the limitless environment. If the urban area is more attractive in some sense than the external environment, then there exists a flow into the area until a balance is obtained. For example, a policy which makes the simulated urban area more attractive for underemployed than other like areas would cause a net influx of the underemployed until the area is no longer more attractive. Implicit in this type of policy is that it is applied to this urban area only, and to no other area within communication distance. This is the assumption implicit in all of Forrester's policy evaluations, and is most important in understanding and evaluating his results.

Chapter 3 is a simulation of the growth from essentially empty land to an urban area in the stagnation condition. The main purpose of this chapter is to demonstrate that the computer model exhibits realistic behavior. This is the major proof offered in support of the model. It may not be sufficient proof for critical readers.

Chapters 4, 5 and appendix B contain evaluation of various policies designed to stimulate urban revival. Chapter 4, "Failures in Urban Programs," shows the computer-predicted results from four commonly employed programs: a job program where jobs are directly supplied; training programs where the underemployed are trained to qualify as labor; financial aid where outside money is added to the local taxes available; and low-cost housing construction. The computer simulation shows that these programs are at best ineffective, with the low-cost housing program being, in the long run, quite detrimental to the urban areas.

Other policies evaluated include worker housing construction and manager housing construction, which are both detrimental, although in lesser degree than the low-cost housing construction program. Policies to encourage construction of new enterprise and



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demolish declining industry are also evaluated. After trying many combinations of policies, Forrester concludes that the basic problem of the decaying urban area is twofold: too much housing and too little new enterprise. Thus the policy which he finds to be the most effective is one where the underemployed worker housing is demolished at a steady rate and new enterprise is encouraged by local government policies to occupy the newly vacated land. After this policy has been in force for a length of time sufficient for the system transients to smooth out, the urban area is now able to provide more jobs for the underemployed and a greater potential upward economic mobility. The only potentially negative aspect of this policy is the substantially greater crowding of the underemployed into the remaining houses. Forrester comments that this policy has the superficial appearance of favoring the upper income groups and industry at the expense of the underemployed. For the people whose homes are being demolished to make room for industry, the policy may seem more than superficially biased toward the upper class.

It seems that the best policies, as found by Forrester, all rely on the shortage of underemployed housing to keep the urban area from being flooded by an influx of underemployed. This conjecture is further enhanced by the observation in appendix B that the slum demolition policy is rendered less effective when the underemployed are assumed to be less sensitive to crowded housing conditions.

## books ...

The policies which may be best for the long-run urban revival have the interesting property that they go the wrong way when first instigated. In addition, the good effects take on the order of 50 years to be really felt. These two properties make it highly unlikely that any politician would stay in office if he were to install the policies. Forrester realizes these inherent difficulties and mentions that the public will have to be educated to support long range goals if the policies are to remain in effect long enough to take effect.

One of the flaws in the book lies in the concepts of the limitless environment and attractiveness, or at least in the manner in which the parameters used to control the relative attractiveness are set. A policy which is applied to an over-all area, of which the urban area being simulated is only a part, has not been simulated by Forrester, and it would be enlightening to see whether his policy conclusions would be altered.

Since by his own admission the book is not designed to offer concrete policy suggestions, but to initiate dialog in the language of modeling, Forrester cannot be faulted for this omission.

The book may also be criticized on the grounds that the level of aggregation of the model variables is too great. For example, it is tacitly assumed that both black underemployed and white underemployed have the same mobility and job opportunities. The model does not allow for the geographic segregation of housing known as ghettos. Forrester also uses value words such as stagnation and decay as characteristics of an urban area, yet these terms are never made specific in terms of the model variables. Although upward relative changes in person-to-job ratios or economic mobility are good, one does not know how much better off a community would be which demolishes slum housing in order to obtain these changes. It is possible that the values which are implicitly espoused by Forrester in his choice of good policies are not widely held. Before any rational choice can be made, the value system of measuring the results must be made more explicit. Otherwise one cannot balance the negative aspects of a policy such as an increase in underemployed housing shortage against the positive aspects of increased job opportunity and economic opportunity.

This book is important in the fields of systems analysis, computer applications, social science and urban renewal. It represents an original and creative wedding of the four areas and should be the start of a highly effective branch of applied science.

—THOMAS A. BARBER

Datamation Nov. 1969

1st of 2 pages

INDUSTRIAL MANAGEMENT REVIEW Spring 1970

# Book Reviews

## Urban Dynamics

Jay W. Forrester
Cambridge, Mass., MIT Press, 1969, 285 pages, $12.50

Reviewed by David L. Birch
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For some time, social scientists have been modeling bits and pieces of urban areas. Now, Jay Forrester has marched into this arena with a new, wholistic approach and a total disregard for all that has gone before. It is not surprising, therefore, that his results, summarized in *Urban Dynamics*, have sparked controversy. There is plenty in the book to attack; that's the contribution of the book. It was designed to be attacked, not worshiped. It lays bare a total, complex systematic model of an urban area and invites those who would criticize it to improve upon it.

The structure of the model is very simple in concept. The "urban area" consists of three kinds of businesses (new, mature, and young), three kinds of housing (premium, worker, and underemployed), and three kinds of people (managerial-professional, labor, and underemployed). The number of businesses, houses, and people at any point in time depends on "the rates of flow" into and out of each category during all previous intervals. These rates of flow, in turn, depend upon a number of factors which Forrester thought were important — ranging from taxes to land density to job availability — as well as the "level" of each category. The model starts with a set of initial conditions and keeps track of the flows into and out of the stock of houses, businesses, and people. The system oscillates at first, and then settles into equilibrium. Policy recommendations are based on the effects of various "programs" on the equilibrium.

The model is complex because of the large number of factors which must be taken into account in setting the rates of flow. As the complexity increases, the model takes on a character of its own, and, in the process, reveals a number of interesting properties of complex systems. For example, complex systems are counterintuitive — they behave in just the opposite manner you would expect. They resist change. They are perverse; what is good for the long run (50 to 100 years) is frequently bad for the short run (10 to 15 years), making change politically difficult. Worst of all, they are deceptive. What appears

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to be a root cause, such as the shortage of low cost housing, turns out to be merely a symptom. Attacking the symptom frequently causes more problems than it solves.

So far so good. As a discourse on complex systems, *Urban Dynamics* is superb. The difficulties arise when the model is held forth as a portrait of urban reality. While fault can be found with many of the hundreds of subjective estimates on which the model is built, the book cannot be criticized on this count. The purpose of writing it was to encourage such fault finding. More basic, though, are weaknesses in the design of the model itself which will prevent it from ever replicating reality no matter how accurate the individual estimates may become.

Forrester's concept of an urban area is one which "could be a suburban area or the core area of a city but probably not an area containing both." Surrounding the "area" is a "limitless environment." Throughout much of the book, attention is focused on the core areas. Having drawn a boundary around the core, the "cause-and-effect relationship between environment and system are unidirectional, whereas the internal elements are structured into feedback loops that cause the internal elements to interact. The environment can affect the system, but the system does not significantly affect the environment." This statement scarcely survives its utterance. The core area and its adjacent suburbs clearly feedback on one another, and to ignore such feedbacks is to ignore the metropolitan growth process. By forcing the core to be self-contained, Forrester's model precludes the very economic specialization on which many central cities are now depending for survival. Forrester's policy recommendation, for example, that core areas should encourage the growth of labor-intensive industry makes very little sense when put into the perspective of the total region and the alternatives that exist within it.

A second inherent weakness in Forrester's model is its dependence upon a fixed set of relationships over an entended period of time. Policies for cities are evaluated in terms of the "equilibrium" conditions they produce after, say, 50 years. The implication, of course, is that the values of society, as reflected in the hundreds of coefficients built into the model, will remain static over this period. There is much which suggests that societal values are constantly changing, and that the concept of "equilibrium" makes little sense. Forrester has compensated for this in a limited way by varying one or two parameters and tracing the effects, but he has no mechanism for interactively updating all the constants and curves. If societal values change over a period shorter than the one for which the model evaluates policies, which is probably the case, then the model's output has little meaning.

Finally, Forrester's model is dangerous. It is dangerous because men of good will, but with little technical background, may take it seriously. It should be clear, even to the lay reader, that a clever man can construct a model which will make *any* set of policy recommendations winners. Since this model has never been tested against actual data for a city, there is no way of knowing whether the multitude of assumptions are correct. If anything, Forrester assures us that they are not, since they were derived by a group of mortals sitting in a room speculating, and, as Forrester puts it: "Intuition and judgment, generated by a lifetime of experience with the simple systems that surround one's every action, create a network of expectations and perceptions that could hardly be better designed to mislead the unwary when he moves into the realm of complex systems." Despite warnings to this effect, there is an easy tendency to jump to the policy recommendations, and attribute validity to them simply because they were derived by some complex, mathematical model which uses computers. As they stand, Forrester's hunches are no better than anyone else's. Hopefully, the emphasis of his future work will be empirical verification rather than policy formulation. Whatever the case, let us make certain that we read the present book in the spirit in which it was written — my hunches against yours.

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M.I.T. Spring 1970

Forrester


# GEOGRAPHICAL REVIEW

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URBAN DYNAMICS. By JAY W. FORRESTER. xiii and 285 pp.; diagrs., bibliogr., index. M.I.T. Press, Cambridge, Mass., and London, 1969. $12.50. 10¼ x 7¼ inches.

