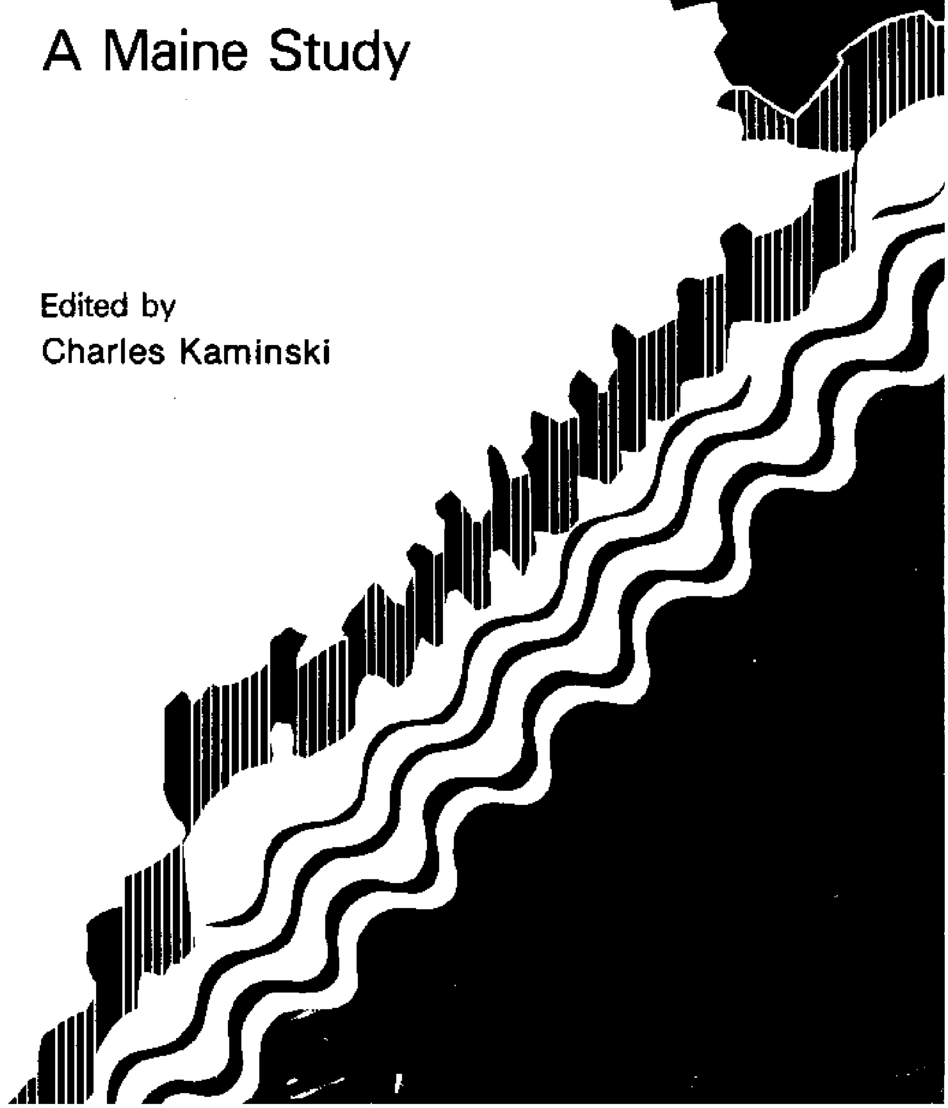
MODELING AND GAMING FOR REGIONAL PLANNING

A Maine Study



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MODELING AND GAMING FOR REGIONAL PLANNING

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MODELING AND GAMING FOR REGIONAL PLANNING

A MAINE STUDY

An Interdepartmental Student Project in Systems Engineering
at the Massachusetts Institute of Technology

Edited by
CHARLES KAMINSKI

with a Foreword by William W. Seifert

M.I.T. Sea Grant Program
Massachusetts Institute of Technology
Cambridge, Massachusetts

Modeling and Gaming for Regional Planning: A Maine Study

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FOREWORD

This volume reports the findings of a student design subject entitled "Special Studies in System Engineering" offered during the spring term of 1972. Students in that subject have, each year, explored a different topic and the results have subsequently been published. The topics chosen typically involve a broad mix of technical, social, and economic aspects and attract students from a variety of disciplines.

The decision to have the group examine the problems facing the coastal region of Maine was based on several considerations. First, the problems facing the region were receiving considerable attention in the media. Increasing demand for petroleum and petroleum products was forcing an examination of possible sites for deep-water ports and refineries in New England. Maine offered possibilities for both. On the other hand, many environmentalists and residents of Maine were adamantly opposed to any development that might detract from the unique beauty of Maine's coastal area. The opposing sides were vocal in promoting their particular viewpoints, but too often the arguments tended to be based more on emotion than on fact and lacked the breadth of view needed for a full understanding of the issues. I hoped that a student group examining the situation in an impartial way and employing techniques as rigorous as the task warranted would provide some important new insights that would be of value to decision-makers.

A second consideration in choosing the situation in Maine as a study topic was that the area was sufficiently close to Cambridge that a certain amount of direct interaction with individuals and organizations in Maine was possible. Finally, the Sea Grant Program of the National Oceanic and Atmospheric Administration was providing some support for the conduct of the study and the publication of its results. Consequently, the desire was to select a topic related to the ocean or to the coastal area.

The problem statement initially provided to the class cited the heated debate in Maine between those urging development and an increase in job opportunities and those resisting development on the grounds that it would lead to environmental damage. The students were asked to examine steps that should be taken if the state is to achieve a balance between a reasonable rate of economic growth and preservation of its natural environment. They examined a variety of documents outlining past and current conditions in Maine and proposals for specific projects such as power plants, deep-water ports, and refineries.

After having developed a good working knowledge of current conditions in Maine and having considered at some length how they might most effectively contribute to the development of rational plans for the state, the students decided that they should concentrate on the development of methodologies for planning rather than on the appraisal of specific plans and projects. This decision was based on the belief that they could hope to add, at best, only a small increment of understanding to the analysis of a particular development issue, whereas the development of methodologies that could be used as tools for elucidating a variety of development issues would be useful to a much larger group and over a much longer period of time.

The students formed two teams, one to develop a systems dynamics model and the other to develop a game. Both the model and the game were to relate to the coastal area of Maine and utilize data relating thereto. However, the emphasis was to be more on developing methodologies than on an in-depth examination of specific issues. Because of this emphasis, we believe that although the results of the project provide some important general guidance, more detailed follow-on work is required if full benefit is to be derived in specific situations from the techniques illustrated.

In May 1972 the class presented its results to an audience including representatives of a variety of groups concerned with development in

Maine and other coastal areas of New England. However, considerable further work was required to elaborate upon the results accomplished during the term and to prepare these for publication in the present form. Fortunately, one of the students, Charles Kaminski, agreed to carry on the work and serve as editor for the final document. That the task was completed is due in large part to the sense of responsibility which he showed in carrying on with this work while a student in the Harvard Business School and having a full-time job in the summer of 1973.

At the end of July 1973 the results of this work were summarized at the Sea Symposium held at the Maine Maritime Academy, and on August 30, 1973, Kaminski and I met with a group assembled by the Maine State Planning Office in order to play the game described in this book. Each of these efforts helped to clarify our thoughts and thereby improve the final document.

The following students participated in this effort:

	Department	Year
Richard E. Czlapinski	Ocean Engineering	Graduate student
Stephen C. Ehrmann	Urban Studies & Planning	Senior
Thomas M. Gearing	Electrical Engineering	Graduate student
Peter C. Heinemann	Mechanical Engineering	Graduate student
Charles A. Kaminski, Jr.	Electrical Engineering	Graduate student
Robert E. Kasameyer	Mechanical Engineering	Special graduate student
Si-Shian Liang	Mechanical Engineering	Graduate student
Henry Montgomery, Jr.	Electrical Engineering	Graduate student
David S. Nichols	Mechanical Engineering	Graduate student
Boonsrang Niumpradit	Mechanical Engineering	Graduate student
James C. O'Connor	Ocean Engineering	Graduate student
Francisco G. Restrepo	Mechanical Engineering	Graduate student
Edward W. Rich	Mechanical Engineering	Senior
Jean-Paul Wisniewski	Harvard University, Graduate School of Arts and Sciences	Graduate student

In addition to myself, Professor Robert E. Stickney of the Department of Mechanical Engineering and Professor Joseph B. Lassiter III of Ocean Engineering served as faculty advisers. John C. Artz, of the Maine Maritime Academy in Castine, Maine, was a Visiting Engineer in Ocean Engineering at M.I.T. at the time of this study and was an active participant in the effort.

I should like to thank Joan Coughlan for typing the draft of the final report and Thomas F. Orowan for typing the copy reproduced in this book. To Arthur J. Giordani of the Electronic Systems Laboratory at M.I.T. goes the credit for preparation of the figures. I also should like to acknowledge the editorial assistance provided by Mary Cox.

The follow-on work, including preparation of the final manuscript, was supported jointly by the Henry L. and Grace Doherty Charitable Foundation, Inc., the NOAA Office of Sea Grant, Grant No NG-43-72, 1972-73 project element "Interdisciplinary Systems Design Course," and the Massachusetts Institute of Technology.

Cambridge, Massachusetts
August, 1974

William W. Seifert
Professor of Civil Engineering
Massachusetts Institute of Technology

CONTENTS

Part I

INTRODUCTION

Chapter 1 MODELING AND SIMULATION GAMES

PLANNING

The problem of balanced economic growth in the United States is immense and baffling. Its dimensions -- to say nothing of potential directive policies -- are not well understood. The problem is made more difficult by the complex nature of the U.S. economy, particularly when it comes to determining the perhaps unanticipated secondary effects of policies designed to control it. Witness recent efforts to curb inflation while still keeping the unemployment rate down. Neither problem seems to have been solved by the policies initiated. Many economists say that simultaneous pursuit of these two goals is an impossible task and that at best we could have either limited inflation or low unemployment. Others see the present situation as the result of an apparent shift in the Phillips curve (Samuelson, 1967),* reflecting a change in the historical trade-off between unemployment and inflation.

Why have the government's policies not produced the expected results? Why has it not been possible to reverse the adverse shift in the Phillips curve? A possible answer is that the full implications of the primary and secondary effects of the corrective policies were not fully known, studied, or evaluated when the decisions to take action were made.

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* References cited in the text are listed in Appendix A. Additional supporting references are provided in Appendix B.

Planning can be thought of as structuring the future. The result of successful planning is a scheme by which people can alter a natural chain of events or can create a planned series of events so as to maximize benefits while reducing the likelihood of unwanted outcomes.

When the streets of Denver were laid out, the city's planners chose a checkerboard pattern with a few diagonal streets added to accommodate traverses. In later years, Denver's traffic signals were programmed to allow uninterrupted movement through successive intersections as long as the speed limit was observed. Denver drivers today benefit from this case of successful planning.

All planning, however, does not result in improving those conditions or avoiding those problems that it addresses. New conditions or unexpected occurrences can turn even well-thought-out plans into nightmares. An all-oxygen environment, a seemingly reasonable part of a complex plan, contributed to the deaths of three Apollo astronauts when an electrical spark turned their capsule into an inferno. The purist could say if the Apollo plan had been evaluated to perfection the potential danger of the all-oxygen environment would not have been overlooked. But who is to define the point at which a plan is perfect? NASA's people must have considered the plan for the capsule environment at least complete enough to begin testing it. Yet, for all the careful planning by thousands of trained people, three astronauts died.

Regional planning is a daring enterprise that necessarily draws on the expertise of many different fields. It must take into account natural and economic resources, legal and political considerations, demographic patterns, and public opinion. The job of a regional planner is often a thankless one; if he is successful, he receives little credit, but if he fails, he is singled out as a scapegoat.

The toughest external problem facing the regional planner is the need to satisfy as many interests as possible while still meeting the basic objectives his analysis points to. The conflict between the wishes of ecologists interested in preserving the resources of the area and those of businessmen interested in developing the same resources is an example of the sort of problem common to the process. Growth versus no-growth, industry versus tourism, and regional benefits versus global benefits are similar points of conflict.

Internal problems such as the difficulty of coordinating information from the various disciplines and the necessity of allowing for the unexpected compound the difficulties experienced by the planner. Furthermore, the planner deals not just with information but with individuals and groups. Ideally, the interchange involved when opposing sides sit down together and discuss a problem in a reasonable manner offers a great opportunity for resolving an issue. In reality, all too often such confrontations only polarize the issues further.

Is there a device that would allow opponents to consider sides of an issue other than their own? Also, are there vehicles that could facilitate coordination of the various disciplines involved in regional development? Such techniques would be of great value to the regional planner -- and in fact do exist in rudimentary form. The chapters that follow present a regional development model and a game that are at least a partial answer to the questions just raised.

The model depends heavily on the computer as an analytical and prescriptive tool for the planner. Before a development problem can be simulated on a computer, all the variables and the interactions between them must be specifically defined and values must be assigned to them. For this present study, a specific region -- Washington County in Maine -- has provided the factual data on which the analysis is based. The game described here was developed primarily to illustrate the application of gaming techniques to the planning process. Nonetheless, the game was designed to reflect actual conditions in the coastal area of Maine, and its outcomes may have relevance to actual planning in that region.

MODELING TECHNIQUE

In the study reported on in this book, the primary purpose of the modeling effort was to present a methodology. We were interested in answers to the following questions:

1. What situations lend themselves to model simulation?
2. What can we expect to learn from a model?
3. How do we go about creating a model?

An additional goal was to determine whether or not modeling could result in specific conclusions about the impact of locating an oil refinery in Washington County, Maine.

During the past dozen years, considerable progress has been made in developing techniques for formulating dynamic computer models of a variety of socioeconomic systems. One of the earliest efforts in this field was made by Professor Jay Wright Forrester of M.I.T., who directed his initial attention to the dynamics of industrial corporations (Forrester, 1961). Later he extended his work to a study of the dynamics of cities (Forrester, 1969) and, most recently, to a study of world dynamics (Forrester, 1971). Others have developed models of sectors of national economies (Holland, 1961; Lieftnick, 1969; Manetsch, 1971; Picardi, 1973; Kaminski, 1972).

Our goal in developing a model for Washington County, Maine, was to illustrate how a model representing the dynamics of a region could lead to a fuller understanding of the probable impact of a proposed project or proposed legislative policy. This effort employs the techniques developed by Forrester and his group and applies them in an analysis of the relationships among the industry, government, demography, environment, and economy of Washington County.

SIMULATION-GAME TECHNIQUE

The other planning aid described in this book is a simulation game, also based on the actual conditions in Maine, which relies heavily on human interaction. It requires a minimum of eight participants, seven of whom take active roles in the play and one of whom acts as a controller. The goals and motivations of the players representing business and governmental interests are given as part of the game situation. These representative players interact to determine the evolution of the region under study over a twenty-five year period.

The game has potential practical value. Interested business and community leaders with similar development problems will be able to profit from playing their own roles within the framework of the game and observing the consequences of the strategies they choose to pursue. Then, additional insight into the problems of development will be gained if roles are switched. By such an exchange, proponents of a particular point of view must take on, at least temporarily, their opponents' values and motivations. Better understanding among interested groups should result from this exchange.

Chapter 2 DEVELOPMENT IN THE STATE OF MAINE

GEOGRAPHY AND ECONOMY

Maine is blessed with abundant natural beauty. Forests, rivers, and lakes cover much of the interior; the seashore is rugged and majestic. Among the natural assets of the inland regions are 2,500 lakes and 500 rivers and navigable streams. Maine's inland waters cover one and a half million acres and constitute 63 percent of the inland waters of New England. The straight-line length of the coast of Maine is only 228 miles. However, if all the areas washed by the tides are measured, the coastal frontage becomes 3,478 miles. (The many islands and inlets account for the difference.) The coast also offers several sheltered deep-water harbors.

Slightly fewer than a million people inhabit Maine. They are spread over the 30,000 square miles of the state, whose population density is less than one-twentieth that of Massachusetts. Several major cities exist, the largest of which is Portland, with a 1970 population of 65,000. Most of the larger urban concentrations are near the coast.

Maine's 17 million acres of forest land are one of her greatest assets. Thirty-eight percent of the state's manufactured product is derived from the forests. Over 30,000 people are employed in forest-related industries, which in 1970 produced, among other things, 700 million board feet of timber.

Information on which this chapter is based is taken largely from Maine Pocket Data Book 1971, prepared by the state Department of Economic Development.

This lumber was valued at $215 million, while the state's paper and paper products accounted for another $714 million. Wages from the forest-related industries totaled $200 million in 1970.

Another important industry is agriculture. Over $250 million in cash receipts resulted from farm products sold in 1970. This total accounts for approximately 30 percent of all farm receipts for New England and reflects the percentage of farm acreage in Maine compared to that of New England as a whole. Eggs, poultry, potatoes, and dairy products make the four largest contributions to the cash value of the state's agricultural output. Although Maine produces the largest share of the agricultural output of New England, the average value of Maine farmland and buildings is the lowest for the same region.

The Gulf of Maine is a rich fishing ground. Bounded by Nova Scotia, Maine, Cape Cod, and the Georges Bank and favored by a special set of oceanographic circumstances, the Gulf is particularly productive. As the warm waters of the Gulf Stream move up the eastern coast of the United States they pass along the continental shelf in the Georges Bank area and, further east, become the North Atlantic Current. One branch of this current sweeps in a great counterclockwise half-circle back toward Nova Scotia and distributes nutrients picked up from the ocean floor throughout the entire northwest portion of the Atlantic Ocean, including the Gulf of Maine. As a result, many varieties of fish are attracted to and supported by the area, and fishing is not only an integral part of Maine's character but also an important sector of her economy.