It is usually a fair indication that a book will demonstrate an author's prejudices and ignorance to an unusual degree when the writer of the Foreword predicts that the rightness of the conclusions "will be a matter of considerable and spirited debate" and notes that the author "offers them as tentative proposals and invites challenge, comment, or amendment." This is the case here, and in my opinion, it is a great pity that such conclusions should be launched upon the wider world between the covers of a rather expensive book. I can only hope that

the author will be as receptive to criticism as the writer of the Foreword is bold enough to suppose.

In Professor Forrester's book, according to his statement in the Preface, "the nature of the urban problem, its causes, and possible corrections are examined in terms of interactions between components of the urban system." Unfortunately, the author is obliged by limitations of space to take a somewhat generalized view of the nature and causes of the urban problem, and hence his prescriptions for a cure appear simplistic, politically ingenuous, and, one might say, socially obnoxious. For these reasons, even the most circumspect suggestion that the prescriptions should become instruments of public policy is quite unacceptable.

The author's basic proposition (with which, I believe, no one will quarrel) is that the city is a dynamic system. The steps that follow involve (1) the identification of what the author regards as the principal elements of the system and their interrelationships; (2) the reduction of the system to a mathematical model; (3) the operation of the model and the graphic and numerical portrayal of the system's development through time; (4) the experimentation with certain public-policy proposals and the tracing and display of their consequences; and, finally, (5) the author's conclusions concerning the counterproductive effect of certain current instruments of public policy, together with some alternative suggestions of his own.

Forrester recognizes nine major components in his urban model: three personnel categories (the underemployed, the labor force, and the managerial-professional group), their associated housing (slum, worker, and premium), and three types of economic activity (new enterprise, mature business, and declining industry). At this point I might usefully remark on a rather curious view that the author has of both his model and real cities. He speaks of his economically differentiated model as applying only to a spatially restricted segment of the city; thus "the appropriate area is small enough so that cultural, economic, and educational interchange is possible between its component populations. It could be a suburban area or the core area of a city but probably not an area containing both." Our knowledge of cities, however, indicates that the residential locations of the underemployed, the work force, and the managerial-professional group (and, hence, of the type of housing associated with each) are in the broadest terms spatially separated from one another and from workplace locations. We also know that, regardless of the separation, spatial relationships exist between these elements within the metropolitan area as a whole, if not, indeed, within the nation as a whole. But, in any case, why is it necessary for the operation of the model to adopt this totally false picture of reality? The model will still produce results for the metropolitan area as a whole, even if its elements are represented as spatially diffused (as they are), rather than spatially concentrated (as they are not). One is left at the outset, then, with some disquieting thoughts about the author's perception both of reality and of the analytical relevance of his model.

In Chapter 3, the author displays the operation of the model graphically and in tables of numerical data. Here growth, maturation, and stabilization of the nine elements of the urban model are traced over a 250-year period, together with changes in various indices that express one element in ratio to another; for example, housing construction and demolition, the birth and death of industries, and the transfers from one employment category to another. These few pages are perhaps the most interesting in the book, since they present

for easy scrutiny the working of the model. And the picture they reveal of the various elements rising to maxima, falling, and then leveling off, is entirely credible and compatible with what is generally known about growth patterns in major United States cities.

In the fourth chapter, "Failures in Urban Programs," Forrester examines the effect of various remedial programs upon the city—specifically, job programs (that is, the creation of employment opportunities by government intervention), training programs for the underemployed, the provision of outside financial aid to the city, and the construction of low-cost housing. The incorporation of these programs in the model generates results that "range from neutral to detrimental," according to the author. These conclusions would probably have been applauded in the 1870's, but they do not represent a viable point of view a hundred years later. One is led to think that the author has failed to ask the relevant question and/or that the context in which he has asked the question is much too restricted. Evidently he fails to realize that the policies he criticizes are designed to upgrade not the cities themselves, but the people in those cities; for current thinking states that it is socially desirable and politically wise to invest in the training of the underemployed, to change them from welfare-dependent individuals into productive citizens capable of assuming their share of the tax burden. Referring to the impact of the job-training program, Forrester cites the increased flow of unskilled labor into the city and of skilled labor from it. "People come to the area because of the training program and leave when they find there is no use for the skills they have acquired. As a service to society, the program might be considered successful. But as a service to the city, its value is far less clear." Here we have the author's admission of the net social good of a training program in juxtaposition with his seeming inability to comprehend that there cannot be an urban policy, only a national policy, for the United States in the 1970's.

The author's lack of comprehension of the real issues in America's cities is underscored by the restricted scope of the references at the end of the book. In this connection, the author in his Preface has this to say: "Several reviewers of the manuscript criticized the absence of ties to the literature on the assumption that such ties must exist but had not been revealed. Actually the book comes from a different body of knowledge, from the insights of those who know the urban scene firsthand, from my own reading in the public and business press, and from the literature on the dynamics of social systems for which references are given." Since the references to which the author alludes are six in number, and of these, five are authored by himself, I am not convinced that he is as conversant with the broad subject of urban dynamics as he should be. In sum, the book impresses one as a hastily written work, lacking a reflective quality, and imparting little credit either to the author or to the well-known public figures who are cited in the Preface as helpful critics of the first draft.—Bruce E. Newling

have generally included too many papers, which have been insufficiently interrelated and synthesized. The consequence has been that these volumes have consisted of hardly anything more than a vast essay of un-coordinated empirical data, pertaining to a wide range of unrelated phenomena and issues. The only concepts that have been used to 'integrate' these books have been such terms as 'urban', 'urbanism', or 'urbanization', which generally speaking have remained ill-defined or, at the very best, vaguely formulated. Clearly, if collections of papers are to make any contribution, the editor must 'do his homework'. He must select papers in such a way that they illuminate and attempt to explain specific aspects of particular issues. Only in this way can the papers be inter-related, and the reader's knowledge of specific issues and phenomena, clarified. *The American city* meets these requirements.

The theme around which Strauss has selected papers for this book is urban imagery. That is, the way in which different urban settlements and areas have been perceived and conceptualized by various populations, differentially located both in space and in time. Therefore, Strauss has selected papers to demonstrate the way in which the city can be seen to possess a wide variety of characteristics, according to the perceptions of the actors involved. For example, the very same city can be seen as an avenue for upward mobility when viewed from the perspective of one group, but, at the same time, as a place of despair and deprivation when viewed from the perspective of another population. Similarly, an area viewed as a slum by planners can be perceived as a community, and therefore a source of identity and security, by its immigrant inhabitants.

However, Strauss does not limit his selection of papers to the perspectives of the city as held by such diverse populations as prostitutes, businessmen, immigrants, and journalists. At the same time, he has included selections to represent the range of perceptions that various writers have held of the city. For example, social reformers have identified the city with violence, anonymity, and various other alleged characteristics of 'social disorganization', while other writers have equated the city with 'fun', adventure, sin, variety, and so on.

Finally, Strauss includes papers which illustrate the various images that cities acquire. Hence some cities define themselves as 'progressive', others as 'cosmopolitan', and yet others as 'rural'. Strauss therefore suggests that an interesting research area would be to investigate the consequences that such diverse images have for urban life styles and behavioural patterns.

In studying these perceptions, he has utilized both the historical and the comparative approaches. This is in pleasing contrast to many of the works published in urban sociology, which tend to be both ahistorical and non-comparative. Clearly if any phenomenon is to be explained adequately, an attempt must be made to identify both its antecedents and the various social circumstances under which it is likely to appear.

This is such a large collection of papers—in all there are no fewer than ninety-four—that it is impossible to comment upon each of them. The majority of the papers are interesting and provide enjoyable reading, but the most stimulating is probably Strauss's own 'Strategies for discovering urban theory'. Here Strauss identifies some of the major weaknesses in contemporary urban theory and suggests possible avenues for future research. First, he suggests that there is a need to study a wider variety of cities than has been customary, so that typologies of urban imagery may be formulated. At present, he claims that research has tended to concentrate solely upon large metropolitan areas, with a failure to investigate other city types. Secondly, the editor suggests that more attention should be devoted to the study of 'the unusual', 'the odd', and 'the different', since the analysis of these often illustrates a number of 'key' urban processes. Thirdly, he suggests that more time should be spent analysing the various ideological commitments of urban sociologists, planners and others concerned with the study of urban phenomena. This clearly is an area for fruitful investigation. For example, what are the historical and contemporary bases for the 'anti-urbanism' of modern British town planning? Why is it that social reformers have equated the city with all that is 'evil', and the rural community with all that is 'good'? At the moment the explanation of such views remains virtually untouched. Finally, the editor stresses the need for more comparative studies. Urban analysis, he says, must shift away from the study of one city, suburb, or neighbourhood. The comparative method is fundamental if an integrated theory about urban social relationships is to be developed.

How useful is this volume to planners? If the planner merely glances at the titles of the papers, he will probably think that it is of little value. In fact, a number of the titles are somewhat 'weird' or 'exotic', and the cities discussed are all American. But he should resist the temptation to put this book to one side. He should at least look at a few of the papers. I suggest this for two reasons:

First, a reading of this book will lead the town planner to a heightened awareness that his perspective of the city is but one among many. At the moment, I feel that there is a tendency among town planners and some sociologists to assume that their own perspective is the only one that is 'valid' and relevant, because it is 'scientific' and therefore 'objective'. This book stresses the futility of such an idea and demonstrates that the planners' perspective is as value-laden and ideologically committed as any other perspective, and therefore, is no more 'legitimate'.

Secondly, a mere glance at this volume will be sufficient to cause the reader to question the assumption held among a number of planners that the interests of the sociologist and the town planner are identical. The papers of this book demonstrate that the sociologist is interested in a far wider range of issues than the planning of urban areas. Furthermore, there are papers to suggest that their ideological commitments are often diametrically opposed.

This, then, is a valuable collection of papers. It is of probably greater relevance to the sociologist than to the town planner. But for the town planner who does read this book there are rewards, the most important of which is a reassessment of professional values and goals.

RICHARD SCASE

## Urban dynamics

Jay W Forrester. MIT Press, Cambridge, Massachusetts, 1969. 117*s*.

Building theoretical models of the city which can be validated in the real world is no easy task. The model builder has to design and test theoretical structures which may be subject to a variety of diverse and often conflicting requirements, posed by our present modelling technique, data availability and the purpose of the venture. Already, several levels of spatial aggregation and a lesser number of levels of topical aggregation have been explored using land use models, but hitherto the temporal dimension has been virtually ignored.

It is therefore somewhat refreshing to read a book about a model of the city which is based upon the dimension of time. Professor Forrester's book describes his work with a theoretical model which simulates the life cycle of a hypothetical urban system through 250 years. The model organizes the city into three subsystems based on population, housing and industry; these subsystems are disaggregated into professional-managerial, skilled and unskilled populations, three classes of housing to match the populations, and new, mature and declining industry. The nine components represent the levels of activity in the model, each level being influenced by rates of change which alter the structure of activities through time. Changes within the system involve the obsolescence of the stock of housing and industry and movements between the different classes of population. Outside the system, construction and demolition of industry and housing and births and deaths in the population sector cause the city to change. The activity levels are linked to each other through a complex of multipliers based on past levels of activity in the city; these multipliers determine the rates of change. Forrester suggests that a model which is so organized provides a suitable simulator for the processes of change characteristic of the twilight areas of our cities.

The model is deterministic and has a recursive structure. The process of growth is started by an initial specification of activity levels and 'normal' rates of change. As the city grows, the normal rates are modulated by the present state of the system. Mathematically, the model is composed of a set of first order and second order difference equations, although the network of relationships connecting these equations is so complicated that the system defies analytical solution. Forrester, however, is able to solve these equations using simulation techniques which he pioneered for problems in industrial dynamics.

After describing the model's theoretical organization, Forrester shows how change in his hypothetical city can be simulated. The trajectories of activity levels, rates, and ratios reveal that after a period of initial growth, the system settles down to an 'uneasy' equilibrium, which is dominated by a large proportion of unskilled workers and old housing. In projecting the impact on the city of traditional renewal policies, such as job and housing programmes for the unskilled, the model indicates that these policies exacerbate the present condition of the system by attracting even more unskilled workers. To model a more balanced equilibrium, Forrester shows that it is necessary to design programmes for industrial construction coupled with policies for slum demolition. Using these results, he tentatively suggests that planning policies designed to alleviate blight should be based upon programmes for economic growth.

Forrester concludes by emphasising the difficulties involved in grasping the dynamics of complex city systems. Only a hard look at the structure of such systems will aid in identifying policies that can be made more effective. Detailed discussions of the mathematics of the model and sensitivity testing of the parameters of the model are provided in the appendices.

One fundamental criticism must be made—the model has no spatial dimension. Surely the basic components of spatial competition have been validated sufficiently for their inclusion in any model of the urban system? Their absence is reflected in the process of change which the model simulates for it is difficult to read into the results any operation of the market process. Until the model has been tested on a real situation, it is impossible to generalize from the results given in this book.

The rates of change used in the model are based upon functions hypothesized from general observation. Alterations to the form and structure of these functions could result in a very different model. The absence of an explicit transportation variable also gives the model an unreal quality. Furthermore, the boundary of the system is fairly arbitrary and it is certain that the process of change simulated by the model is dependent upon other parts of the urban system which are excluded. But only by empirical development of this model can its structure and performance be thoroughly evaluated.

Technically, the model is extremely interesting. The emphasis upon dynamics and the presentation of the growth paths of urban activities is laudable in itself and Forrester indicates that his techniques of simulation are highly relevant for modelling urban systems whose mathematics may appear intractable. He also proves that the structure of such systems is considerably more important than their parameter values.

As Professor Forrester points out, the model is only a starting point in the simulation of urban dynamics, and there is an urgent need to involve other urban specialists in making the model more realistic. Viewed in this way, the book is certainly a useful contribution to the literature on urban systems.

MICHAEL BATTY

## On human ecology

Roderick D McKenzie. University of Chicago Press, 1968. 108*s*.

It is some tribute to the author that his contributions to a number of American journals between 1921 and 1936, on various facets of this broad subject, should be published together at the present time. It is indeed remarkable how few of the articles one notices to be some 30–40 years old. McKenzie's essay, in 1933, on 'Industrial expansion and interrelations of peoples', with particular reference to the (still) explosive rise of Japan, and his insight, in 1926, that 'the secret of environmental control lies in the ability to conquer

Reverse side also

# The Analyst's Bookshelf

*Reviews*

**JAY W. FORRESTER, *Urban Dynamics*, The MIT Press, Cambridge, Mass., 1969, 285 pages, $12.50**

THERE ARE two traditions in the modelling of an urban area. Economists have used Leontief's input-output formalism for industry and—in a modified way—for population. As exemplified by BERMAN ET AL. in the *Technical Supplement to the New York Metropolitan Regional Study* (Harvard Univ. Press, 1961), the economic models have been weak in that they did not account for land accessibility or use and in that they were insufficiently elegant in coping with the boundary problems imposed by the artificial separation of a local economy from its national environment. In contrast, transportation planners have espoused land-use models, both market oriented and accessibility oriented, which have done well in representing intraurban development, but have failed to consider the sources and extent of human or business migration and conception. These two traditions have been brought together somewhat in PROFESSOR FORRESTER's book, wherein his well-known 'industrial dynamics' method is used to construct a time-dependent simulation model of an urban area.

Forrester's model follows the construction and subsequent decline of industry and housing in a permanently delineated finite land area. The area matures and reaches equilibrium as the uncommitted land decreases eventually to zero. Further changes may be induced thereafter by land clearance or by external stimuli to alter the distribution of land use. The urban inventory is divided into three basic sectors: industry, housing, and population. Each of these is, in turn, divided into three subsectors. There are new enterprises, mature businesses, and declining industries; premium housing, worker housing, and underemployed housing; managers and professionals, workers, and the underemployed. There is an external environment, capable of supplying immigrants and absorbing emigrants without limit, but otherwise not part of the system. All residents work in the defined area and all who are employed live in it.

The inventory of industrial units, housing units, or members of the work force in any one subsector is changed by flows to or from other subsectors and, where physically possible, the external environment. The flow-rate equations are functions of the various inventory levels and of specified parameters such as land requirements, tax payments and needs, labor required by an industry unit, and family size. Where several quantities affect a flow rate, a function of each is specified and the several functions usually are multiplied together to form a composite flow-rate multiplier. The functional relations, forming the backbone of Forrester's model, are not viewed as parameters; they are claimed to be reasonable, and no sensitivity or calibration-analysis is reported on them.

A novelty of the book is the use of the DYNAMO programming language for all equations—on which I have mixed feelings. Though surprisingly readable and quite appropriate to following the argument, the language is limited to the most elementary arithmetic statements. Thus sophisticated relations, such as differential equations, always are presented in a form reduced for numerical evaluation. If the reader wishes to engage in any analysis or manipulation of functional relations, he must first translate the material into classical notation.

There are patent weaknesses. By not dividing industry into local-market and external-market components, and by requiring all participants to both live and work in the defined area, the model offers a description of a relatively self-contained, walled medieval town. Further, by not including some formalism to describe both the accessibility of the area to its environment and the external socio-economic climate affecting its industry, the model's structure ensures that the area develops to the point when a near-maximum population saturates its facilities for growth. Thus, it cannot be appropriate to the description of the vast majority of towns that have lost growth momentum long before physical saturation. Even where such saturation has occurred, as in the center cities of the New York and Boston conurbations, the model cannot be used because growth continues in the land area, population, and industry of the suburbs.

Much of the book is devoted to demonstrations of how the model, initially near equilibrium, reacts to a variety of stimuli of the types used today for urban renewal and antipoverty campaigns. The model reacts to most of these in either a trivial manner or by exhibiting an influx of underemployed persons who immigrate in response to the stimuli. These demonstrations are confined to changes in the study area, with the environment held constant. Since an ever increasing majority of the United States population lives in urban areas and since all such areas tend to use similar renewal incentives, it is not correct to draw utility conclusions on the basis of a constant external environment.

Despite all weaknesses, Forrester's model is an important and instructive landmark in society's efforts to effect quantitative understanding and efficient planning of its environment. The general approach, the melding of land-use modelling and industrial dynamics, and the ingenious techniques for exhibiting relations among apparently disparate variables all are destined to remain as important guideposts to the next generation of urban simulators.