In 1970, almost 159 million pounds of fish caught in the Gulf of Maine brought over $30 million to Maine fishermen. Ocean perch, herring, whiting, lobster, and shrimp made up the largest takes, with lobster providing by far the greatest market value.

Other important sectors of the Maine economy are the leather industry and recreation, including tourism. The output of the leather industry has slackened a bit. Tourism, however, has been on the upswing. Over five million visitor-days were recorded in the public recreation areas of the state in 1970, a rise of 64.5 percent over the 1965 figure.

ECONOMIC AND SOCIAL PROBLEMS

In spite of Maine's natural assets, all is not well with the state's economy. Many of the state's most talented and productive people are moving away. Fishermen are reporting drastically reduced takes, in spite of the use of increasingly effective fishing methods. The threats of spreading urbanization and consequent increased pollution are very real. These and other problems have generated considerable concern among those responsible for developing policy for the state.

While in the long run it may actually be more of an advantage than a disadvantage, planners now see the low rate of population growth within the state as a problem. The growth rate is lower than the rates for both New England and the country as a whole. Between 1940 and 1950 the annual rate of increase was 0.8 percent per year, but the rate dropped to an average of 0.6 percent per year from 1950 to 1960 and to less than 0.1 percent per year from 1960 to 1970. In 1970 the population of the state stood at 977,000.

More important than the population statistics themselves are the reasons for the low growth rate. Average wage rates in Maine are significantly below the U.S. average in almost all categories of employment. For example, in 1970 the average annual gross wage for all manufacturing production workers in the United States stood at $6,736, whereas in Maine it was only $5,950. Per capita personal income in the United States in 1970 averaged $3,921, while the average in Maine was only $3,257. Unemployment in the state runs consistently higher than the national average. By numerous other measures, such as the number of doctors per 100,000 population, Maine is also below the average for the entire country.* These factors have combined to cause a large out-migration from the state, particularly of young adults in the 20-34 age bracket.

The fishing industry in the Gulf of Maine has a history of recurrent increases in the catch of a specific species followed by a reduction in the

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* In 1970 Maine had 131 doctors per 100,000 population; the national average was 171 doctors. (Statistical Abstract of the United States, 1972, Table 102.)

catch, a resulting drop in income, and a decline in fishing activity associated with that species. This pattern was first seen after technological innovations in canning and shipping methods greatly expanded accessible markets in the nineteenth century. The menhaden fishing industry grew during the 1860s and 1870s to become a multimillion-dollar operation, only to experience total failure when the menhaden suddenly disappeared from the region in 1878.

The lobster industry provides a more recent example of the same pattern, but the decline has moved at a slower pace, partly because the Maine legislature acted to guarantee the lobster's survival. Limits on the size of the lobsters taken were imposed, and the methods used to catch lobster were restricted. Reaching a peak catch of 24 million pounds of lobster in 1957, the industry is now experiencing a gradual decline. Only 18 million pounds were taken in 1970 in spite of increased activity. Rising prices reflect the growing shortage of this desirable product.

Overall, the American take from the Gulf of Maine is down dramatically from a peak of over 300 million pounds in the 1950s to less than half that in 1970. Competition from modern, efficient Russian and West German trawlers has been a prime cause of the present problem of severe overfishing. Restriction of the fishing activities in the area is now being negotiated, but the damage may already be irreparable.*

While a number of the citizens of Maine, like others in this country, tend to place great emphasis on statistical measures such as population growth rates and average wages, many State-of-Mainers are emphatic in saying that they live in Maine because it is free from the crowding, pollution, and general social pressures that characterize life in the big cities and rapidly growing regions of the country. They believe that the existing quality of life in Maine should be preserved regardless of anything else the state may do, and they are forceful in promoting this point of view.

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* The International Conference on North Atlantic Fisheries (ICNAF) has established quotas for the various nations fishing in the North Atlantic, but many observers question the effectiveness of this system.

CATALYSTS OF CHANGE

Despite the influence of preservation-minded groups, pressures for change are growing. Most of Maine's 3,000 miles of coastline are under private control. Shore frontage is now selling for $100 to $200 a foot as residents, out-of-staters, and land developers are buying it up. The coastline provides attractive sites for electric power plants because of the abundance of cold water for cooling. The consequent availability of cheap electric power, along with good ocean transportation, makes feasible the operation of facilities for aluminum reduction and for recovering magnesium from seawater.

Some very interesting work by several groups in the United States and abroad is under way in the field of fish farming, or aquaculture. The Japanese have farmed the sea for many centuries, and such efforts may hold considerable potential for Maine. This is especially true if it is shown that aquaculture operations can be effectively coupled with electric generating plants, using the thermal discharge from the plant to enhance fish growth.

Increasing demand for oil has focused attention both on the possibility of developing deep-water ports in Maine to accommodate tankers loaded with foreign oil and on the possibility that the coastal waters off New England may themselves contain significant oil deposits.

Of the New England states, only Maine has sheltered harbors sufficiently deep to handle tankers drawing more than 80 feet of water. Machiasport is an example of such a natural harbor. Recently, a $150 million, 300,000 bbl/day oil refinery was proposed for the area, to provide some relief to oil consumers in the Northeast. This proposal has proved to be a touchy issue. A 40,000-gallon oil spill near Portland in the summer of 1972 served to reinforce the belief of conservationists that the potential for an ecological disaster represented by an operating refinery would nullify the economic benefits of the refinery to the state and to the New England region (New York Times Index, July 16-31, 1972).

Although the existence of offshore oil deposits is not yet confirmed, a number of issues related to them have already arisen. Plans for seismic exploration and exploratory drilling have raised storms of protest from fisherman and environmentalists. If exploration proceeds and oil finds occur outside the territorial limits of the United States, as is very likely, questions will arise at the international level -- who will have rights to the oil?

Increasing demand for coastal recreation areas has magnified the problems of compatible land use. People come to the Maine coast because of the attractiveness of the area. But as more people come, facilities to accommodate them must be built. These in turn attract more visitors. Eventually, crowding and uncontrolled development will become a significant problem.

People whose livelihood depends on the tourist trade are among those most strongly opposed to anything having to do with oil. They fear that the attractiveness of the area will decrease appreciably if oil is discovered or if refineries are built.

THE NEED FOR PLANNING

A publication entitled A Maine Manifesto (Barringer, 1972) voices a concern that Maine people are expressing more and more often:

> Maine is at a crossroads. . . . Its economy is in the throes of change, and the effects are felt. . . in every aspect of what has come to be valued as the distinctive and proud Maine way of life.

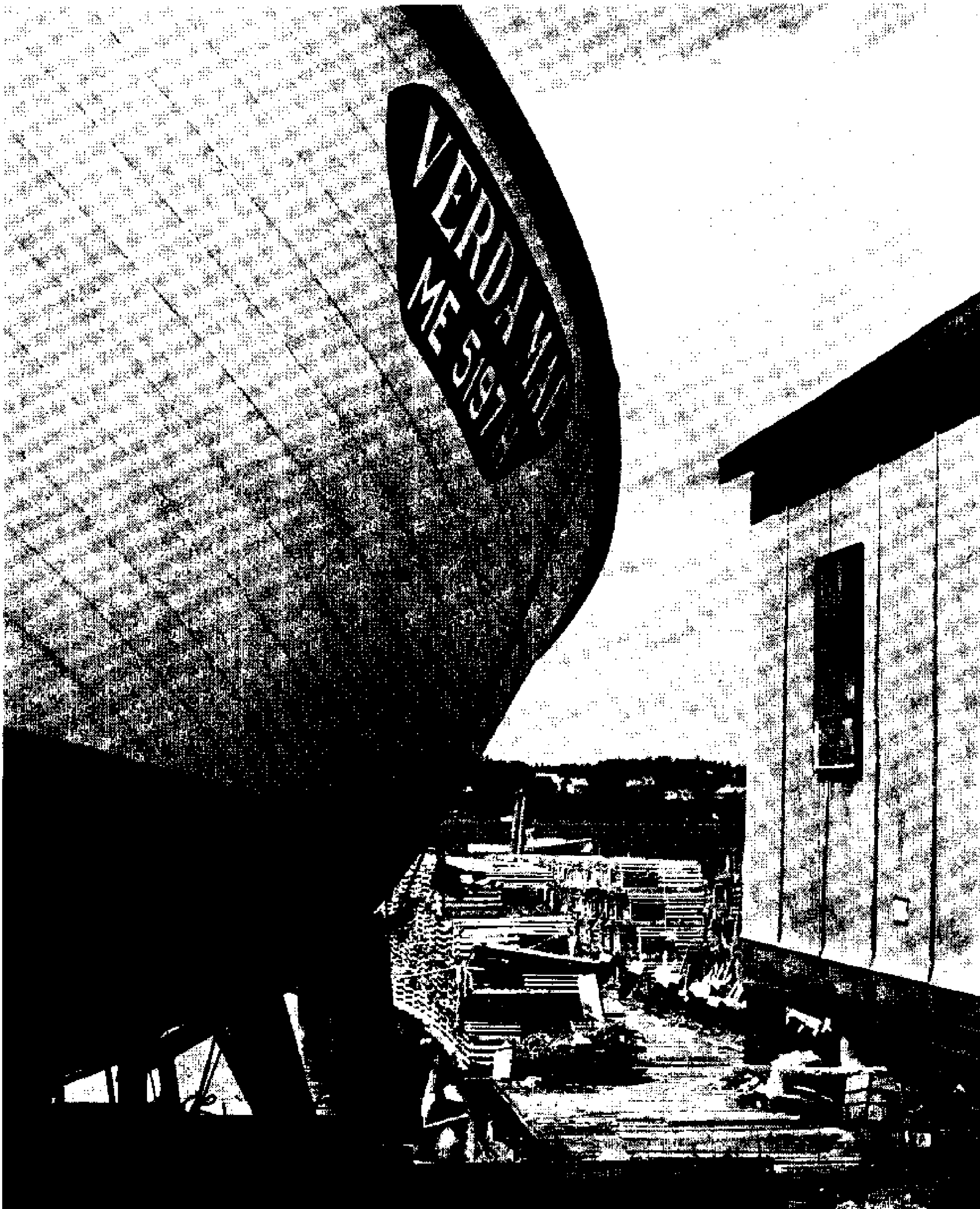
An obvious question is raised: What, if anything, should Maine do to deal with change? In what direction should the state of Maine proceed from the so-called crossroads?

A number of different proposals have been put forward for guiding the state in this period. However, it is difficult to appraise the full effects of many of these proposals before they are implemented. Do the solutions answer immediate needs and neglect other, more subtle ones? What effects will they have in ten years? Which options do they cancel and which are left open or are created?

The State Planning Office is examining some of the alternatives, but a long-range study is urgently needed. The implications of technically oriented development represented by oil refineries and combined power-and-aquaculture facilities must be looked into and evaluated in terms of the economy and quality of life in the state and in the New England region.

It is hoped that insight into these problems and sounder policy judgments will be gained from the development and use of the techniques described in the remainder of this book.

Part II THE DEVELOPMENT MODEL



Chapter 3 THE USES OF MODELS

As hard as technological systems may be to understand, they lend themselves to rigorous study much more easily than do social systems. Qualitative elements compound problems associated with the formidable tasks of planning and understanding the implications of policies meant to guide the social system. However, in spite of analytic difficulties, it is becoming increasingly important that these tasks be undertaken.

For all their good intentions, government planners and legislators often have a sense of futility about planning because, in many cases, programs they initiate do not produce the impacts they expect. In some cases, a program may even aggravate the problems it was supposed to alleviate. With the ever-increasing complexity of our society, is it not reasonable to pursue a methodology that can lead to a better basic understanding of the effects of social and economic policies and can result in efficiency and facility in guiding the system?

Models have been used for many years in high-technology disciplines and have provided useful insights into systems studied. A complex system with large numbers of interdependencies can be studied so as to yield a working knowledge of the system, sometimes even before the system actually exists. Thus, many of the surprises usually associated with implementing a new procedure may be anticipated and possibly compensated for by changing the proposed procedure before it is put into effect. Potential weaknesses can be identified before they turn into full-blown disasters.

And so it should be with social systems.

To be sure, the modeling of social systems is not an exact science. Many situations will arise in which the details of interactions, especially those involving the human element, will defy exact representation. Also, there is no guarantee that, even if specification inaccuracies can be overcome, the model will indicate a real and practical solution to the problem. Nevertheless, when used correctly, modeling can be a tool of great value.

We are at a point in our society at which problems are so complex that by judiciously choosing a given set of assumptions about a system (all of which are reasonable ones), we can obtain practically any conclusion as to the impact of a policy. People within their own "universe of assumptions" may be perfectly correct in drawing the conclusions they are presenting, but these justifiable conclusions will be of little help in a discussion with another person holding a different point of view, one that is also perfectly justified -- but by different premises. One definite asset of the modeling technique is that it requires people to talk about their assumptions. Once these are agreed upon, the people can then progress to conclusions.

Moving the arena of initial debate from conclusions to assumptions does not necessarily produce an atmosphere in which a single point of view prevails. However, it directs the main thrust of analysis to central aspects of the system itself. Modeling draws on people's abilities to perceive correctly the parts of the system. It then provides an efficient notation for remembering large quantities of detail. Finally, it offers a quick means of testing alternative strategies or assumptions.

Properly constructed, a fully developed model ensures that no important aspect of the dynamics of a system will be overlooked in the evaluation process (a constant pitfall when a complex system exists only in the mind). Useful debate on assumptions about the workings of the system is facilitated because the people involved can physically refer to a particular component of the written model rather than citing a mental image that may or may not correspond to the image in another person's mind. Thus, part of the value of a written model comes from its thoroughness and concreteness.

The process of creating a model may prove to be as valuable as the finished model itself. Because of the specificity and completeness the creation requires, it increases people's understanding of the system under study.

A model does not in any way lessen human responsibility for making decisions that affect the system, nor does it free the policy-maker from the responsibility of careful analysis. Rather, it is a tool to enable the policy-maker to comprehend the total environment of a problem and test alternative strategies designed to cope with it.* It should be considered only an aid to, not a substitute for, the decision-making process.

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* For this discussion it is assumed that the task of guiding a specific portion of a social system has been given to policy-makers. They create or are given a set of goals, and the word "problem" refers to the necessity of getting the system to react so as to meet these goals.

Chapter 4 SIMPLE MODELS

Modeling is not a new concept to most of us. For example, the static mental image of the layout of a city that helps us navigate from place to place is a model. We call upon a simple dynamic model when deciding to fill our car gas tank upon seeing that the gauge is fast approaching Empty. A projection is made, using prior knowledge of the way in which cars operate. It tells us that if we continue to drive without refueling we might arrive at our destination on foot.

TWO APPROACHES TO MODELING

Traditionally, there have been two methodologies for approaching the modeling task. In the first, the model is obtained by drawing on past or present experience with similar systems, making whatever changes are necessary to reflect the new situation. In the second, an entirely new approach is used to isolate and model the system. Because of the scarcity of good models of social systems, almost any new endeavor in this field has to be of the second type.

To be useful a model must contain a theory of behavior. The model should parallel the internal workings of the actual system; at the same time it must incorporate our perceptions of that system. We should be able to interpret experiences in terms of the model.

A good model does not necessarily result simply from an attempt to create it. Inaccuracies in the perception of experiences and in the transformation of them into model relationships can thwart the endeavor. Much care must be taken to enusre that the model has an actual resemblance to the real system.

MODELING A DRAINABLE RESERVOIR SYSTEM

As an introduction to modeling technique, let us look at a simple system that can be easily modeled -- a reservoir being filled by water at a variable rate (figure 4.1).

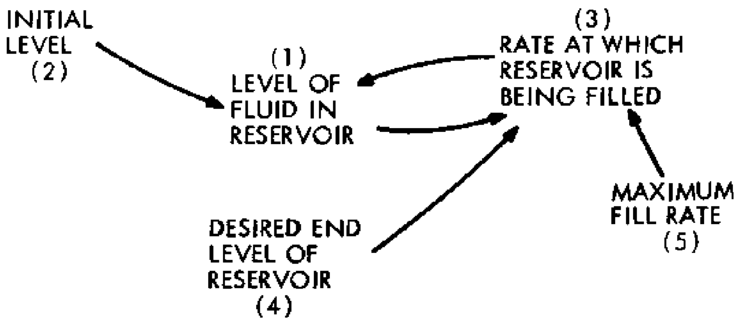

FIGURE 4.1. Reservoir System With Variable Fill Rate

If the flow of water is inversely related to the level of water in the reservoir, then, as the height of the water in the reservoir increases, the rate at which the valve allows more fluid to enter decreases. When the desired water level is reached, the valve will cut off flow completely. This is a system we encounter daily; it is the one that operates in a toilet tank.

The system can be expressed in a computer language. In this case, DYNAMO, a systems-oriented computer language developed at M.I.T. (Pugh, 1970), has been used. The DYNAMO flow diagram for the system appears in figure 4.2. In equation form this model appears as follows:*

(1) L LEVELR.K=LEVELR.J +(DT) (RATEFIL.JK)	reservoir level
(2) N LEVELR=0	initial level of reservoir
(3) R RATEFIL.KL=(CUTOFF-LEVELR.K) (MAXRATE)	water flow rate

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* See Appendix D.