Walter Helly
The Polytechnic Institute of Brooklyn

## *Books Received*

Russell L. Ackoff, *A Concept of Corporate Planning*, Wiley-Interscience, New York, N. Y., 1970, 172 pages, $7.95.

William J. Adams, Allan Gewirtz, and Louis V. Quintas, *Elements of Linear Programming*, Van Nostrand-Reinhold Co., New York, N. Y., 1969, 192 pages, $5.50.

A. V. Balakrishnan (editor), *Computing Methods in Optimization Problems*, Springer-Verlag, Berlin, W. Germany, 1969, 197 pages, $3.50. Nineteen papers

# Book Reviews

Jay W. Forrester, *Urban Dynamics*, with a Foreword by John F. Collins. The M.I.T. Press, Cambridge, Mass., and London, England, 1969. 285 pages, Price $12.50.

Forrester's book on *Urban Dynamics* reminds one of an early scientific treatise on chemistry or physics. Being under the influence of what Isard has called the "Anglo-Saxon bias" which is the notion that relationships expressible through time are more fundamental than those extending across space, the author sets out to develop the "equations of motion" of the "urban system." And he accomplishes this task with unique rigor and scientific elegance through the development of a model capable of simulating a hypothetical city (or "urban area") from birth to old age, a life cycle of 250 years of internal development, maturity, and stagnation.

The model deals with a fixed land area; starting initially with nearly empty land, it generates the life cycle of development leading to full land occupancy and equilibrium. A variation of the model is started with equilibrium initial conditions in order to explore the impact of alternative policies on the following 50 years.

The internal structure of the model consists of the identification of three subsystems, namely industry, housing, and people. The three subsystems interact through nine *state* (or level) and twenty-two *rate* variables. The interrelationships among the variables take the form of initial parameters, rate equations, level equations, and auxiliary equations. The rate equations are "the statements of system policy," in that they express the discrepancy between the goal and the observed condition and also the action that will result from the discrepancy. The level equations compute a new value by taking the old value and adding the change during the preceding time interval. The auxiliary equations translate information about levels of variables through various multipliers to produce changes in rates within the system. No rate can directly affect any other rate and no level directly affects any other level. One level can affect another only through an intervening rate. It is in setting up the interrelationships for a dynamic model of a complex system that Professor Forrester exhibits, as in his previous work,[1] his great talent and skill. He succeeds in developing an operational dynamic model of the urban system, which, although it might not yet be a good representation of the real world, helps the reader understand some fundamental functional relationships of the system.

The first subsystem in the model is the industrial subsystem which contains three levels and four rates representing business activity. Initially there is only new industry in the city, which through the natural process of aging is gradually transformed to the categories (levels) of mature business and then to declining industry. The flow from one business category to the next depends, in Forrester's words, "not only on time but on the condition of the entire urban system."

The second subsystem, containing three levels and six rates, represents the construction, aging, and demolition of housing. The third subsystem, with three levels and twelve rates, represents the population. Each level of the housing and/or population subsystems corresponds to one of the three kinds of people in the city: "managerial-

[1] Jay W. Forrester, *Industrial Dynamics* (The M.I.T. Press, Massachusetts Institute of Technology, Cambridge, Mass., 1961).

*Technological Forecasting* **1** (1970), 427–432

professional," "labor" (skilled labor fully participating in the urban economy), and "underemployed" (including unemployed and unskilled workers). The three levels of housing are: premium housing, worker housing, and underemployed housing. Premium housing is initially constructed for the managerial-professional population, and with the passage of time deteriorates into the worker-housing category. Worker housing can also be directly constructed, and this category ages and declines into the underemployed housing category. It is of interest to note that the process of growth to stagnation, reflected in the city life cycle, is structurally built into two of the three subsystems of the model. In the industrial subsystem new enterprises become mature business and then declining industry; similarly in the housing subsystem premium housing becomes worker housing and then underemployed housing.

The internal city system, with its three subsystems, is embedded in an external environment which for the city represents a sink-source of infinite capacity. Depending on the attractiveness of the particular urban area relative to the environment, people will flow in or out of the city. The concept of attractiveness together with the delineation of the urban system geographic boundary are of fundamental importance for the policy implications of the model.

Unfortunately, the boundary concept remains somewhat ambiguous because Professor Forrester does not list the relevant criteria for boundary delineation. He only suggests that one should "choose a system boundary that defines the concepts that interact to produce the behaviour of interest." At another point he states that "the area is best thought of as a section of one of our older cities, not as the entire area within the political boundary." It would appear that daily commuting across the system boundary will not influence the model results. This of course is open to serious question, even at the local level, on account of the well known central city—suburban problems.

At the global level the Forrester boundary is subject to more serious misinterpretations. The outside environment is implicitly taken as a point of reference, since flows from and to the outside are controlled only by the levels within the system boundary. For example, a shortage of "underemployed housing" makes the city less attractive to low income people, the result being that fewer come and more leave; the question, however, remains as to where do they go? The assumption of a reversed trend of migration from city A to city B or to rural life is very questionable even under the most adverse conditions. Furthermore, the rural-urban split is not applicable any more in an increasingly urbanized world, requiring global instead of localized solution to problems. In other words, what happens to the cities cannot be separated from the surrounding environment, and urban policy planning should take the whole nation into account.

The concept of attractiveness which determines the types of people and the migration patterns to an urban area is of fundamental importance for the model. In deriving what Forrester calls "attractiveness for migration multiplier (AMM)," he combines through multiplication five factors, for example a public expenditures multiplier, an underemployed-housing program multiplier, and others. Each of the five multiplier inputs is represented in the model by a nonlinear "table look-up" function that permits any choice of interdependence between variables. For example, the per capita tax expenditure in the urban area is taken as one measure of attractiveness, and is expressed through the public expenditure multiplier (PEM). Forrester postulates a nonlinear table function connecting PEM to the tax per capita ratio (TPCR), which is the ratio of taxes per capita in the specific urban area to the tax per capita in the outside environ-

ment from which people come. The expenditure of taxes is here used as an indicator of public services, schools, welfare, and other public-supported activities. When TPCR is equal to 1, the PEM is also equal to 1 indicating that the tax per capita in the area is the same as that outside; hence there is no incentive to move from the outside into the urban area. It is in the identification and quantification of such measures by means of table functions that Forrester's contribution to the emergence of an urban system science lies, which is essentially what Doxiadis calls Ekistics.[2] Although some of the curves employed in the exemplary model runs might not be accurate representations of real-life situations, they are as important for the emergence of a rigorous and meaningful discipline for city planning as Boyle's law for the ideal gases was for chemistry more than a century ago. There is not yet enough empirical evidence to substantiate the ranges and the shapes of the assumed functions; however, this approach might pay off by getting around the intuitive and phenomenological models used so far for simulating the impact of alternative urban policies.

In my view the major shortcoming of Forrester's work is that he never explicates the criteria used in evaluating the performance of the hypothetical city. The unique characteristic of the urban system is that it is the type of system where one is dealing with multiple objectives, multidimensional factors and viewpoints. The set of viewpoints from which a particular urban planning program is examined is of basic importance. The ultimate objective, of course, should be to improve the quality of life for all groups of human settlement dwellers, whether they live in the country or in the city.

ALEXANDER N. CHRISTAKIS

[2] C. A. Doxiadis, *Ekistics: An Introduction to the Science of Human Settlements* (Hutchinson Publishing Group, London, 1968).

Yehezkel Dror, *Public Policymaking Reexamined*, Chandler Publishing Co, San Francisco, 1968, 370 pages, $7.50.

For the last few years the name Yehezkel Dror has been associated with articles and RAND Corporation reports on the subject of public policymaking. In this book Dr. Dror's studies and conclusions are presented systematically. His concern is not with specific policies and their content, but with the ways in which policies are made and the question of whether they are made as well as they can or should be.

The intended audience for this book includes "students and teachers of political science and of the social sciences in general, policy practitioners, such as planners, government officials, and contemplative politicians, and other persons interested in policymaking and public affairs." The objectives the author hopes to achieve for this audience are "(1) to advance the study of public policymaking as a major topic of the social sciences and of human thought in general, and (2) to contribute to the improvement of public policymaking." To a large extent, the author has succeeded in writing a book which will be found readable by this diverse audience. No student of the social sciences will be "turned off" by the feeling that the topic is treated in a superficial manner or that the book is too insubstantial. Similarly, no practicing policymaker will be driven away by technical jargon or by dry presentation. While making no compromises with intellectual rigor, Dr. Dror presents his arguments in such a way that they can be followed easily even by those not accustomed to reading the social science literature. Whether the ideas presented will be accepted equally by all members of this audience, however, is another matter.

agricultural historians, achitectural historians, and art historians" (p. 238). It is singular that the historian of technology fails to be included in the litany. What Glassie might have succinctly stated is that the field needs the attention of American scholars working in the genre of the Welshman, J. Geraint Jenkins (see my review of his *Traditional Country Craftsmen* [New York, 1966] in *Technology and Culture* 8 [1967]: 104–105). Until that happens material folk culture as presented by Glassie will remain largely an enigma to the historian of technology.

The format of the book presents a problem. Footnotes are at the bottoms of pages, commendably. The bibliography is long and will suggest and aid further study. Illustrations and cuts are crisp throughout the text. In spite of this the book suffers, for there is no table of contents, no list of illustrations, no chapters and chapter headings as such, and finally, no index. Glassie sounds the clarion for an interdisciplinary attack upon a threatened field. These mechanical additions to his book would have helped the cause.

PETER C. WELSH*

*Urban Dynamics*. By Jay W. Forrester. Foreword by John F. Collins. Cambridge, Mass.: M.I.T. Press, 1969. Pp. 285; tables; charts; graphs. $12.50.

This study is the result of a sophisticated methodological approach to metropolitan problems, and it offers policy recommendations which deviate markedly from current programs. The author rejects continued low-income housing construction in favor of slum demolition and encouragement of industry in order to revive the economy of the city. This conclusion rests on a specific method of analysis and the validity of the theory derived from it; the following remarks will emphasize this aspect of the book.

*Urban Dynamics* is a study of urban growth from the perspective of systems analysis. It is based on the assumption that complex social systems are inadequately understood by normal human thought processes. This is because the intuitive way we learn to think is formed within the context of linear relationships, where an action (cause) leads directly to an observable result (effect). By contrast, the city is a nonlinear, "counter-intuitive" entity made up of the constant flow of many interacting variables, wherein a single cause may have unforeseen and contradictory consequences throughout the system. When applied to such a system, intuitive, linear thought will focus on symptoms rather than basic causes of problems. Policies arrived at by this ap-

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proach are, the author asserts, short range in effect, and either neutral or actually detrimental in the long run. Thus there is a need to examine the city by means of a computer model which can handle the multiple interactions between various parts of the system, and in so doing provide a theory of urban growth and structure.

Such a model is simulated by a digital computer which, on the basis of mathematical equations entered into it, produces flow charts illustrating the interaction of various urban components. Two models are presented in this study, a growth model representing 250 years of urban development, and an equilibrium model used to test the results of certain policies over a projected fifty-year period. They do not represent a specific city but are meant to illustrate processes common to all urban areas. The urban area generated is conceived as "a closed dynamic system," a self-contained and self-regulating entity which evolves its own development and problems but is little affected by, and has small impact upon, the surrounding environment. The main contact between the outside environment and the urban system is the movement of people into and out of the area. This flow is determined by the attractiveness of the city, relative to the surrounding environment, in terms of (1) jobs provided by industry, (2) housing, and (3) population mix. These three variables, industry, housing, and people, are the main interacting components of the city.

In the growth model, the life cycle of an urban area is charted. The charts plot interactions and different ratio levels among the three basic components, now subdivided into nine variables: new enterprise, mature business, declining industry, premium housing, skilled-worker housing, underemployed housing, managerial-professionals, skilled workers, and underemployed. Beginning with empty land, the city develops to full land occupancy in the first 100 years, at which time new enterprise and premium housing have peaked, while the managerial-professional and skilled-worker population as well as worker housing are at a near maximum. The next 150 years see a realignment of internal variables which finally emerge into an equilibrium stage of stagnation marked by slums, underemployment, flight of industry to the suburbs, high tax rates, and increasing welfare rolls. What has happened after 250 years of growth and stagnation is that the city has increased its attractiveness for underemployed and become less attractive to new enterprise which could provide jobs, thus raising the underemployed to the skilled-worker class. The success of a city, the author contends, is not its ability to concentrate the economically less successful into areas of little economic hope but its effectiveness in providing upward economic mobility for the underemployed.

Which programs are most likely to achieve this goal? Using the equilibrium model, computer runs show the neutral results of a job training program and a tax subsidy, and the detrimental effect

of low income housing construction. In regard to the latter, a program providing housing for 5 percent of the underemployed per year for fifty years has a detrimental effect on worker housing, the labor population, the underemployed/job ratio, the tax rate, new enterprise, and mature business. Another group of computer runs, based on a different set of policy variables, provides results which convince the author that the most efficient way to revive the urban economy is to pursue a program of slum clearance and replacement with new business enterprise.

Some of the questions that can be asked of Forrester's method concern the uses of data and the extent to which the computer model corresponds to reality. What kind of information or evidence formed the basis for the mathematical equations which were fed into the computer? It will not satisfy some to be told that the sources of information have been "people with practical experience in urban affairs . . . from the insights of those who know the urban scene firsthand, from my own reading in the public and business press, and from the literature on the dynamics of social systems." It is even more unsatisfactory to find that only three of those practical people are named, and that out of a total of six references five are to the author's own works. The dismissal of historical evidence and the historical dimension is made explicit when the author asserts that, with few exceptions, the stagnation of a city does not depend on the city's history (p. 106), and that "today's problems extend from the present into the future." The failure to recognize that urban reality is three-dimensional, consisting of *past*, present, and future, and that every city is to some extent unique because of its past, is a fault which will cause some to question the validity of Forrester's model and theory. Finally, when readers of this journal learn that "the model does not, and need not, deal with changing technology" (presumably on the grounds that technology exists outside the system in the limitless environment), they will rightfully ask what kind of reality this systems analysis model is supposed to represent.

PARK DIXON GOIST*

*Agricultural Development and Economic Growth.* Edited by Herman M. Southworth and Bruce F. Johnston. Ithaca, N.Y.: Cornell University Press, 1967. Pp. xv + 608. $12.00.

This book is not about technology as such but does contain much valuable information on important and related areas in agricultural development. Some thirteen subjects are covered in detail, including development theory, social barriers to change, infrastructure, education,

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'Town and Country Planning' July/Aug 1970

# REVIEWS

## model cities

### urban dynamics
by JAY W. FORRESTER
The MIT Press. 117s.

In an earlier study, *Industrial Dynamics* (1961), Professor Forrester of MIT explained the use of computer simulations in the analysis of complex systems. In the present study he turns to the most complex system that man has created and explains the methods and results of developing and operating two related simulations of urban systems. The first model takes the city from inception, through maturity, to decay over 250 years. The second, taking over where the other left off, utilizes such variables as employment, industrial development and housing in an effort to revive the city over a fifty-year period.

"This book is more an opening of a subject than it is a package of final results and recommendations", notes the author in his summary. But one advantage in the development of theoretical models is that variables have to be defined and relationships established, in short, the system has to be systematized. Propositions derived from such considerations not only support the framework design for simulation, but also provide hypotheses which can in themselves be considered, the author's views of "the limitless environment" and "the attractiveness concept" deserve attention here.

As a result of his work, Forrester challenges existing responses to problems of American cities. He suggests that for the long-term improvement of the decaying city, training programmes for the unemployed and extensive low-cost housing may not be the solution, and that seemingly less social moves such as large-scale demolition of inner area slums and replacement by industry might do more to aid urban recovery.

American cities act fairly independently in their attempts to resolve problems, and this means that the models developed here refer to individual city systems rather than a national urban system. Though of considerable value in formulating urban models, the methodology and results discussed here will be of interest to an American rather than a British readership.

BRIAN GOODEY

## Heap's help

### an outline of planning law
by DESMOND HEAP
5th edition, Sweet & Maxwell
30s. paper, £2 10s. hard cover

The digestion of many a town planner and town planning lawyer of the present generation would surely have suffered far more than it has from the lumps of planning legislation squeezed through a long-suffering Parliament at frequent intervals, had it not been for the publication of successive editions of Mr Heap's *An Outline of Planning Law*. The fifth edition of 1969, most modestly priced, comes to our aid over The Town and Country Planning Act, 1968, and other Acts that have emerged before it as amendments to the Act of 1962, which still survives as the principal planning Act on the statute book.

In the midst of speculation on how much longer the 1962 Act will occupy the place of principal Act, and of apprehension that the time will not be far off when the complexities of planning law are still further increased by the legislature, we are comforted by the knowledge that the author of *An Outline* is

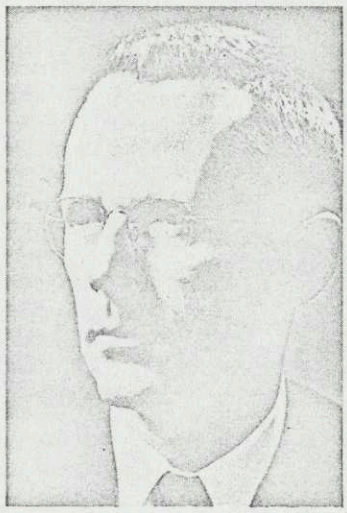
# A daring look at city ills

## New books by men trained to work with computers fuel the controversy over the systems approach to urban problems

**Imagine a candidate** for mayor of New York, Chicago, Los Angeles or any tension-ridden city today who ran for office pledging to:

- Tear down 5% of its already-scarce low-income housing every year.
- Clear away an equal volume of aging business enterprises.
- Spurn programs for housing, job training and outside financial assistance.

He would probably get as many votes as Richard Daley at an SDS convention. But just such policies are what a distinguished expert on industrial management thinks city officials should be following.



Jay W. Forrester

In his Urban Dynamics, an unsettling, complex and ground-breaking new book about our cities and the decay that afflicts them, Jay W. Forrester, professor at the Massachusetts Institute of Technology and holder of some basic patents in the computer field, offers findings that shatter established notions about curing urban ills.