(4) C CUTOFF = 1 desired level

(5) C MAXRATE=.20 maximum flow rate

The equations indicate that the reservoir (1)* initially has no fluid in it (2). For any time thereafter, the rate at which fluid is being added (3) is determined by the difference between the eventual desired level of the reservoir

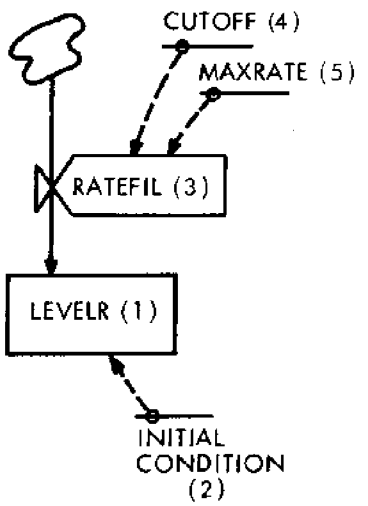

FIGURE 4.2. DYNAMO Flow Diagram of Reservoir System

(4) and the present level (1), multiplied by the maximum rate at which the valve is able to fill the reservoir (5).

A graph of the dynamics of this set of equations appears in figure 4.3. The system reacts as expected: the flow rate drops and finally stops altogether as the water in the reservoir rises to reach the desired level.

We might want to determine the dynamic changes that will occur if the value of one of the model parameters changes. Figure 4.4 presents the case in which the maximum fill rate (5) is reduced. The reservoir fills more slowly than in the original case because of the lower flow capactiy of the valve.

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* Numbers in parentheses are the equation numbers.

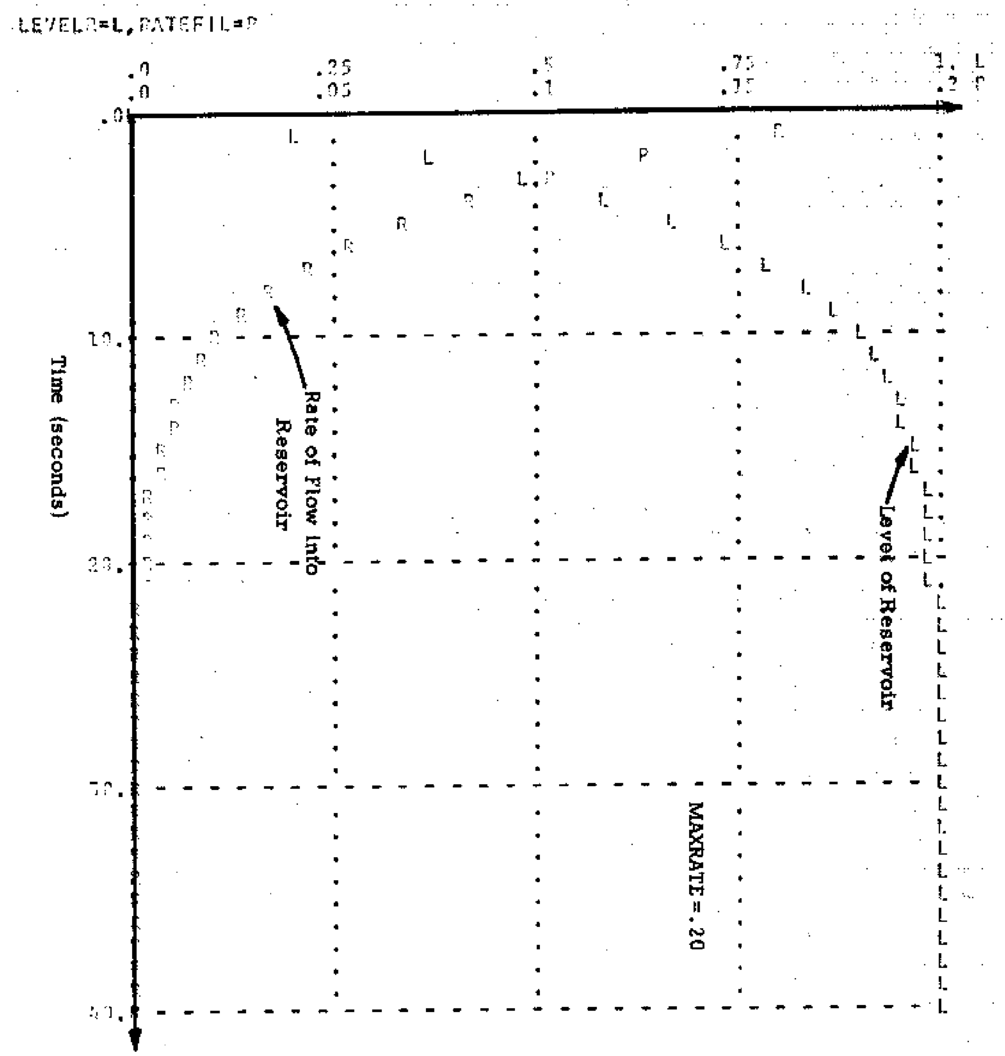

FIGURE 4. 3. Reservoir Filling at Maximum Rate

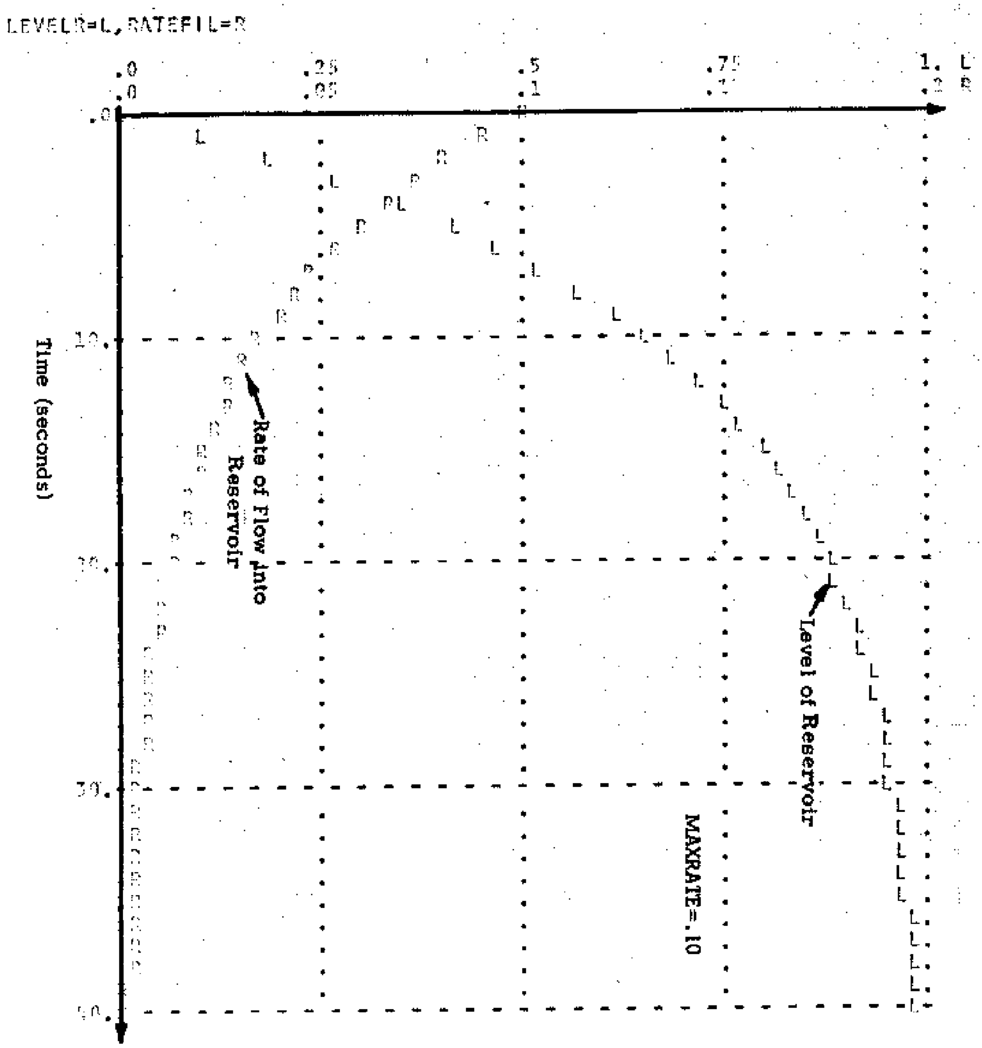

FIGURE 4.4. Reservoir Filling at Reduced Rate

For this simple system it is easy to predict how a parameter change would affect the system's normal dynamics. However, predicting the effects of modifications in a complex system is a formidable task. It is difficult enough even to determine how the system would react given the original parameter.

A SIMPLE POLICY MODEL

The reservoir model is easy to understand. It represents a readily observable physical system with relatively few modes of operation. We know by experience how it will act.

Figure 4.5 goes a step beyond the model of a physical system and presents the interrelationships of a structure common to many social systems. This model states that, in addition to being affected by births and deaths, the

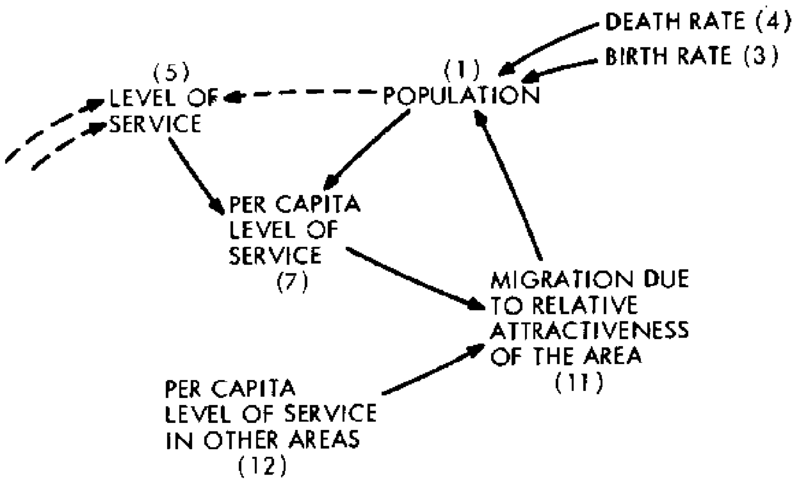

FIGURE 4.5. A Simple Policy Model

number of people in a given area is a function of how desirable that area is relative to others in terms of the level of service per capita. The relative levels of the particular service under study determine the incentive for people to move from one place to another. (In a more typical situation, of course, there would be many variables influencing the migration factor and making it hard to isolate the effects of any one. These complications have been ignored for the sake of this illustration.)

While the level of the service may be in part determined by population characteristics and other factors (represented by the dotted lines in figure 4.5), it has been chosen as the policy variable for this limited system. In order to influence the system, we will control that variable. The flow diagram appears in figure 4.6.

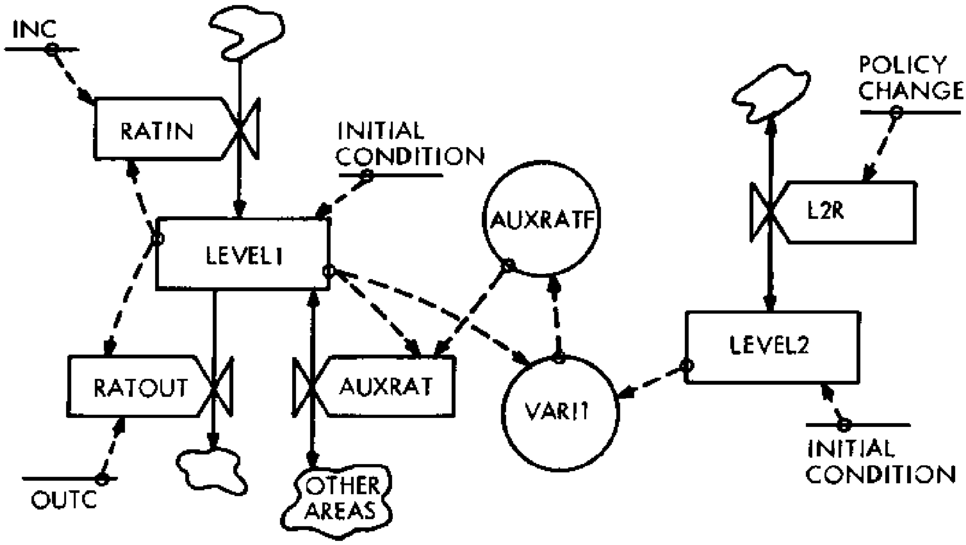

FIGURE 4.6. Flow Diagram of Policy Model

Expressed in equations, this model takes the following form:

(1) L LEVEL1.K=LEVEL1.J+(DT) (RATIN.JK-RATOUT.JK+AUXRAT.JK)	population
(2) N LEVEL1=10000	initial condition for population
(3) R RATIN.KL=(INC) (LEVEL1.K)	birth rate
(4) R RATOUT.KL=(OUTC) (LEVEL1.K)	death rate
(5) L LEVEL2.K=LEVEL2.J+(DT) (L2R.JK)	service expenses
(6) N LEVEL2=10E6	initial condition of service expenses
(7) A VARI1.K=LEVEL2.K/LEVEL1.K	per capita service expenses
(8) R AUXRAT.KL=(AUXRATF.K) (LEVEL1.K)	migration rate
(9) C INC=.02	in-migration rate
(10) C OUTC=102	out-migration rate

```
(11) A AUXRATF.K=TABHL (ARFT, VARI1.K        migration
     500,1500,100)
(12) T ARFT= -.30/-.16/-.08/-.04/-.02/0/
     .02/.04/.08/.16/.30
(13) R L2R.KL=TABHL (L2RT1, TIME.K, 5, 6, 1)
     +TABHL (L2RT2, TIME.K, 6, 7, 1)
(14) T L2RT1=0/2E6
                                             increase in service
(15) T L2RT2=0/-2E6
```

Implied in the choice of values for the parameters expressed in the equations are the following assumptions:

1. The initial number of people in the area is 10,000 (2).

2. Both the birth and death rates equal 20 per thousand population (9) and (10). (This assumption is made so that the resulting equilibrium condition allows for easy analysis of the effects of changing the service expenses.)

3. The initial level of service expenses is $10 million per year (6).

4. As an attempt is made to raise the per capita level of service, expenses jump to $12 million per year in year 5.

5. Migration (12) is determined from the schedule represented in figure 4.7. The three curves shown in figure 4.7 represent the per capital level of service elsewhere as being higher than, the same as, or lower than that of the area under study. At the point at which the curves cross the horizontal axis, there is no migration (in or out) as these values represent equilibrium conditions. Deviations from the equilibrium cause population movements. For the C1 curve, equilibrium is reached at A. A jump in service expenditures in the prime area results in the move to B, where an in-migration is generated (C) as people shift to the more desirable area. The opposite dynamics would hold if the other area raised its per capita level of service relative to the prime area (C1 → C2).

It should be clear from this model that if the system moves out of a state of equilibrium the dynamics of the system act to bring it back into balance. The result is that, while there is a short-term benefit from trying to raise the standard of living in an area by increasing service expenditures, the long-term benefits are nullified by a resulting shift in population.

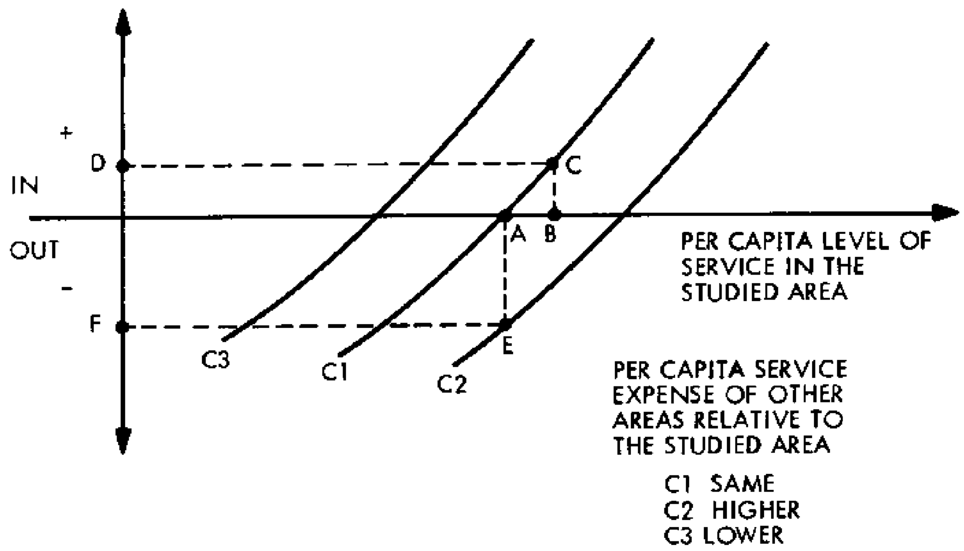

FIGURE 4.7. Three Levels of Per Capita Service

Figures 4.8, 4.9, and 4.10 represent the effects of implementing the policy of increasing per capita service in the studied area. Different initial conditions are assumed, reflecting three possible relative levels of service (higher than, the same as, or lower than elsewhere). The basic equilibrium-seeking tendency is common to all three situations.

The first case begins with the system in equilibrium. The attractiveness of the prime area and that of the "other" area are identical. During the fifth year, services are increased. They take effect the next year, as the per capita level of service immediately jumps to a much higher level. In time, however, it undergoes rapid deterioration, returning to the original level as the population adjusts (figure 4.8).