Forrester insists that only by restoring the proper dynamic equilibrium between housing and jobs can cities be returned to economic and social health. For most cities today this means more emphasis on premium housing and managerial-professional jobs rather than on low-income housing and low-skill jobs. He draws upon an array of head-spinning equations, fed through a computer, to show that as things stand now most of the programs aimed at helping cities will make things worse. In fact, he asserts that no outside help in the form of housing, job training programs, or financial assistance really comes to grip with a basic cause of a city's unemployment, bad housing, or economic decline.

Forrester says, in brief, that our cities will sink even deeper into decay unless the people who run them apply some of the things he has been teaching business about the management process.

**Applied systems.** What he wants them to apply comes under the heading "industrial dynamics," a term for his version of the "systems approach;" a bundle of techniques for analyzing highly complex situations by treating them as a system of interacting parts. A year or so ago, enthusiasm for turning trouble-plagued cities into modern Utopias by using these aerospace-derived techniques reached near faddish proportions. But actual experience in the hurly-burly of city politics, and the vastly complex task of identifying and reducing to numbers the countless variables that impinge upon the city threw a dash of cold realism on the subject.

Some cities have achieved modest success in using these valuable tools. In New York, for example, Rand Corp. has helped improve decision-making in very specific jobs, such as how best to deploy fire engines. The city's Bureau of the Budget is busy installing a so-called planning, programming, budgeting system for more purposeful control over city spending. But by and large, efforts to bring very broad problems, such as poverty, under a systems analysis approach has failed to deliver the benefits that enthusiasts hoped for. A speaker at a recent meeting of the National Conference on Public Administration, which was devoted entirely to urban systems, summed up talks on the present state of the art as "a report on different degrees of disillusionment."

**Not quitting.** But as Forrester's book demonstrates, the experts aren't giving up. Much of the earlier enthusiasm, in fact, shines through in a second new book on the subject, Simon Ramo's Cure for Chaos. Ramo, vice-chairman of TRW, Inc., is a businessman-scientist-engineer. Unlike Forrester's technical and detailed exposition, Ramo's readable book is avowedly a primer for the nonprofessional, a broad-brush description of what the systems approach is all about. Compared to Forrester's ambitious effort, some think Ramo's book is so broad-brushed it falls into the earlier excesses.

Simon Ramo

Harold Wolf, management consultant and student of systems, feels that way. Ramo's book, he says, "does not present the kind of documentation or detail that will give the uninitiated much feel for the potentialities of systems techniques." He calls it "a translation into homilies and over-simplified analogies of the systems approach to social problems," that confirms that "the most ardent proponents of the application of new systems techniques to social problems are, by their over-enthusiasm and under-explicitness, often its worse enemies." On the other hand, Wolf believes Forrester makes "a clinching case for its usefulness and its limitations."

**Redefinition.** Forrester's starting point is the now commonplace observation that the city is a system. According to Wolf, "Prior efforts to apply systems analysis to social problems, have been verbal and quantitative. Therefore, they weren't precise enough to disclose the true dynamics of the urban system. Forrester is the first to analyze the city as a closed system in which all the significant cause and effect factors are accounted for and are linked together to show how a change in any one will reverberate throughout the system. This is what Forrester means by the term 'urban dynamics' and it is what he believes the management of the city, or any other complex organization such as a business, is all about."

Trying to understand this closed system through intuition or logic, Forrester asserts, leads to the kind of mistakes he finds officials enmeshed in today. His major contribution has been to put numbers on the factors and interactions at work in the city, and to write equations that describe statistically how changes in any one factor will affect every other. His equations enable him to simulate a hypothetical city in his computer in order to study the impact of given policies and programs and record their effects in quantitative terms.

**A landmark.** It's this process rather than conclusions about

city problems, that Wolf believes gives Forrester's book outstanding value. Forrester calls it "a method of analysis," offered as a "contribution" to understanding "the growth and aging processes of a city."

Forrester's reputation insures that his contribution will receive sober attention from other experts trying to construct computer models of urban problems. But his approach, involving long-range, macroeconomic data, will churn up the running controversy with model builders who lean toward other techniques, especially short-range, microeconomic models.

The factors that Forrester decides should go into his model, of course, determine the results. To identify and evaluate what is crucial to the city, Forrester worked with people experienced in city affairs, such as former mayor John F. Collins of Boston, who wrote the introduction to the book. Forrester copes with a lengthy list of factors, but focuses primarily on the interaction of different kinds of employment and housing, and the different kinds of people they attract to the city.

His figures indicate that a city must maintain a balance between the sorts of jobs and housing it offers people. Left alone, the city's business and housing ages. But corrective policies that draw in and overload the city with unskilled people who fill up the aging housing lead to inevitable decline of the city. And this is what he says is happening today.

**Housing cycle.** To cite one example, Forrester asks his computer what happens when the federal or state government gives the city new housing for low-income people. In the short run, it means an increase in housing and jobs. But over the years, both will decline.

This occurs because as such housing takes over available building sites, it discourages others in the neighborhood, including housing for skilled workers, higher-income tenants, and new business. As job opportunities decline in relation to the increase in unskilled people, unemployment rises. Business and skilled people leave in greater numbers, the tax base narrows, the city raises taxes, and more business is driven away. The process of decay steps up.

Forrester sees a similar cycle of decay in federal financial assistance to cities to provide an increase in services to poor groups, which are then drawn into the cities in greater numbers.

Forrester isn't arguing that the city should draw no poor or unskilled people. He is simply saying the city can handle only a given volume. As conditions stand today, he feels, the major plague of the city is an out-of-balance relationship between employment opportunities and living space.

A third and very different kind of new book about cities reaches somewhat the same conclusion as Forrester. In The Economy of Cities, Jane Jacobs, the planners' bête noire, also contends that the vitality of the city depends heavily on stimulating a diversity of new business enterprises.

**What to do?** What, then, should the city do? To Forrester, the answer is obvious. The city should pursue policies that make it more attractive to new enterprises and managerial-professional people, and less attractive to aging business and unskilled people. Specifically, Forrester says the city should stimulate the growth of new business enterprise. Equally important, it should use its tax, zoning, and other powers to cause the demolition of at least 5% of low-income housing a year. The land thus freed, he believes, will enable the "natural dynamics" of the city to take over and restore healthy balance.

With his general policy findings, Forrester comments on specific city functions. Three examples:

- He feels taxes should openly favor high-employment industries that pay high wages. He wants reduction of commercial tax rates relative to residential and possibly even a tax credit based on salary levels of high-skilled people.
- He wants to reverse present zoning policies that tend to restrict industry and favor residences.
- He thinks urban transportation should connect industrial areas with one another rather than industry to housing. This would help business and cut down on long home to job commuting.

**Social answers.** Forrester is sensitive to the social implications of his prescriptions. To the question "Would they work a hardship on the city's poor?" he admits that "policies that lend to urban revival will give the superficial appearance of favoring upper-income groups and industry at the expense of the underemployed." But he points out, "the number of underemployed people living in a city is not a measure of the city's social value."

Reducing the volume of low-cost housing, he insists, won't drive the poor from the city, but it will discourage more from coming, and this will enable the city to perform more efficiently its traditional role of upgrading its existing inhabitants. Forrester's answer to potential social critics: "No purpose is served by operating a city so that it is a drain on the economy of the country and a disappointment and frustration to its occupants."

About the politics of his ideas, Forrester admits that "if the city has already reached the point where the underemployed are numerous and politically powerful, these programs may not be open for practical political consideration." But he believes he has shown the high price that pressure groups exact when they press for programs that "trap in poverty the very people they are designed to serve."

FORTUNE

November, 1969

Books & Ideas

# A Computer Version of How a City Works

*by John F. Kain*

The intense interest in the problems of the cities in recent years has produced a great outpouring of books diagnosing and proposing remedies for the "urban crisis." The majority of these works are hardly noticed, being undistinguished and rather pallid imitations of one another. Jay W. Forrester's *Urban Dynamics* (M.I.T. Press) stands out in all this verbiage. The book has attracted attention because of the unorthodoxy of Forrester's recommendations, the self-assured manner in which he presents them, and his prominent use of the prestigious tools of systems analysis. With so many insistent voices saying that cities need more financial help from state and federal government, readers are likely to be impressed with Forrester's conclusion that help from the outside may "worsen conditions" in cities. Forrester, moreover, makes it difficult for readers to argue with him. With its appearance of rigor and scientism, its charts and diagrams, its arrays of numbers printed out by a computer, *Urban Dynamics* is rather intimidating.

Forrester, a professor at M.I.T.'s Sloan School of Management, relies on a computer model he developed to simulate the growth, decline, and stagnation of a hypothetical city (or "urban area") from birth to old age (250 years). Such methods have a great deal of potential for the analysis of urban problems and have already demonstrated their value in a number of specific, though limited applications. However, the development of truly useful and trustworthy urban simulation models remains a distant objective and will require much greater resources than have yet been devoted to the task. Before adequate models become available, many inadequate ones will be put forward. Forrester's model is a conspicuous example. In his first chapter Forrester warns the reader that caution should be exercised in applying the model to actual situations. Subsequently, however, he expresses few reservations about the model's validity and freely uses it as a basis for prescribing public policy.