The second and third cases do not begin in equilibrium. Figure 4.9 represents the second case, in which the "other" area's per capita level of service is initially lower than that of the studied area. The dynamics exhibited in the first case are superimposed on the trend toward equilibrium from the initial imbalance. Case three assumes the opposite initial condition and is represented in figure 4.10.

These models show us that what initially appeared to be a good idea for helping the region turns out to have little long-term effect. Eventually, each person is left with the level of service he started with. And the burden on the area to supply services is increased because there are more people in the area to service.

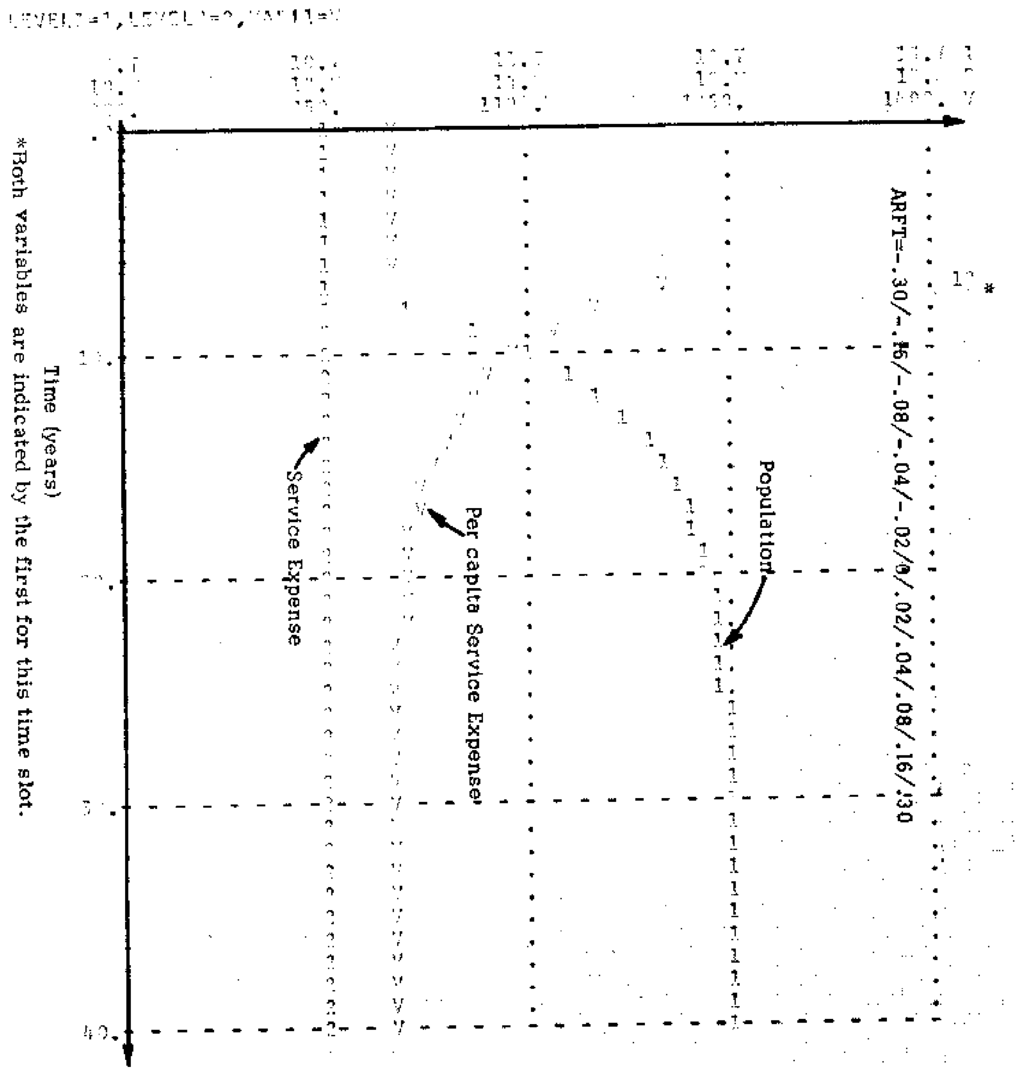

FIGURE 4. 8. Effects of Sudden Increase in Per Capita Service (Attractiveness Level of Both Areas Identical)

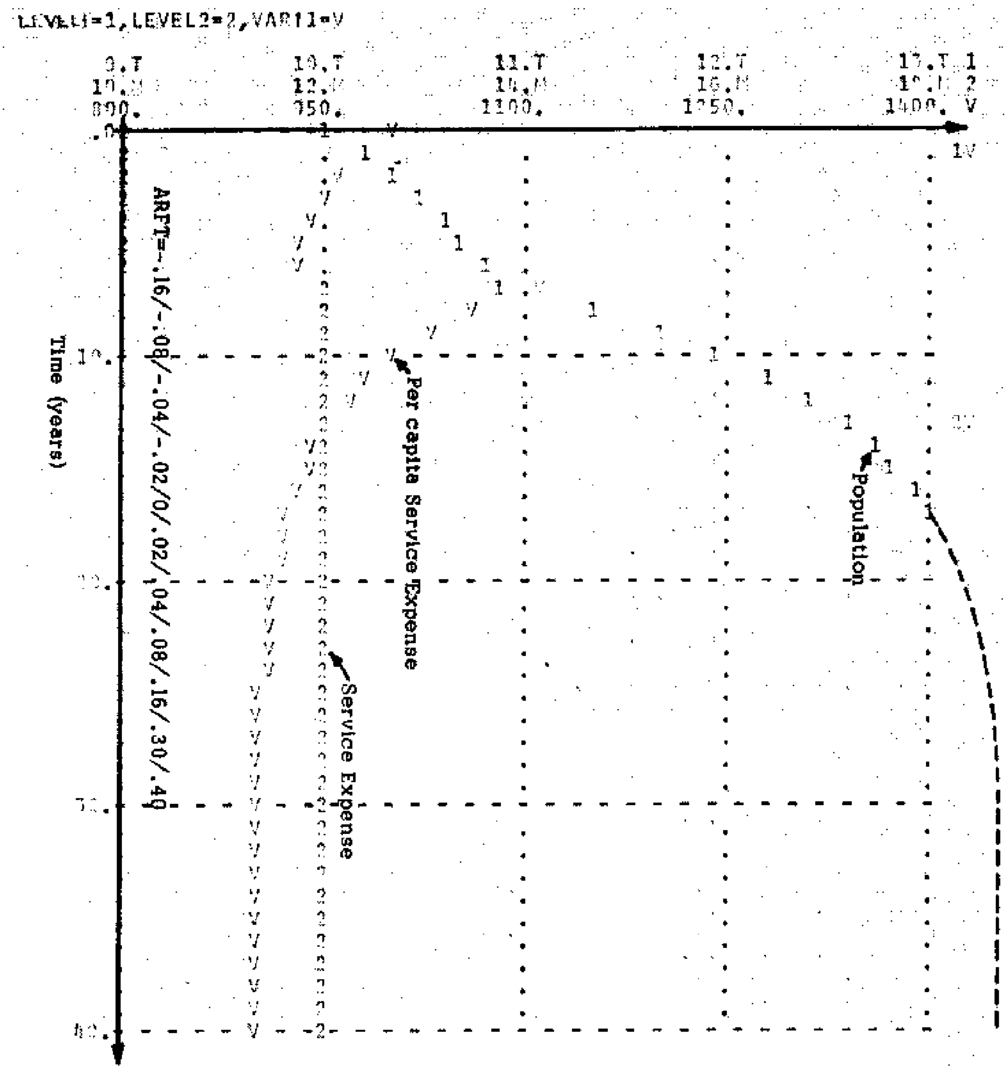

FIGURE 4.9. Effects of Sudden Increase in Per Capita Service ("Other" Area Less Attractive Initially)

FURTHER USES OF THE SIMPLE POLICY MODEL

What can be learned from the simple policy model? The dynamics exhibited in figures 4.8, 4.9, and 4.10 indicate that an immediate change in the level of service causes an initial per capita increase in that service, followed by a rapid decrease to the original level. The question at this point is, What policy will improve the per capita level of service on a long-term basis?

In analyzing how the system reacts to increasing the service expenses

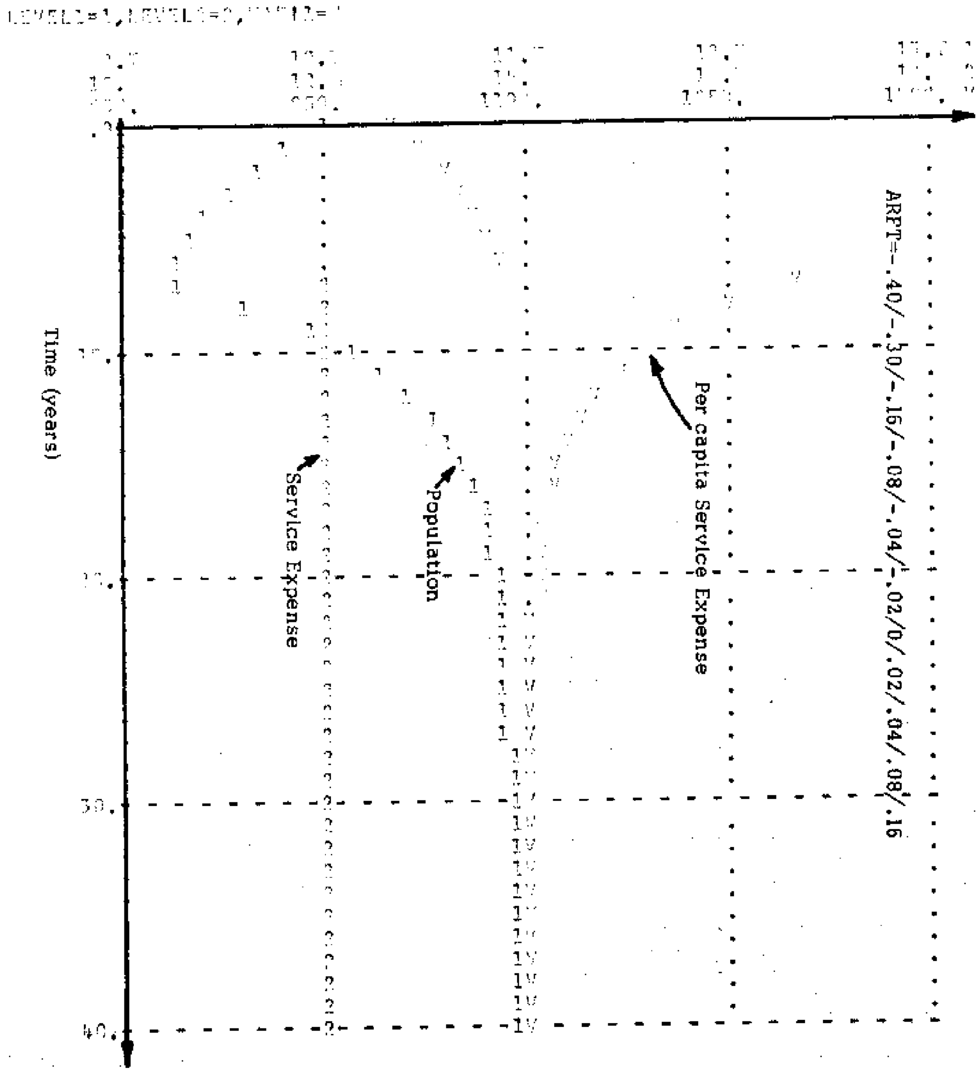

FIGURE 4.10. Effects of Sudden Increase in Per Capita Service (Studied Area Less Attractive Initially)

in the area it would be easy simply to stipulate that no adjustment in variables of the services would be allowed -- that is, to assume that the effects of a change in service are independent of other factors in the system. But such a move would do little for creating a useful model or an accurate understanding of the actual system. When building the model, care must be taken to prevent any self-fulfilling prophecy from replacing the true structure of the system. Otherwise misleading information about the dynamics of the system will result.

In the case under consideration, let us assume that rather than instituting an immediate increase in service, a gradual increase takes place over a number of years. Gradually stepping up the amount of increase and avoiding the large, sudden jump in per capita service also avoid the accompanying quick adjustment to the change. Figure 4.11 shows the effects of inputing one-tenth of the total increase in each of ten successive years. Note that the per capita level of service does not reach as high a peak as in the case shown in figure 4.8, but that the effects of the change cause a temporarily stable condition at B.

If extended, this policy would eventually lose its impact because of the particular parameters of the model. Migration is measured as a fraction of the present level of population. Therefore, as migration increases, the number of people migrating as a result of a given differential in services also increases. Because the fixed-value rise in service has less effect on a per capita basis when spread over a larger number of people, the policy loses its efficiency.

A modified program that would compensate for increasingly faster adjustment in population by migration could sustain the higher level of service. Figure 4.12 shows the effects of a policy that increases service at a fixed <u>percentage</u> of the existing level of service each year for two years. Because this function grows at a rate that matches the population's ability to adjust, it is able to stay ahead of the pressures working to bring the system back into equilibrium.

For the same magnitude of increase used in the example in the preceding section, the results of this policy are almost identical to those of the gradual fixed-increment policy. But if this policy is continued, its effects do not diminish with time. The policy does, however, demand increasing service expenses at an accelerating rate in order to sustain the higher per capita level of service.

Even the simple policy model can exhibit many modes of behavior. Had just one more loop been included in the original formulation (e.g., the

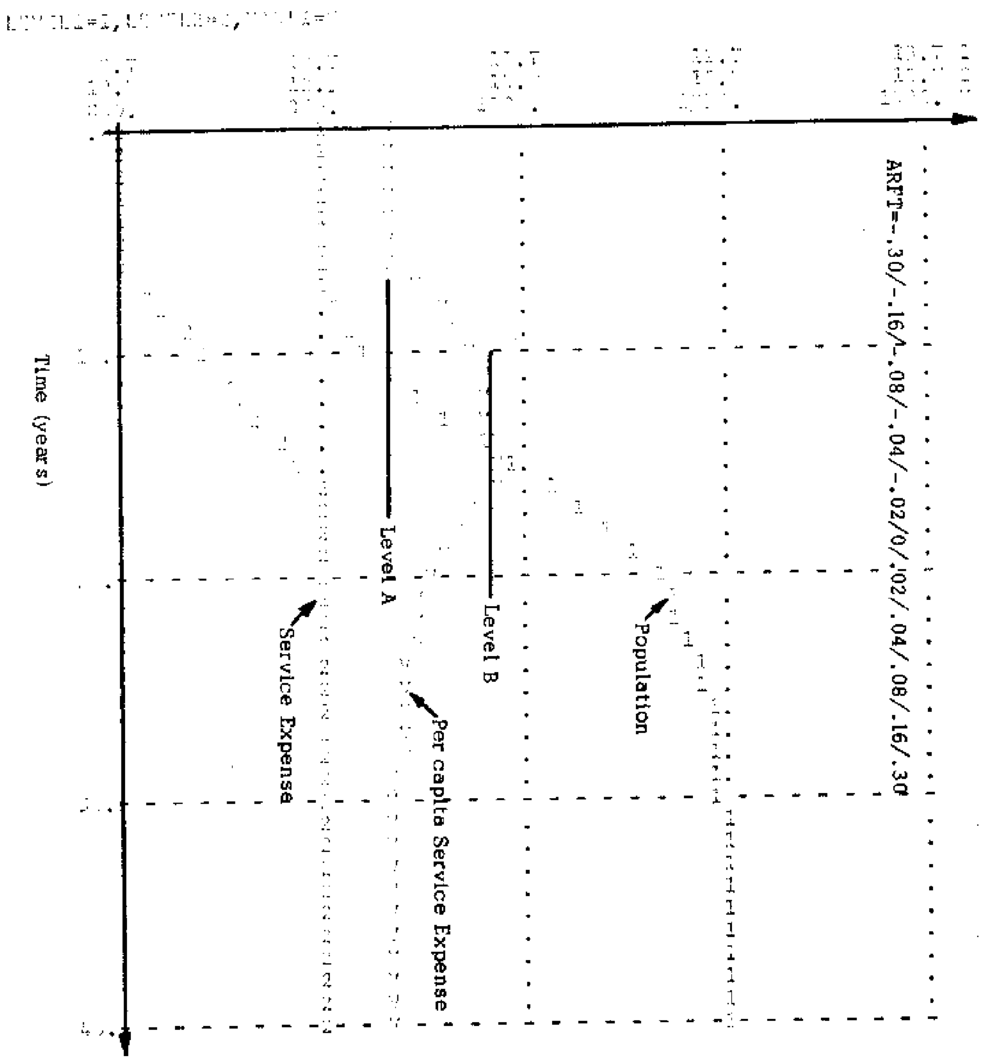

FIGURE 4.11. Effects of Gradual Increase in Per Capita Service

relationship suggested by the dotted line between population and level of service in figure 4.5), the system's dynamics would have become noticeably more complex. Interaction between the two loops would have greatly expanded the repertoire of possible patterns of behavior.