*John F. Kain, an associate professor of economics at Harvard, specializes in the new field of urban economics.*

## A goal of minimum taxes

The hypothetical city in *Urban Dynamics* is, in Forrester's words, "a system of interacting industries, housing, and people." At the start of the simulations there is only new industry in the city, but as time passes enterprises mature and then decline. The speed of this aging process depends on conditions in the city. As businesses pass through these successive stages, they employ fewer workers and a smaller proportion of skilled workers.

There are similarly three kinds of people in the city: "managerial-professional," "labor" (skilled or high-income workers), and "underemployed" (including unemployed and unskilled workers). And there are three kinds of housing, corresponding to the three kinds of people: premium housing, worker housing, and underemployed housing.

The criteria used in evaluating the performance of the hypothetical city and the efficacy of alternative public policies are never explicitly set forth. However, minimization of taxes per capita would be a fair rendering of the underlying criteria. Forrester seems to think that the objective of the city is to produce the lowest possible tax rate.

The fiscal relationships in Forrester's urban system are intricate, but can be reduced to three fairly simple propositions: (1) Low-income households cost the city more in taxes than they pay, whereas the city makes a profit on high-income households. (2) Growing business enterprises are an unqualified good because they pay taxes and, by assumption, cost the city nothing in services. (3) Increases in local taxes and increases in local government expenditures produce "adverse" changes in the city's population and employment structure. It follows from these propositions that "urban-management policies" should be designed to encourage new enterprises and managerial-professional people to locate in the city and discourage low-skilled people from living there.

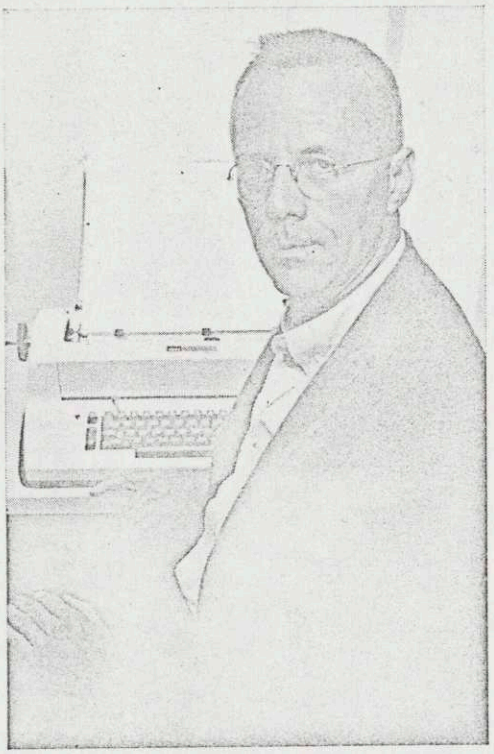
The influence of tax rates on employment and population structure in Forrester's city is powerful and pervasive. "Managerial-professional" and "labor" families are assumed to be repelled by high tax rates, whereas the "underemployed" are indifferent to them. High tax rates, moreover, discourage the formation of new enterprises and accelerate the aging of existing ones. There are still other adverse effects: high taxes retard construction of both premium and worker housing, which in turn discourages the kinds of people who live in these kinds of housing from moving to the city or remaining there.

Increases in public expenditures, the other half of the local fiscal equation, also have disastrous effects on the system. It is assumed that increases in expenditures per capita make the city no more attractive to high-income people and new enterprises, but make it substantially more attractive to low-income people. There are some small offsets in the positive effects of higher expenditures per capita on upward mobility from the underemployed class into the labor class; but these are overwhelmed by the direct and indirect effects on the size of the underemployed population.

These examples are only a few of the "adverse" consequences of higher taxes and increased public expenditures in Forrester's model. Since the model is so constructed that a development in one sector affects other sectors, these adverse effects cumulate throughout the system.

## Help from an induced shortage

Forrester uses his simulation model to evaluate several "urban-management programs" that have been tried or proposed, and he concludes that they "may actually worsen the conditions they are intended to improve." For example, he finds that "financial support from the outside"—presumably including revenue sharing by the federal government—"may do nothing to improve fundamental conditions within the city and may even worsen conditions in the long run." But this conclusion is not at all surprising in view of what he does with the outside funds. Rather than using them to reduce or hold down city taxes, as proponents of such intergovernment transfers envision, Forrester uses them to increase city expenditures. Given the framework of his model, the net effects are inevitably adverse. If instead Forrester had used the outside support to reduce city taxes, the net effects would have been favorable to the hypothetical city. Virtually all of Forrester's evaluations of "conventional" policies are similarly flawed; none is a faithful rendering of policies it supposedly represents.



Jay W. Forrester

Considering the heavy emphasis Forrester puts on tax rates, it is striking that he fails to consider the costs of his principal recommendation: each year demolish 5

percent of the low-income housing. The costs of acquiring and demolishing the properties would increase city taxes, and, within the framework of the model, any increase in city taxes has adverse effects. But Forrester considers only the favorable effects of the demolition program. Given his model, these are considerable. The induced shortage of low-income housing makes the city less attractive to low-income people; fewer come and more leave. (Where they go is a question the model is not designed to consider.) As before, a decline in the ratio of "underemployed" to total population makes the city more attractive to high-income people, encourages formation of new enterprises and construction of premium and worker housing, and impedes deterioration of dwelling units and businesses. In addition, the land cleared by increased demolition of low-income housing provides space for new enterprises and for premium and worker housing.

The supply of vacant land is a critical variable in Forrester's urban model. When more than half the land is still vacant, using additional land produces increasingly favorable effects. But once half the land in the city has been put to use—which in the simulations occurs at about 100 years—further depletions produce increasingly adverse effects. The city's growth is retarded, and stagnation and decline begin. As more land is used up, the scarcity of vacant land slows formation of new enterprises and construction of premium and worker housing, and speeds obsolescence of both enterprises and housing. Given the critical role of land availability in the model, it would appear that these adverse effects could be staved off if the city could simply extend its boundaries so as to absorb additional vacant land; but Forrester does not deal with this possibility.

## Where the solution lies

Simplification is essential in computer simulation models, and neither Forrester's nor any other model can be criticized merely because it omits detail. But Forrester omits some basic behavioral relationships. The model's most serious weakness is that the suburbs never explicitly appear in it. For some simulation purposes, it might be permissible to disregard temporarily the interrelations between, say, the city and the rest of the nation beyond the metropolitan area. But what happens in a city strongly influences its suburbs, and vice versa. If the central city reduced its low-income population by 100,000, the low-income population of the suburbs would have to increase by roughly the same amount. Although Forrester's model reflects no awareness of this aspect of metropolitan interdependence, suburban governments are all too aware of it. Indeed, much of the urban problem today is a result of suburban governments' successfully pursuing precisely the kind of beggar-thy-neighbor policies Forrester advocates for the central city.

Upon scrutiny, *Urban Dynamics* amounts to an intricate attempt to justify the responses of big-city mayors to a harsh fiscal environment. Existing intergovernmental arrangements saddled them with awesome responsibilities for the nation's social problems, but failed to provide them with commensurate financial resources. Much of the mayors' enthusiasm for now much-criticized urban-renewal programs is traceable to their desperate need for cash. In *Urban Dynamics*, pragmatic responses to an unbalanced allocation of responsibilities and tax resources are elevated to the status of rational and efficient policies for dealing with the complex web of problems popularly referred to as the "urban crisis."

The solution is not, as Forrester indicates, the pursuance of narrow self-interest by each local government. Instead we need to develop a more appropriate division of responsibilities and functions among governments, and thereby remove the fiscal incentives for local governments to follow policies that, while perhaps efficient from the viewpoint of narrow self-interest, are inefficient from the viewpoint of society as a whole. END

# PLANNING AND DESIGNING FOR THE FUTURE

## The Breakthrough of the System Approach

René Dubos' *So Human an Animal*[1] and Jay Forrester's *Urban Dynamics*[2] together with Aurelio Peccei's *The Chasm Ahead*[3] (reviewed in the March 1969 issue of FUTURES), although widely different in subject, complete a troika of books published this year which take the same system approach and show the way for futures research. They measure out the vast problems the future holds for us and provide a platform on which to build a body of scientific knowledge that will enable us to deal actively with our own future.

Aurelio Peccei, in *The Chasm Ahead*, deals with the macro-problems that mankind is facing in the near future, with the urgent need for re-designing the world system. At the other end of the spectrum, René Dubos explores in his book *So Human an Animal* the joint systems of man and his environment, the biological platform of the human species which is no less endangered by urbanisation and technology and needs to be built anew continuously. And Jay Forrester, in *Urban Dynamics*, presents the first full-scale simulation study of the dynamic social system which has moved to the focus of concern today, the city.

Apart from their common deep concern with the future, a certain unity of basic approach ties these three books together and may give their almost simultaneous publication enhanced significance. This basic approach is characterised by three essential notions:

- The future of man and society has to be dealt with in the context of systems which link them to the environment shaped by nature, technology, or social development—by what is now called the integrative approach, cutting across many dimensions, social, political, economic, technological, anthropological, psychological and others.
- These systems form complex dynamic systems, which implies that they are high-order, multiple-loop, non-linear, feedback structures—with particular emphasis on their feedback nature.
- Actively shaping the future, and planning for it, imply changing the structure

of these systems, not just the variables. This is done by what may be called system engineering in a broad sense (especially socio-technological system engineering), or, more suggestively, ecological engineering.