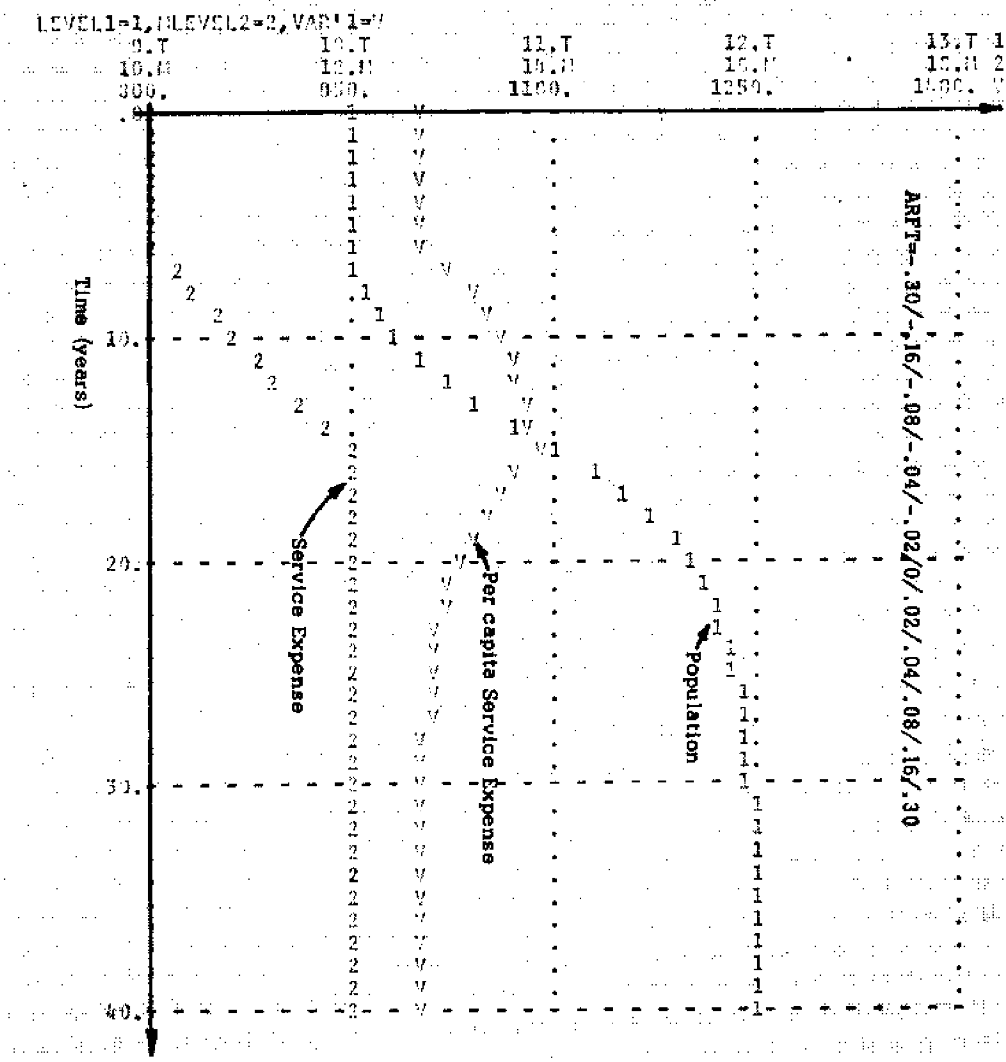

FIGURE 4.12. Effects of Fixed Percentage Increase in Per Capita Service

Fully specifying a useful subsection of a social system could easily lead to a model with a hundred or more interacting loops. It is for no small reason then that a real system is hard to understand completely. Thus the value of model-building -- of being able to carefully specify each assumption, to include it in a model, and to know that its effects will not be overlooked in an analysis -- should be apparent.

Chapter 5 ISSUES IN MODELING

Simulation models allow us to observe a system in detail. A good model includes all relevant factors pertaining to the dynamics of the system in question. By clarifying and specifying the dynamics of a system to the extent that a thorough analysis of it can be performed, we can improve the decision-making process.

As a predictive tool a good model provides a way of anticipating the effects of both policy decisions and unexpected events. Without having to jeopardize the real system in an experiment, a model permits an explicit formulation of cause/effect relationships and allows a thorough study of a system's behavior.

INITIAL CONCERNS

The basic question to ask when deciding whether or not to create a model is, Is there a definite need for the model? For the case in which the system is too complex to be fully understood by the unassisted human mind, a positive answer may result, but first, the evaluation of whether or not to initiate a modeling effort should consider the following additional questions:

1. Will the benefits to be gained from the development and use of the model outweigh the associated costs (staff time, computer time, possible problems associated with postponing a decision until after the model is ready)?

2. Who will be charged with the task of creating the model? Should outside experts be hired to perform all or part of the task?
3. Will the knowledge of the system that the model can provide be enough to justify the effort expended in developing it?
4. What level of credibility and support will be given to the model? Is its development busywork or a serious study?
5. If the model that is developed indicates that changes should be made in policies, will these changes in fact be likely to occur?

For the model to be most useful, the decision-makers themselves should be part of the modeling process. Otherwise a vital bridge between development and use of the model will be lost. However, the tendency to base the model on predetermined or unexamined assumptions is a common one when all the model-makers are close to the system under study. Therefore, outside help should be considered. Out-of-house talent can often provide an unbiased translation of the knowledge of those familiar with the system.

Once the model is believed to be conceptually sound, a decision as to whether or not it should be quantified must be made. Formulation of the set of cause/effect relationships may be the natural stopping point of the process. Exactly specifying each relationship, programming the model, and running it on a computer may cost more than the additional benefits are worth. The final specification of the model is an involved process that sometimes seems deceptively easy.

A computer is not essential to the modeling process in the strictest sense, but it is the vehicle that makes using the finished model practical. For example, the model of Washington County, Maine, presented in this book requires approximately 15,000 calculations for each run. The computer processes them in a matter of seconds and without error. It allows a policy to be inputed, processed, outputed, and analyzed quickly.

CHARACTERISTICS OF MODELS

The form of models varies. The amount of detail necessary for one model could be fatally burdensome for another. The choice among other options, such as how the model will handle uncertainty and whether time series or causal representation will be used, depends on the characteristics of the system and the purpose of the study.

Levels of Aggregation

The level of aggregation used in a model -- that is, the degree to which data are grouped in manageable categories -- depends on the complexity of both the system and the larger setting with which it interacts. In the reservoir model described earlier, it would have been entirely possible to look at the system in much finer detail, but carrying out the analysis would have required considerable additional effort. In that particular case, the detail would not necessarily have led to a better answer to the question being asked, which was, How does the system as a whole work?

Matching the level of aggregation to the task is important. With a low level of aggregation, the cost of gathering and analyzing the extra detail may not be worth the extra accuracy theoretically gained. The danger of being too highly aggregated is that important aspects of a system might be overlooked.

The model in the study The Limits to Growth (Meadows et al., 1972) is very highly aggregated, so that the macrodynamics of the whole world can be simulated. This level of aggregation is appropriate because the concern of the study is the fundamental support capabilities of the earth. The model uses aggregate figures of (1) the world's resources and (2) the demands placed upon these by a growing number of people and an increasing per capita consumption. In some respects, this level of aggregation resembles that used in the reservoir model.

Had Meadows needed greater detail in order, say, to determine the effects of population growth on the air quality of any one nation, she would have had to move to a much lower level of aggregation. In terms of the reservoir model, this would have been like incorporating in the model the flow characteristics of the pipe network used to transport water in and out of the reservoir.

Continuing even further in this direction, Meadows could have chosen to structure her model to show how individual people are affected by growth.

This effort would have been similar to taking into account the movement of individual water molecules as they exist in the reservoir system. Certainly, describing the general operating characteristics of a system in such detail would be very costly. However, sometimes the task given to the model-builder requires a less aggregated approach.

In a model based on completely disaggregated data, the effects of microlevel events are enhanced. Because of the unpredictability of these individual events, it is difficult to derive from the model a correct indication of the likely future behavior of the system. In a more highly aggregated model the effect of an extreme microlevel event is averaged in with the effects of other discrete events, and the combined effect on the system becomes much more reliably predictable.

Time-Series and Causal Models

Models are of two basic types: time-series and causal. Both are formalizations of qualitative models resulting from an accumulation of expert opinions and judgments.

A time-series model allows us to make predictions of the future by an extrapolation of past behavior. This method assumes that short-term trends will not markedly differ from those of the recent past.

A major limitation of time-series analysis is that new events or relationships within the system cannot be analyzed. For example, a change in a critical variable of the system would change the dynamics of the system. The question of how this change would manifest itself, however, could not be answered by the time-series model. A more powerful technique is needed to perform this task.

Causal models allow us to introduce change into a system and still derive useful information about its probable future behavior. By specifying the cause/effect relationships that determine the dynamics of the system, we can understand how trends are generated and how they are altered if the system structure is changed or a variable is modified.

The causal model may incorporate time-series analysis in its development. For example, regression analysis of historical data can provide useful information on relationship strength and parameter values. It is entirely possible, however, that the form of a given relationship in a time-series model will differ from its counterpart in the causal model. Care must be taken to handle the data appropriately so that the true cause/effect relationships are accurately reflected.

A time-series model will possibly outperform a causal model in making short-term predictions. Short-term behavior is particularly sensitive to present conditions and direction of change. The causal model concerns itself with larger relationships. While possibly giving less accurate predictions for the near future or for systems experiencing little change, this model allows for behavior outside the narrow range of present activity.

Deterministic and Probabilistic Models

The manner of handling uncertainty in the model is another important issue. Two basic methods are available, the deterministic and the probabilistic.

In the deterministic method, all parameters are known with certainty or are assumed to be known with certainty. For example, the tax rate for a given condition is, say, 20 percent.

In the probabilistic method the values of parameters are given as a distribution or range of possible values, any one of which could be chosen at any time. This procedure is followed because of problems associated with trying to specify exactly the parameter or because of its inherent variability. As an illustration , assume that a tanker has been unloading oil every day for a hundred days. During those hundred days the following observations were made:

1. On 40 days no spills occurred.
2. On 35 days 20 barrels of oil were spilled.
3. On 25 days 100 barrels were spilled.
4. On 4 days 1,000 barrels were spilled.
5. On 1 day 10,000 barrels were spilled.

What is the expected oil spill for the next day of operation? Anywhere from no barrels to 10,000 barrels have been spilled under similar circumstances, and there is no reason to believe that such behavior will not continue. Therefore we would use the distribution above to predict a .40 chance of no spill, and so on. Note, however, that had the measurement period been ten years rather than only a hundred days, an average value for expected spills might have sufficed. Short-term fluctuations would have been masked by aggregation of data.

Each method of handling uncertainty has its strong and weak points. The choice of which to use is once again determined by the nature of the modeling task.

Because of the exactness with which it specifies parameters and the control it provides over condition changes in the model, the deterministic technique facilitates the process of identifying critical factors in the system by sensitivity analysis. It allows us to vary one or more parameters while keeping all others constant so that the effects of the changes can be isolated and studied. The areas most affected by the changes can then be easily identified.

Problems arise with this method when the model has a large number of parameters. A complete sensitivity analysis would require checking all the combinations of variations in parameters, an enormous task since the number of these combinations would be growing at an exponential rate. Thus, even for a medium-sized model it is practically impossible to do a complete analysis. Careful thought must be given to the choice of those changes and combinations of changes in parameter values that will be included in the sensitivity analysis. The aim is to be as thorough as possible while at the same time to reduce the task to a practical size.

A major drawback of the deterministic approach is that, if there is uncertainty in the values of parameters, it does not easily provide a sense of the normal operating characteristics of the system. It is, of course, possible to run the model for a specified set of parameter values and for specified changes in that set. However, the model contains no information as to how changes or deviations from the most likely values would combine in the system and interact with one another.

Probabilistic modeling solves many of these difficulties. Through the handling of uncertainty, we are able to combine variations in all parameters simultaneously to determine how they might exist together in real time. This affords the opportunity to view the range of normal modes of operation of the system.

These advantages are not gained without costs, though. Understanding how the system is affected by change in the probability distribution of a parameter is much more difficult than understanding parameter-value changes in a deterministic model. As a result, information from a sensitivity analysis is obscured, and studying policy change is not as straightforward a procedure. Also, significantly more computer time may be required to run the probabilistic model. Many trials are needed to complete one run of this kind of model, with each trial requiring the same order of magnitude of computations as a single run of the deterministic model.

Perhaps the best approach to studying a social system would be to develop a model that could be used both deterministically and probabilistically. A sensitivity analysis could be performed using the deterministic approach. Also, an initial analysis of the effects of a policy change could be made. Once a good background of knowledge about the system (sensitive relationships, effective policies, and such) was established, the probabilistic approach could be used to study the operating characteristics of the system under conditions of uncertainty. Drawing on knowledge derived from the deterministic study, the model system could be modified to see if the normal operating characteristics would be significantly affected by any changes that actually could be made in the real system.

MAINE2

The model called MAINE2 was developed at M.I.T. as a concrete illustration of how a practical model can be created and used in the policy-making process. It is particularly designed to answer questions about the impacts of an oil refinery actually proposed for construction at Machiasport, Maine.

The nature of the task required a causal model. A model of this type permits study of the consequences of new conditions in a system and, in particular, the consequences of such exogenous events or policy changes as might be associated with constructing and operating an oil refinery.

The level of aggregation chosen for this formulation was that of county statistics (e.g., Washington County population statistics are the basis for the demographic sector). Business, government, and environmental concerns were also included at a matching level.

Only the deterministic technique was developed. While a combined approach, exploring both deterministic and probabilistic formulations might be desirable, most of the ideas about modeling that we wished to illustrate can be brought out by MAINE2 in its present form.

Chapter 6 THE MODEL-BUILDING PROCESS

INITIAL SPECIFICATIONS

A modeling effort is more likely to be successful in a supportive environment than in an antagonistic one. Another important characteristic of the atmosphere in which the modeling process occurs is belief in the value of the technique. A perceived need for a model is also essential, so that the building process does not become a useless exercise.

As we have said, when beginning the modeling effort, the first question to ask is, What is the purpose of the model? Included in the answer should be information describing the intended scope, precision, and use of the final product. Whether or not there is a need to computerize the model should also be decided.

The choice between a time-series and a causal representation of the system must be made. The primary purpose of the model will dictate which method to use. A time-series model will suffice for trend extrapolation; however, a causal model must be used if new policies or events are to be examined.

The basis for the model is a conceptual framework that roughly describes the relationships generating the dynamics of the system. It becomes a working platform from which the following considerations are addressed:

1. Time frame. What is the period of time that the model will represent? A century? A week?

2. Level of aggregation. Does this model address global or microlevel concerns?
3. Method of handling uncertainty. Will a deterministic, a probabilistic, or a combined approach be most useful?

By this time the model-builder should be able to estimate the amount of effort that will be needed to complete the study. Research, development, testing, and implementation requirements for both personnel and the computer enter into this estimate. Matching these requirements against the set of internal constraints, such as the time and money available, will point to a strategy for the future. If it is determined that the benefits of the model are not worth as much as the model will cost, there is little reason to proceed.

DEVELOPMENT TASKS

Central to the modeling process is the specification of system relationships and parameters. The model-builder should describe in words each of the components that are important to the system and how they interrelate An objective of the modeling effort is to get the people concerned with the issue under study to agree on the set of assumptions on which their conclusions are based. If there is disagreement among these people about a component of the system, the matter should be talked out until a specification can be agreed upon. Only if this step is followed can the model-builders avoid the common problem of getting different conclusions from the "same" assumptions.

Figure 6.1 illustrates how a model might look at this stage of development. It represents a car being driven to a particular destination. The car is influenced in its environment by three operator-controlled variables as well as by external variables generated by the road and other traffic.

The gas pedal influences the carburetor which in turn determines the rate at which energy is generated by the level of activity of the engine. Movement by the car is translated from the engine variable into action by information transforms that depend on the inherent characteristics of the car. Some of these information variables also allow a check on the system's performance (here, the speedometer and road-comparison checks).

By judging where the car is and how well it is operating relative to

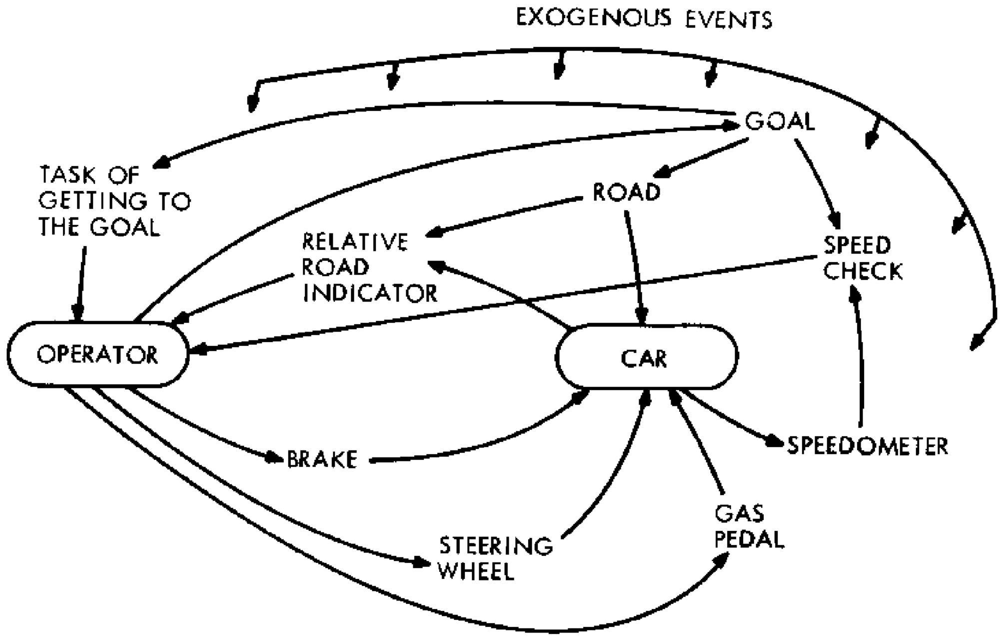

FIGURE 6.1. Preliminary Model of a Car in Operation

criteria set by goals he has formulated, the operator determines policies that guide the car through situations determined by the road he is on. Policies are carried out through the objects under his control: the steering wheel, the gas pedal, and the brakes.