Only Forrester's book treats its theme in a technical and methodical way. However, computer simulation of complex dynamic systems which he applies to the city, and which he adapted from the original 'Industrial dynamics' concept, developed by himself and co-workers over the past decade, carries a most important general potential for dealing with complex dynamic systems at all levels—at the level of the individual, of social systems, and of the world system. It constitutes at present the only fully-developed means to study outcomes of specific courses of action in the context of dynamic system behaviour. With the dramatic shift from input- to outcome-oriented planning, as it is inherent in the development of long-range planning at the policy and strategic levels, this approach will acquire universal significance.

With the books by Dubos, Forrester, and Peccei, research into and planning for the problems of the future will have to abandon their fixation on goals, scenarios, and anticipations of possible futures to the extent that they are all usually conceived in more or less static and piecemeal terms. They will focus on system dynamics, in particular the dynamics of complex feedback systems. Their guiding images will consequently be formulated in dynamic terms, and their dominant criterion will be dynamic system stability—a concept quite distinct from equilibrium and the variety of hedonistic constructs filling the literature so far.

The intellectual games played today with possible and desirable futures have little to do with planning and design leading to real action. The sudden recognition that it may become possible to shape the future actively, and the lack of understanding of evolutionary processes—which are characterised by complex system dynamics—led to some sort of intoxication with unrestrained freedom and even anarchy, and to blindness towards the growing complexity of the systems of human living which, in turn, makes the tasks of planning and design so much more complex. We may now begin to discard these naive attempts to dream up or extrapolate the future. We are led to a profound concern about the basic structures and boundaries of systems whose uncontrolled development we have to get into our hands before we may allow ourselves some extravagance. Here is a basis of rationality for setting priorities, planning, and making decisions—a basis for exerting human freedom in a responsible way.

"Design, rather than anarchy, characterises life", states René Dubos in his book. "In human life, design implies the acceptance and even the deliberate choice of certain constraints which are deterministic to the extent that they incorporate the influences of the past and of the environment. But design is also the expression of free will because it always involves value judgements and anticipates the future."

*So Human an Animal* sums up the conclusions which the famous French micro-biologist, working at Rockefeller University in New York, reached during his life-long concern about man's place in a rapidly changing environment. It is Dubos' finest book to date, and the Pulitzer Prize it has been awarded, is due both to its high motivation and competence and to the simplicity, transparence and elegance of its style.

The basic aim of the book is to bring to light the complex feedback interactions between human and environmental development, and to grasp their implications for the future of mankind. Whereas classical Darwinism and other evolutionary theories focused on particular aspects, and thus failed to explain the development of the integral man-environment system, Dubos recognises a multiple-loop feedback system in which evolutionary development, experiential development, and human free-will interact with each other. "In the course of human evolution, the brain, the body, and culture developed simultaneously under one another's influence, through the operation of complex feedback processes. Integrated inter-relationships of biological constitution and of function necessarily result from this evolutionary inter-dependence of body, brain, and culture."

A change in environment brings new parts of man's genetic endowment into play, only a fraction of which is actually used. This is the cause for man's astounding propensity to adapt himself, especially to the rapidly changing environments affected by urbanisation and technology. But our confidence in an almost infinite capability to adapt ourselves lacks any sound basis of knowledge about the limitations of our genetic endowment on the one hand, and the effects of man-made environments on human life on the other. Here lies the danger of self-destruction through rapid and uncontrolled developments in the man-environment systems, brought about by actions of human free-will.

"Man makes himself through enlightened choices that enhance his humanness." But the basis for making enlightened choices is essentially lacking today. We have developed 'know-how' to change the environment wilfully but we have not developed the 'science of humanity' to clarify the 'know-why', urged by Dubos, and least of all have we developed system analysis and system engineering that are applicable to the man-environment systems and provide a basis for the 'know-what' and the 'know-where-to'.

In particular, Dubos underlines that "the view that man's future is linked to technology can become dangerous if accepted uncritically. Any discussion of the future must take into account the inexorable biological limitations of *homo sapiens*. . . . The first move toward a richer and more human philosophy of life should be to rediscover man's partnership with nature."

Dubos' book comes at the right time to question some of the narrower concepts developing today that focus almost exclusively on joint systems between society and technology. The systems, of which man as an individual is one of the constituents, are in danger of becoming neglected. But it is here that the most stringent requirements and limitations for further development probably become effective, as superficial economic and social criteria lead us to shaping an ever more artificial environment. At present, our actions are more characteristic of anarchy than of design. Dubos' book gives science, including systems science, a new and powerful challenge, the response to which may well decide the fate of the human species.

*Urban Dynamics* had become the subject of heated debate even prior to publication. It has captured the imagination of politicians and managers in the public domain, and it has been furiously attacked and rejected by social scientists. It is a safe prediction to state that it will become one of the most

provocative and stimulating books of our time in a climate which, at least in the United States, is conditioned by a wide recognition of the plight of the cities.

This book constitutes the imaginative application of the 'Industrial Dynamics' concept, looking at systems as feedback processes having a specific and orderly structure, to the problems of the city. It considers the city as a living, self-regulating system of complex nature, exhibiting the same counter-intuitive dynamic characteristics found in other complex dynamic feedback systems (of which the business corporation is the best studied system to date).

The basic approach is simple. The system is described in the form of a structural model with the essential relationships of the real system built into it, including those which give rise to undesirable system behaviour. To build such models is not an easy task. The proof of correctness lies in the dynamic characteristics revealed by computer simulation, matching experience as far as possible.

However, once a model has been adopted, computer simulation permits study of the outcomes of structural changes made in the model. Thus, simulation of this type becomes a most important method for planning at the policy and strategy levels and in the context of complex systems. It permits study of the consequences of alternative courses of action in ways which enhance the potential of human imagination and inventiveness, for example:

- The outcomes of interactions of cause-effect relationships with long time-constants may be studied (for the city of the order of decades); these are usually counter-intuitive
- Complex feedback interactions and their effect on overall system behaviour may be simulated
- Causes (structural relationships), instead of mere symptoms, may be dealt with
- Dominant relationships, determining the overall system behaviour, may be discovered and the effect of changing them may be studied. This may lead to effective and inexpensive ways to restructure systems (if, as Forrester believes and demonstrates, a relatively small number of relationships dominates in this way)
- Simulation of alternative changes may reveal possibilities to build systems with a greater capability of self-regulation and self-stabilisation.

All of these studies could not be made without the help of the computer; outcomes in dynamic system behaviour could not be grasped intuitively. However, the nature of changes introduced and tested by simulation depends on the creative human mind.

To demonstrate the application of the method, the book uses a specific model, built from 153 equations and described in full detail in an appendix. Two types of simulation are carried out, a growth simulation over a 250-year time span from the beginnings of a city to its stagnation, and variations starting with the equilibrium (stagnation) conditions derived from the last stage of the growth simulation. These variations constitute the most significant part of the book, because here real social system engineering—restructuring stagnant

social systems—is tested through simulation to explore how various changes in policy would cause the conditions of the urban area to be altered over the following fifty years.

The counter-intuitive nature of social system behaviour is demonstrated drastically. Measures, which intuitively would be chosen to improve the under-employed: job ratio, one of the crucial variables, turn out to act in the desired direction only in the short run, but to worsen the situation in the long run. This is shown, for example, for measures such as low-cost housing programmes and under-employed job-training programmes (which, as a matter of fact, explains some of the recent failures in intuitive USA urban policies). On the other hand, a slum demolition programme contributes substantially to an improvement of the situation in the long run, because it does not give rise to increased inflow of under-employed into the city, and it furthers gradual and lasting improvements in the economic conditions of the city—in other words, it acts on causes, not on symptoms.

Urban Dynamics is not the only approach to long-range planning and it is not perfect. In its present form, it deals with specific system structures, which are kept unchanged over the time span of the simulation. The introduction of structural changes is reserved for human interference, where, in reality, these structures may also have to be looked at as dynamically changing parts of a living system. These inherent dynamics may ultimately also be simulated in more sophisticated models.

However, Urban Dynamics already constitutes a giant step forward in long-range planning for systems, opening up entirely new potentialities of social system engineering. Without doubt, it will give new food to the naive myths about the computer gaining control over society, as they flourish particularly in Europe in such an indiscriminate way. In reality, Urban Dynamics—or Social Dynamics, as the method might be called even more generally—enhances the role of human creativity and inventiveness in an unprecedented way. By studying the consequences of alternative courses of action for entire social systems, man acquires a new potential for making enlightened choices in a long-range and complex system framework which is impenetrable to mere intuition and simpler techniques.

"Human freedom", states Dubos, "includes the power to express innate potentialities, the ability to select among different options, and the willingness to accept responsibilities." The books by Dubos, Forrester, and Peccei all show us ways to exert this human freedom.

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References

1. René J. Dubos, *So Human an Animal* (New York, Charles Scribner's Sons, 1968) 267 pages, $6.95
2. Jay W. Forrester, *Urban Dynamics* (Cambridge, The MIT Press) 285 pages, $12.50
3. Aurelio Peccei, *The Chasm Ahead* (New York, Macmillan; London, Collier Macmillan) 297 pages, $7.50