To review, five major components make up the system:

1. State variable. A fundamental indicator of the condition of the system, e.g., the horsepower output of the engine in the car model.
2. Rate variable. A cause of change in the state variable. e.g., carburetor regulating fuel flow to change engine speed.
3. Transforms. Translators of information from the state variables to other variables. Transforms depend on the inherent characteristics of the system, e.g., the speed of the car is the result of a transform from the engine activity interacting with the drive train, road, and so on.
4. Policy variable. An item the operator can control in order to guide the system, e.g., the gas and brake pedals.

5. Exogenous events. Uncontrolled occurrences in the environment of the system, e.g., a train blocking the road.

After the relationships within a model are established, they can be quantified. Equations are specified and parameter values chosen. Once again, a consensus similar to the consensus on assumptions described earlier is crucial. Note that because of the lack of some data it may be necessary during the initial runs to guess at a parameter's value. Once the model is working, it will be possible to see if errors in this parameter have noticeable effects on the model's output. If they do, further research is needed to determine the correct value within a reasonable tolerance of error.

It is important to keep thorough documentation of all steps in the modeling process and all research leading to the final form of relationships and parameter values. Most probably, corrections will have to be made in the model. Without explicit knowledge about its foundation, the task would be extremely difficult if not impossible.

VALIDATION

A reasonable criticism often leveled at the modeling technique stems from doubts about model performance. What evidence indicates that a model's predictions are true?

Validation of the model may be carried out by trying to reproduce history. In this procedure, the initial conditions of the model are set to reflect some point in past time. Then the effects of any exogenous events that occurred during the period are added, and the model is run. If the model reproduces historical data we might reasonably conclude that it will perform as well when predicting the future. (In drawing this conclusion we assume that no fundamental system changes have occurred since the time period of the validation run.)

USING THE MODEL

Sensitivity analysis has already been discussed as a means of discovering important information about the characteristics of a system. As a general rule, this kind of analysis will show that changes in most variables have relatively little effect on the dynamics of the system. However, there will be some areas in which the system is particularly sensitive to change. Attention should be focused on these.

Planners and policy-makers may already have been guiding the real system by directing their energies toward controlling those items known to be sensitive. Their reasoning in choosing strategies may seem sound and their intentions correct. However, many times a policy will have conflicting long- and short-term effects on system behavior. A decision resulting from a short-term evaluation may prove to be dysfunctional in the long run. The term "counter-intuitive behavior" has become a favorite label in some modeling circles for this phenomenon exhibited by the system.

Policy decisions can be tested by making changes in the appropriate model parameters and noting the effects on both the near and distant future. Thus by inputing expected changes in jobs, wages, and the environment traceable to building and operating an oil refinery, policy-makers could observe and interpret probable future effects on the system of such a decision. Or, knowing where the model is sensitive, they might experiment with different changes to determine how it is possible to get the system to react in a desired manner.

As time passes, it will be possible to check model results against what happens in reality. Should the model parallel the real system, its success would go a long way toward dispelling the doubts of skeptics. The model-builder should be careful in choosing the time period of observation, though. A one-year projection in a model designed to show five- and ten-year trends is not particularly valuable in illustrating the validity of the model. And yet, demonstrating that the events of the next ten years parallel the model's output does not do a tremendous amount of good if only then is faith placed in the technique.

POTENTIAL PITFALLS

Too much emphasis cannot be placed on the requirement that the users of the model be intimately involved in developing it. They must understand its limitations and its strengths. Only then can they be sure that they are in fact using the model in the manner they intend.

At the time it is first put to use, the model will have been validated against history, if that is possible. Note, however, that good tracking by the model is not a guarantee that the real system is truly represented. The tracking may occur in spite of a mistake that did not have an effect in the operating range of the model during the history check.

No finite set of relationships can account for all the behavioral factors that influence a system. Care must be taken to ensure that the simplification required to make the model practical does not cause the real system to be misrepresented.

It would be fairly easy to fall into a trap by too quickly accepting the results of the model because they are precisely what intuition led us to expect. Expected results offer a false security, because the particular output may have been determined more by input bias than by the actual dynamics of the system. The model's capacity to resemble reality, not its ability to reinforce our intuition, is the first concern.

Bias can creep in at many places on both a technical and a nontechnical level. Multicolinearity, in which the continued effects of two or more variables mask the true independent effects of each, can lead to bias. Further, a large part of the modeling process is assessment. Differences in the goals and objectives of those creating and observing the model can introduce bias. For example, an environmentalist and an oil company executive would probably look at environmental factors differently. Whose point of view mirrors reality? Does either, or is a third position most nearly correct?

Additional inaccuracies can come from other sources. Unexpected technological or sociological changes may have a profound effect on the structural components of the system. If such changes are not included in the model, it no longer represents the real system. Errors can also be made in estimating the expected effects of known changes in the system. These oversights and errors can be minimized by experiments, similar to those of sensitivity analysis, to determine how the system might react to various major changes.

The most dangerous pitfall lying in the path of the model user is that of turning the model into a crutch, or substitute for the decision-making process. This problem is related to the use of a computer and the nature of the model's output. Many people tend to accept computer printouts as <u>the</u> truth. However, the computer is actually only a huge, fast, programmable calculator. Its use does not in any way change the basic nature of the decision-making process, nor does it add to the credibility of the results of the model (except by the assurance of accuracy in performing calculations).

Model results should never be blindly accepted. Factors that cannot be quantified, and therefore are not included in the model, must not be excluded from the overall evaluation of the system. Only through experience and careful thought can sound decisions be made with respect to guiding a system. A model must be looked at as a tool aiding decision-makers, and only as a tool.

USER EDUCATION

An education process is needed to impress people with the powers of the modeling process. Barriers to acceptance resulting from doubts about the validity of the technique will have to be broken down. A potential user's first reaction to modeling might be very much like his first reaction to an adding machine or a slide rule. Although he says he believes in it, he immediately checks his answers by hand because he is not entirely sure of the device's accuracy. This reluctance to trust the technique is a major problem, and there is no guaranteed method of overcoming it.

Chapter 7 MAINE2 EXPLAINED

This chapter describes a particular model, MAINE2, which is an example of the process of translating known information into a regional planning model. MAINE2 deals with the potential effects of building an oil refinery in Washington County, Maine, an area that is relatively depressed economically, but is blessed with a beautiful environment.

The conceptual framework underlying the model includes these elements of the system: (1) the demography of the area, (2) the proposed refinery, (3) the economy, and (4) local, state, and federal governments. Employment, pollution, tourism, and health, education, and welfare are additional conceptual elements of the model. Appendix C lists the associated equations as well as the basis for the values of parameters chosen for the model runs.

THE DEMOGRAPHY SECTOR

The Work Force

The demography sector of the model includes two groups of people: (1) workers with income (employed) and (2) workers without income (unemployed). The total population for the county is derived by multiplying the total number of workers (employed and unemployed) by an average-family-size factor. This factor is not quite equal to the actual average family-size in the county because it must take into account families supported by more than one job. Therefore, it really represents the average number of people supported by one job.

It is assumed that if an employed worker dies, retires, or moves out of Washington County his job will immediately be filled by a worker from the unemployed pool and the change will be reflected only in the category "workers without income."

A change in the number of jobs available in Washington County affects the model in a different manner. If the job market expands, the category "workers with income" is directly increased, with an accompanying reduction in "workers without income."

The size of the work force and of the population in general changes over time in response to various forces. MAINE2 includes the following factors affecting work-force and population size:

1. births, as reflected in the rate of maturation into the work force
2. deaths and retirements
3. the physical attractiveness of the area
4. the attractiveness of the area due to other attributes
5. the size of the job market relative to other areas and to the population

These factors, considered together, produce the diagram of relationships in the demography sector shown in figure 7.1.

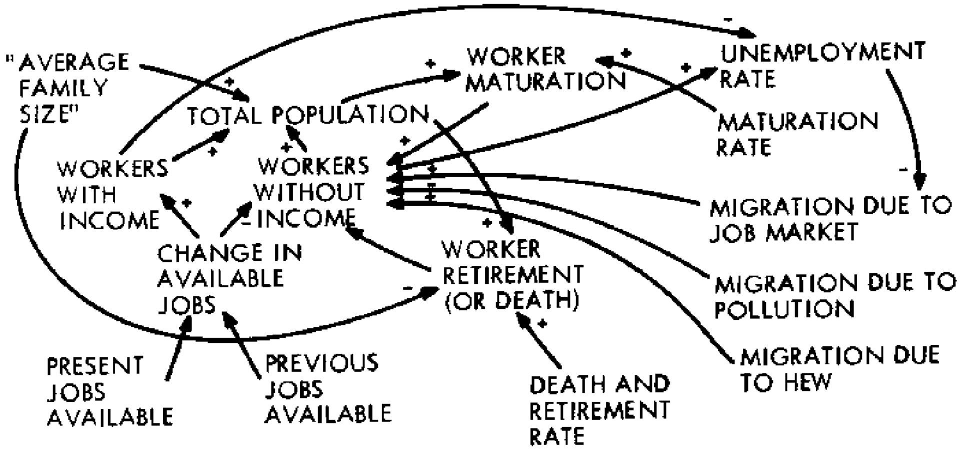

FIGURE 7.1. Relationships in the Demography Sector of MAINE2

Migration Variables

The combined effects of three migration variables influence population movements and are a function of the relative desirability of the area. The area's physical attractiveness and its employment opportunities are two of the determinants. The third deals with the question, Are there sufficient support facilities (e.g., health and education facilities) to make the area attractive? The indicators used in the model to derive these effects are the level of normalized pollution, the rate of unemployment, and per capita health, education, and welfare expenditures.

A number of components make up the pollution variable. It is assumed that assaults on the physical characteristics of the local environment and climate can be lumped together as a negative attribute. A normalized pollution factor is derived, which in turn determines the movement of people according to the graph in figure 7.2. If the present value of the normalized

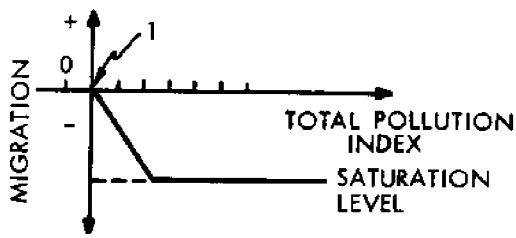

FIGURE 7.2. Migration in Relation to Pollution Level

pollution factor is 1, no migration occurs. However, a rise in the level of pollution causes an out-migration, the magnitude of which grows as pollution increases until the highest level of out-migration is reached.

The job-market variable is a function of the unemployment rate. It, like pollution, is a negative attribute in that the greater the unemployment the greater the out-migration. Low unemployment in the area influences people to move in from more depressed areas. During periods of very high unemployment, many people will move out. For unemployment rates in the normal middle range, there is minimal variation in the migration rate; however, at the extremes of the unemployment-rate range, the migration factor becomes very sensitive (figure 7.3).

Health, education, and welfare facilities and expenditures have a positive effect on migration. It is assumed that the higher the per capita value of this variable, the more attrative the area becomes (figure 7.4). HEW migration can flow in or out and varies between two clamping values as a function of the relative level of per capita HEW activity.

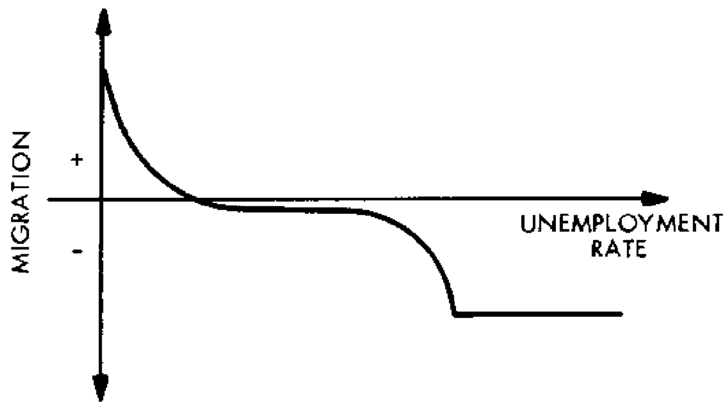

FIGURE 7.3. Migration in Relation to Unemployment Rate

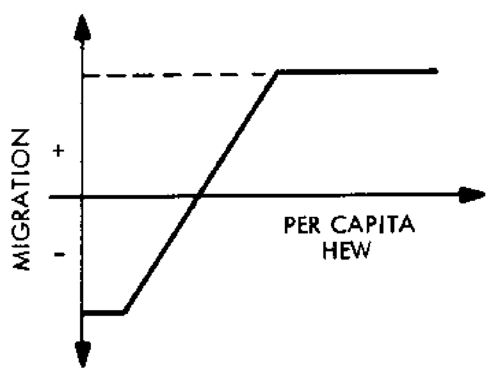

FIGURE 7.4. Migration in Relation to HEW Activity Level

To complete the structure of the demography sector, a number of auxiliary relationships should be added to the diagram shown in figure 7.1. They represent the driving variables for the migration factors just described (figure 7.5).

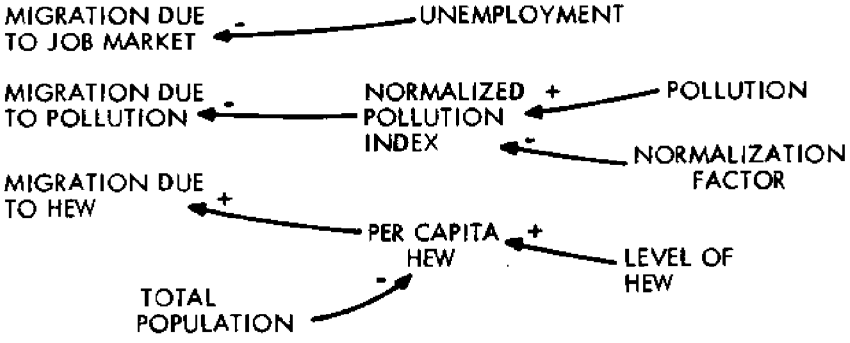

FIGURE 7.5. Driving Variables for Migration

THE REFINERY PROJECT

Figure 7.6 depicts the relationships associated with the capital-plant aspects of the refinery project. The project begins with a schedule of payments to be made when building the refinery. They feed an accumulator (capital investment in the refinery) which represents plant and equipment.

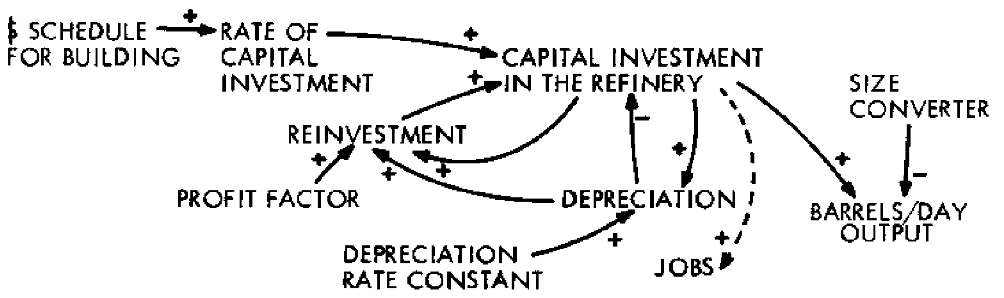

FIGURE 7.6. Relationships in Refinery Capital-Plant Development

value. The output of the refinery and the number of its employees are derived from the capacity of the plant, which in turn is derived from the size of the investment and current construction costs.

Once the refinery is in operation, two factors, depreciation and reinvestment interact to determine long-term trends in the level of capital investment. The level of the investment depreciates at a rate determined by the depreciation constant. In order to maintain or increase output, money must be reinvested in the form of maintenance, replacement equipment, or additional equipment.

Reinvestment is a function of the availability of money. It is related to the profitability of the operation. The magnitude of reinvestment is also dependent on how quickly the capital is deteriorating through depreciation. The greater the rate of depreciation, the greater the reinvestment must be in order to balance the effects of use and time.

Refinery Pollution

The amount of pollution from refinery operations can be derived from output. Depending on the characteristics of the refinery operation, including any pollution-control devices that are part of its design, an average mix and amount of pollution can be expected for each barrel refined (figure 7.7).

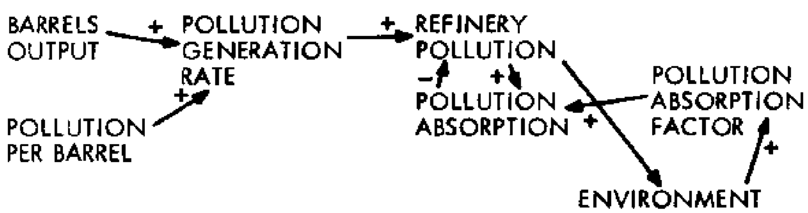

FIGURE 7.7. Relationship of Refinery Output to Pollution

Like capital investment, pollution is an accumulating variable. As more barrels are refined, the generation rate adds to the level of pollution. An absorption factor decreases pollution in a manner similar to the effect of depreciation of capital investment. The rate of absorption is proportional to the level of pollution and the natural ability of the environment to dissipate it.*

Refinery Employment

Construction jobs. The potential effects of an oil refinery are not all bad. Building and operating the refinery would create a large number of jobs (figure 7.8).

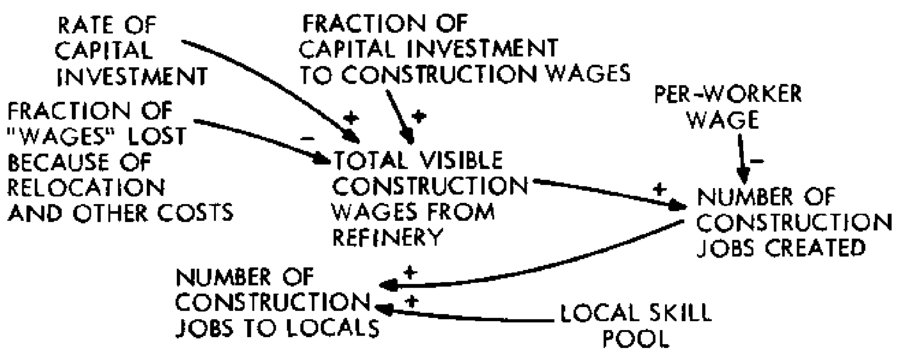

FIGURE 7.8. Jobs Created by Refinery Construction and Operation

During construction a fraction of the investment is paid to the people who build the refinery. The number of construction jobs created can be determined by dividing the average wage into a factor called total visible wages. This factor is obtained by reducing the amount of money available for labor by the amount of money used for such things as (1) relocation costs incurred when workers are imported to do work the locals are not able to do and (2) "hardship" compensation to outsiders who are away from their families.

It is assumed that money paid to local people will be plowed back into

* It is assumed that pollution has not saturated the environment to the extent that permanent ecological damage has been done. If extensive damage has occurred, more factors would have to be included, such as the repairability of the damage and the rate at which compensating action could take effect.

the local economy. Outsiders, it is assumed, will spend only a small amount in Washington County, sending most of their wages home. Therefore, the number of construction jobs for locals (and money paid to them) is derived for use in the model.

Permanent jobs. Operation of the refinery creates a number of permanent jobs. They will be filled by local people, new people who will become locals, and a few nonresidents. The present level of capital investment compared with the expected total construction cost determines the fraction of the project completed. This fraction, multiplied by the expected size of the full operating staff, determines the number of permanent jobs created. The value of wages paid to the permanent force is derived from the number of jobs and the average wage for the operation. The money injected into the local economy through wages paid to the permanent job force can be expected to bolster the depressed economy of the region (figure 7.9).

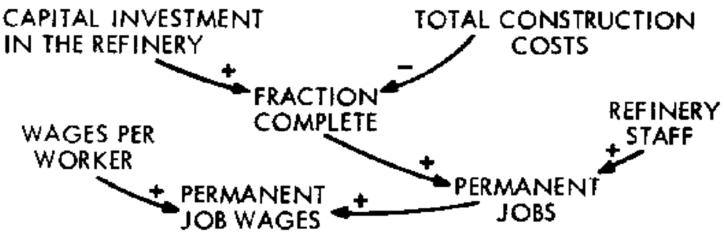

FIGURE 7.9. Relationships of Refinery Capital Investment, Construction Costs, and Wages

Two things should be noted about the derivation of the number of jobs. First, it is assumed that the refinery, once in operation, will always require a full staff. In light of the demand for petroleum products in the area it is also assumed that the refinery will always run at maximum capacity. Second, in modeling a single project it is hard to represent exactly the pattern and timing of hiring for the permanent staff. The method of linking the number of jobs to the fraction completed in the construction phase was chosen to minimize discrepancies between real life and what happens in the model. People brought on the payroll early can be thought of as trainees and as managers recruiting the work force.

The problem of representing the hiring pattern could be overlooked if a number of projects were being considered for the region. Fluctuations caused by singular occurrences tied to one project would be dampened by the averaging effects of the combined dynamics of all the projects.

Refinery Tax Revenues

The remaining aspects of the refinery project deal with tax revenues from operation of the refinery, as shown in figure 7.10.

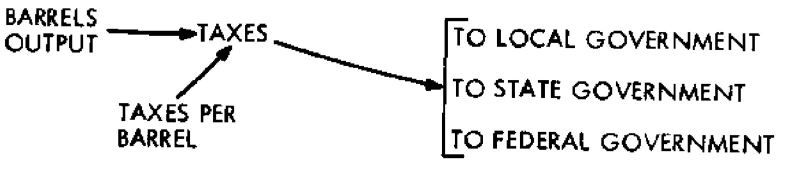

FIGURE 7.10 Tax Revenues From Refinery Operation

Taxes are determined per barrel of output and are distributed among various governmental recipients. MAINE2 concerns itself with all tax money made available to the local area from the operation of the refinery whether it comes directly to the local government or is channeled through the state and federal governments.

THE ECONOMIC SECTOR

The economic sector of the model deals with the needs and products of different occupation groups and how they interact to determine the number of jobs and wages. Activity both inside and outside Washington County results in a mix of local people in the groups presented in figure 7.11.

As a general rule the categories in figure 7.11 are not independent. For example, in a highly aggregated model we could say that, as the economy grows, more demand is placed on the manufacturing and service sectors. More farm products are demanded by all groups. Government, in order to handle the complexities of the expanding system, grows along with it. And demand for more productivity in a certain category might come from within that category itself.

Because of the complex and numerous interrelationships between job groups, the introduction of a new industry providing one hundred new manufacturing jobs will actually create more than one hundred jobs. Consumption by workers filling these jobs will augment demands placed on other groups. More services will have to be provided, which will result in more service jobs. Government will grow, and so on and so on.

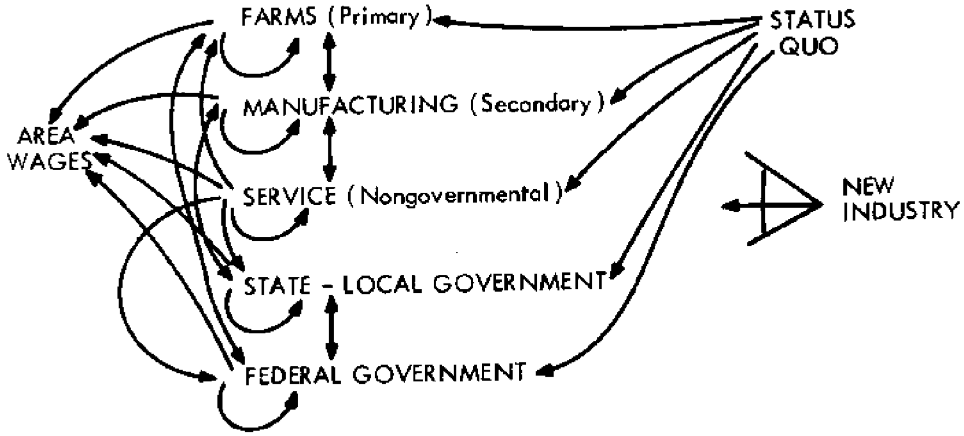

FIGURE 7.11. Job/Wage Interactions

The general case shown in figure 7.11 can be simplified for Washington County. A diagram of the simplified economic structure of the county appears in figure 7.12.

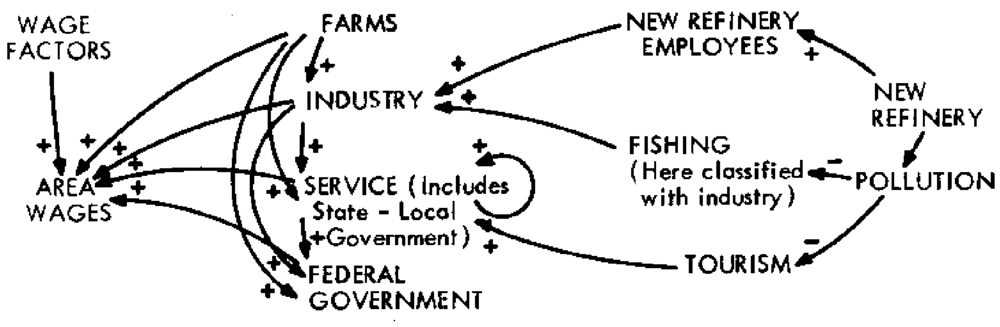

FIGURE 7.12. Economic Structure of Washington County

A number of coupling coefficients between the categories of labor are so small that they can be ignored. For example, we would not expect a great shift in the number of farm jobs in the county resulting from the size and location of the proposed refinery. On the other hand, we would expect the number of jobs in service industries to increase because of demands by the new refinery employees. At the same time, a possible decrease in jobs in the service sector, caused by declining tourism, must be considered.

The effects that operating a refinery could have on tourism in the area are shown in figure 7.13. The number of actual tourist-days recorded in the county results from the interaction of the relative attractiveness of the area

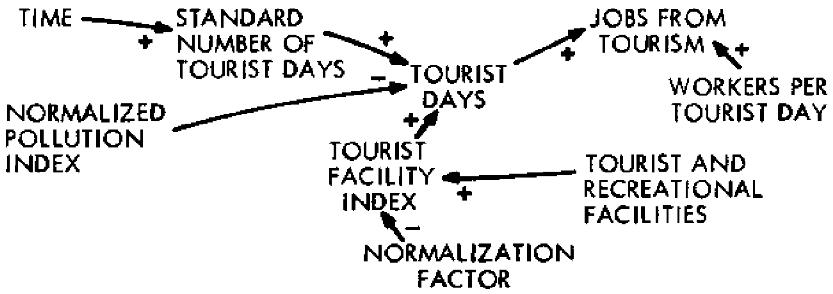

FIGURE 7.13. Effects of Refinery on Tourism

with a trend generator indicating general tourist activity. The standard is the present level of tourism. Superior facilities act to increase it. Pollution, as we have said, is likely to decrease it.

THE GOVERNMENT SECTOR

Requests for Governmental Services

The next three sections of the government sector of the model have approximately the same structure. They deal with (1) industrial support facilities, (2) tourist facilities, and (3) health, education, and welfare facilities. In each case, a comparison of the desired level of service and the existing condition yields a perceived deficiency. To bring the service up to the desired level, demands are made on government which in turn allocates funds, taking into account budget constraints as well as the specifics of the demands (figure 7.14).

By itself, the negative feedback loop of this structure would tend to bring the system into equilibrium. However, these variables must interact with others in the model, and the equilibrium-seeking tendency may be overpowered.

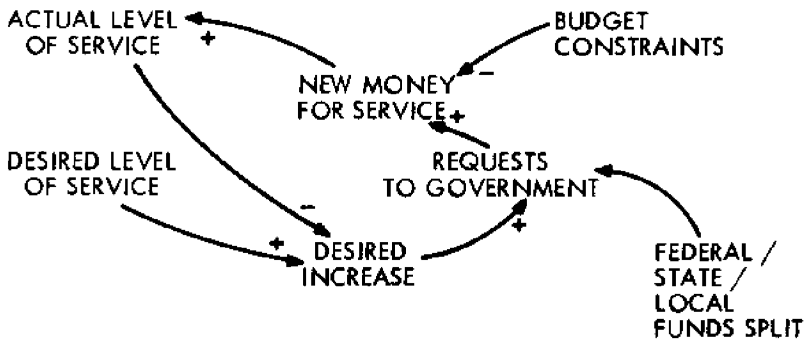

FIGURE 7.14. Demands for Government Service

Industrial support facilities include such things as the road system servicing the area, seaport facilities, airport facilities, and sewage-treatment capabilities. As shown in figure 7.15, the desired level of industrial support

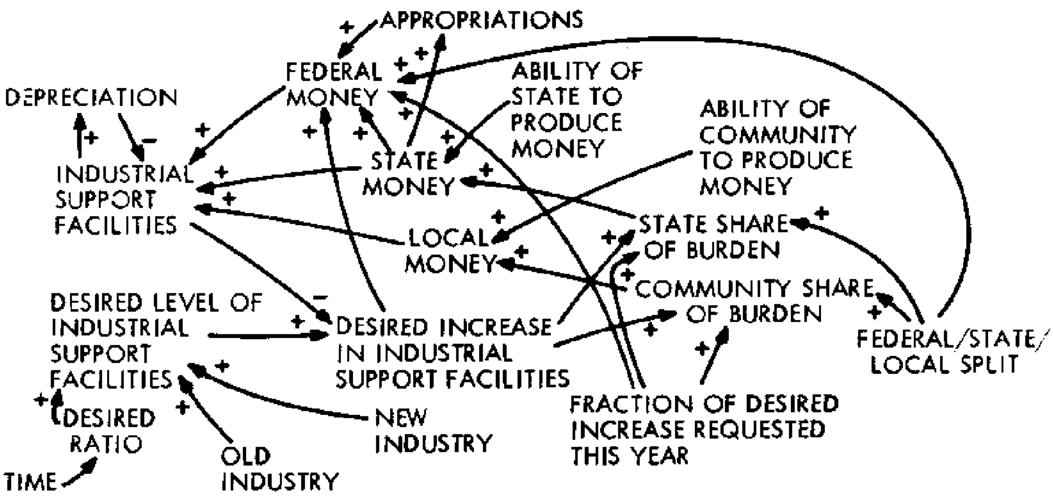

FIGURE 7.15. Relationships Affecting Industrial Support Facilities

facilities is derived from the level of industrial activity in the area and a ratio that describes the relationship between industry and industry support. Probably this ratio will change as the intensity of industrial activity increases but for the range of development included in this model it is assumed to be a constant. It is further assumed that this ratio changes over the period of interest, reflecting increases in the real cost of doing things as well as the trend toward greater capital expenses as the system matures and grows more complex.

Money is allocated in the following manner: the desired level of support is compared to the actual level to obtain a perceived deficiency. Target amounts for the area and the split factor (the division between local, state, and federal responsibility) determine how much is needed and how the burden might be shared. Finally, the effects of budget constraints and lobbying interests are included, and the expenditures by each level of government are determined. Government spending increases the level of industrial support facilities, while depreciation decreases it.

Another subsector of the model exhibits dynamics virtually identical with those of industrial support facilities, but deals with money used to improve or create tourist facilities (figure 7.16).

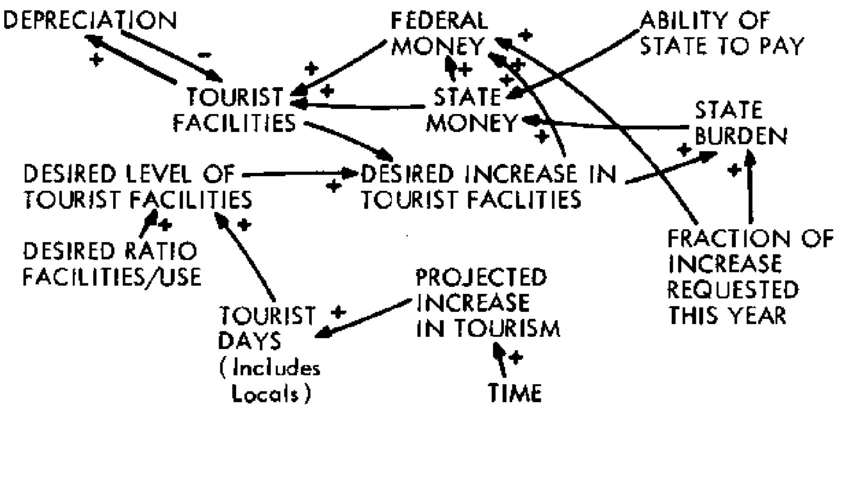

FIGURE 7.16 Relationships Affecting Tourist Facilities

Health, education, and welfare services are handled similarly in a third subsector (figure 7.17).

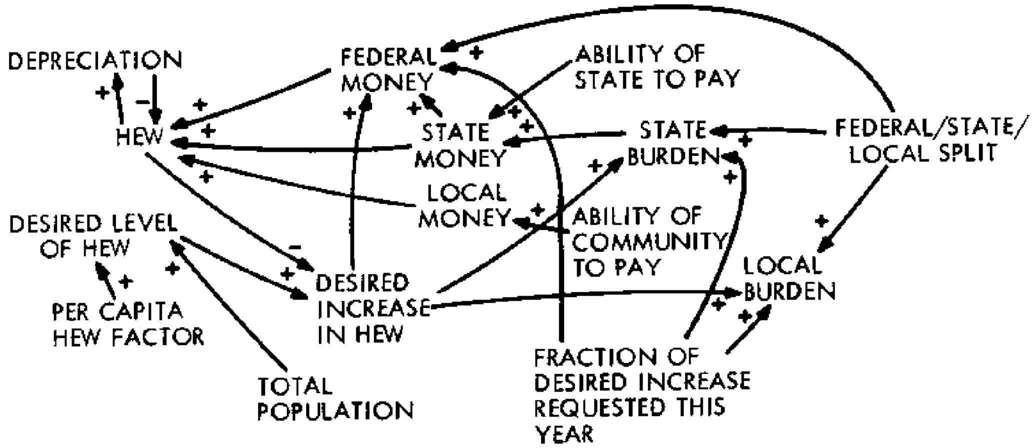

FIGURE 7.17. Relationships Affecting Health, Education, and Welfare Services

State Tax Revenues and Disbursements

Until now, the level of aggregation of the MAINE2 subsector has been matched to the purpose of the model. In developing the state tax subsector greater detail has been used to illustrate a lesser degree of aggregation. This detail goes not improve the performance of the model, but, if another purpose were given to the study, this detail might be necessary to perform the task.

State tax revenues are made up of the following components:

1. sales taxes
2. personal income taxes
3. corporate income taxes
4. hunting and fishing license fees
5. motor vehicle taxes and license fees
6. gasoline, liquor, and cigarette taxes.

The dynamics of state tax revenues are shown in figure 7.18.

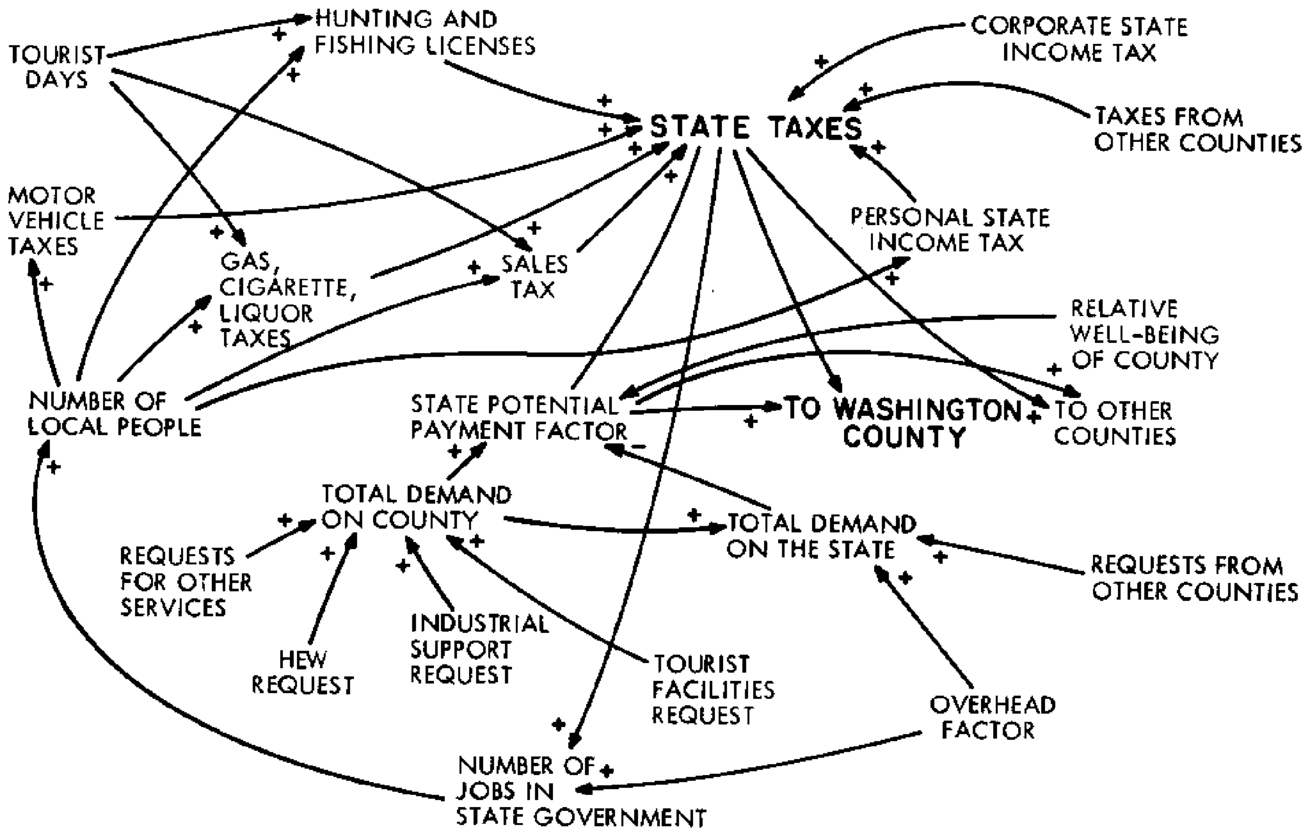

FIGURE 7.18. Dynamics of State Tax Revenues

For the purposes of the model, population and income characteristics determine the level of state personal income taxes for the county as well as the number of motor vehicles registered there. Corporate income tax is derived as a fixed percentage of the net corporate income realized in the county. Finally, a weighted average of the number of local people and tourists determines the amount of revenue generated from sales taxes, license fees, and taxes on gas, liquor, and cigarettes.

The other aspect of the state sector deals with fund allocations. Requests for money interact with budget constraints to result in disbursements. Washington County requests, added to those from other counties, determine the total demand on the state. Payments to Washington County are derived from the interaction of the following factors:

1. funds used to finance state government
2. taxes generated
3. total demand for state funds
4. Washington County demand for state funds
5. a factor describing the immediacy of the needs of Washington County relative to those of other Maine counties.

Local Tax Revenues and Disbursements

Local taxes and allocations are determined in a manner similar to that described for the state sector. Property taxes, however, are the basis for revenues (figure 7.19). The number of people residing in the area roughly determines the amount of personal property and, as a result, the tax generated. Corporate property tax is derived from the level of corporate activity in the country.

The method of disbursement is also similar to the state's. A fraction of the combined requests for facilities for HEW, tourism, and industrial support approximates the total demand on local budgets within the county. Once an overhead factor, which takes into account the cost of local government, is included, the potential payment factor results. Allocations to the sectors requesting money follow.

An additional set of relationships has to be included if we wish to incorporate in the model the benefits that would accrue to the local community as part of an actual plan offered by Occidental Petroleum (Hammer, 1969).

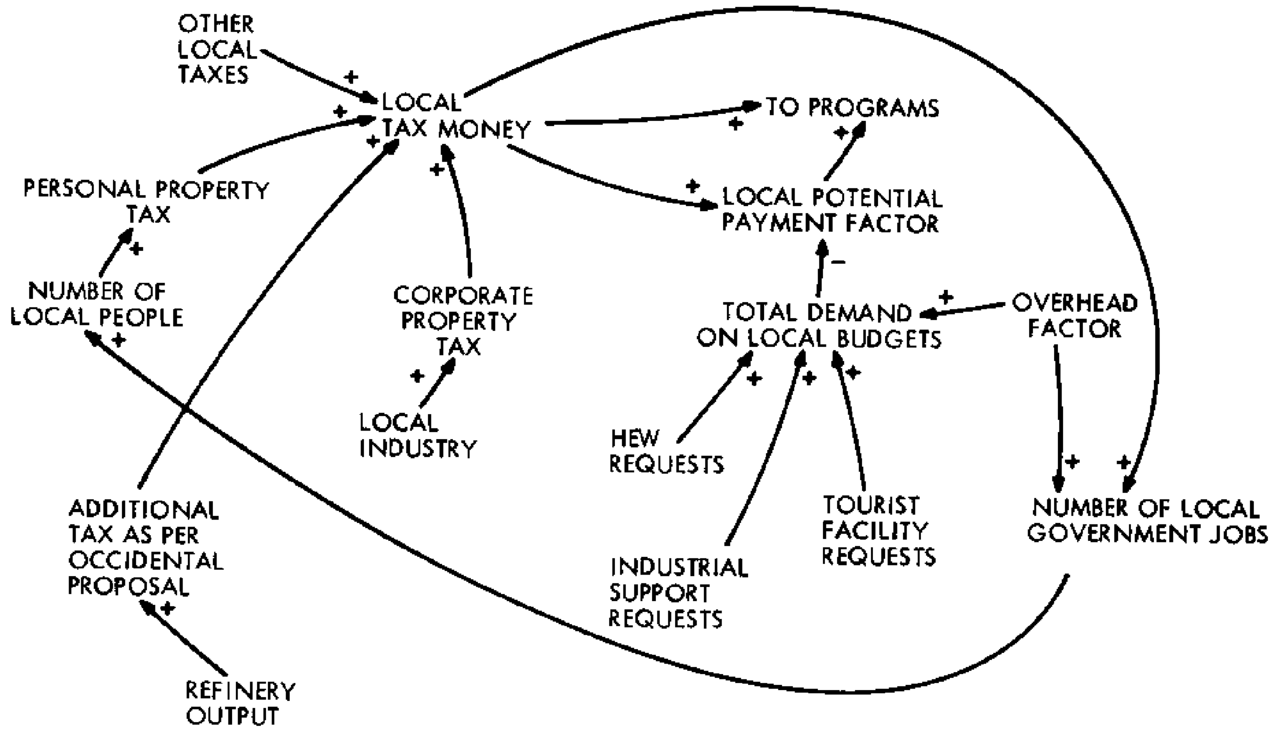

FIGURE 7.19. Dynamics of Local Tax Revenues

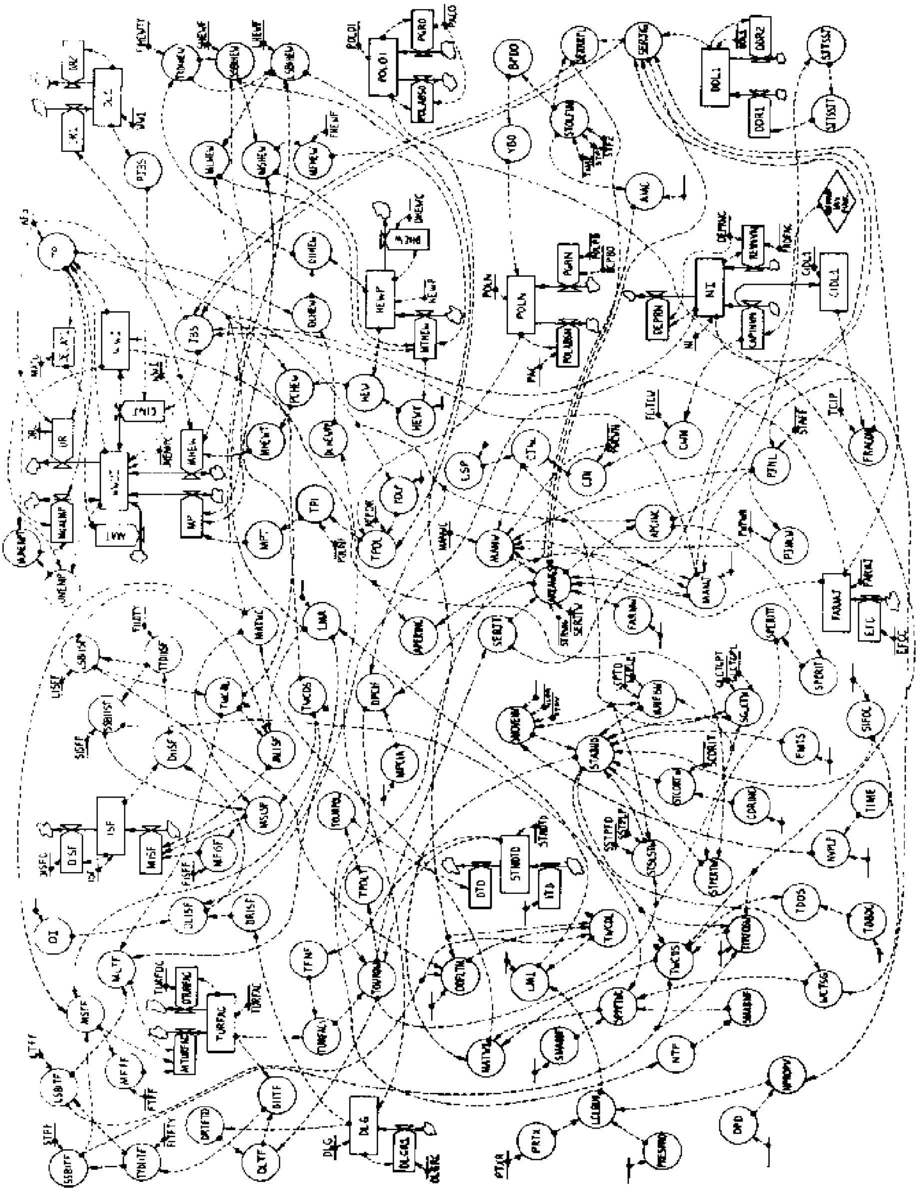

FIGURE 7.20. DYNAMO Flow Chart for MAINE2

In its original proposal, the company agreed to pay a per-barrel tax to the localities adversely affected by their proposed refinery. The extra revenues resulting from such payments would certainly help local government finance its projects, and these are included in the structure shown in figure 7.19.

THE COMPLETED MODEL

The completed model, shown graphically in figure 7.20 and defined by equations in Appendix C, specifies the relationships described in words in this chapter. The labels in the diagram in figure 7.20 correspond to the variable names used in the equations. Each variable is represented in the diagram by a symbol, and each interdependency is noted by either a solid or a dotted line. Appendix D provides an explanation of the symbols and equation forms.

Only a deterministic version of MAINE2 is presented here. It is the more easily understood of the two modeling methods, and we believe that including the probabilistic counterpart would not add much to this exercise, whose purpose is to describe the modeling technique in general. For a similar reason, a sensitivity analysis of MAINE2 does not appear with the results of running the model, which are discussed in the next chapter.

MAINE2 RESULTS

The purpose of MAINE2 is to illustrate by example how a planning problem can be tackled by the modeling technique. Running MAINE2 as presented in Appendix C allows us to analyze the impact of putting an oil refinery in Washington County, given the assumptions outlined in the preceding chapter. This is done by comparing the base situation, from which the exogenous inputs of building and operating the refinery are omitted, with what the situation of the county would be if the refinery were built.

WASHINGTON COUNTY WITHOUT A REFINERY

Figures 8.1, 8.2, 8.3, and 8.4 show predictions for the county for the next twenty years, assuming that no refinery is built.

On the assumption that, because of the county's depressed economy, HEW money would be put into the county at a rate faster than that in other parts of the state (F8.1-H),* a marked effect on migration (F8.1-2) due to increased per capita HEW expenditures results in a gradual increase in population (F8.2-P). (Note: Parameter values could have been chosen so as to have this component of population migration remain at its initial value or actually decrease. However, because this approach compares the same inherent HEW dynamics for both cases (with and without the oil refinery), the

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* The code given in parentheses refers to the figures cited. The figure number (F8.1) appears first; the letter or number following the hyphen is that used to graph the movement of the variable of interest.

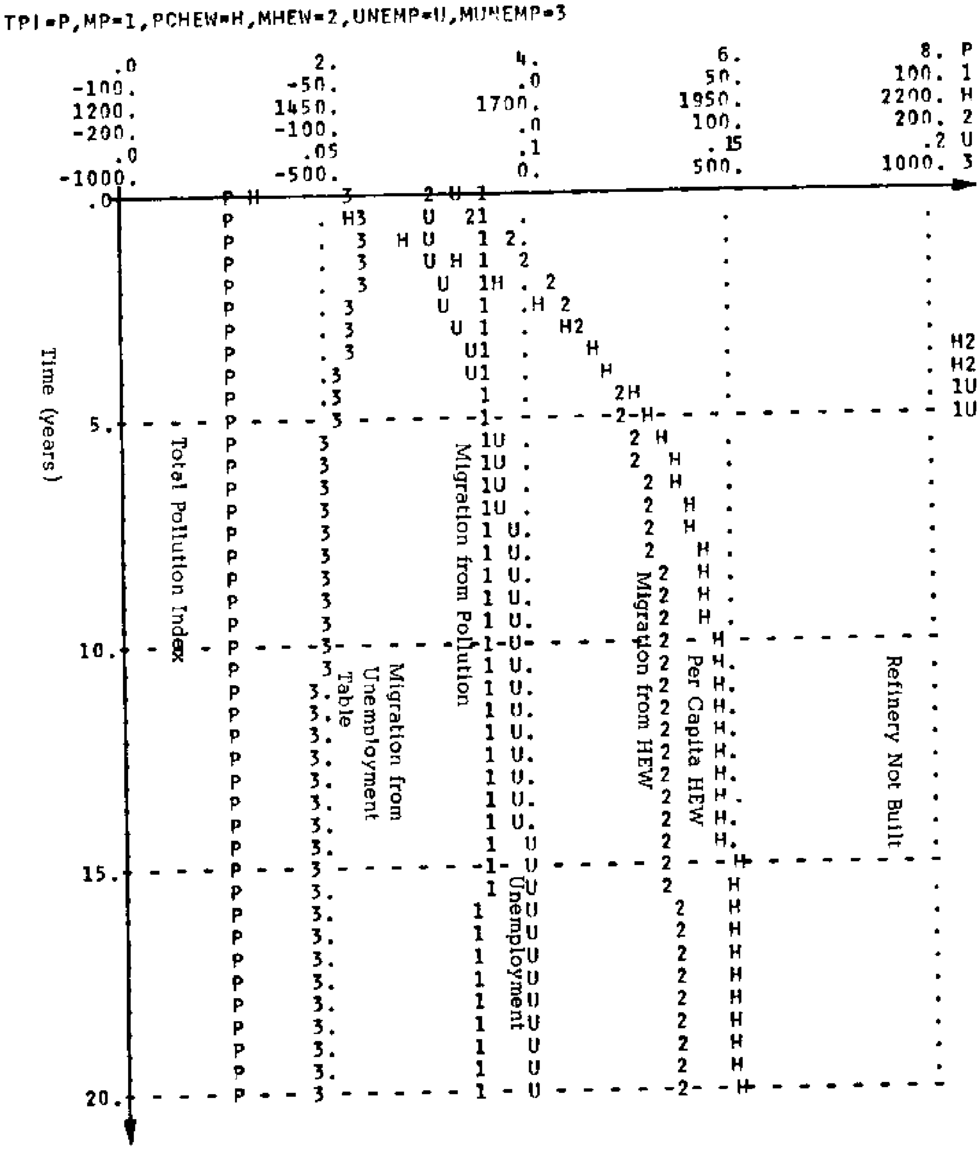

FIGURE 8.1. Twenty-Year Employment Predictions for Washington County Without a Refinery

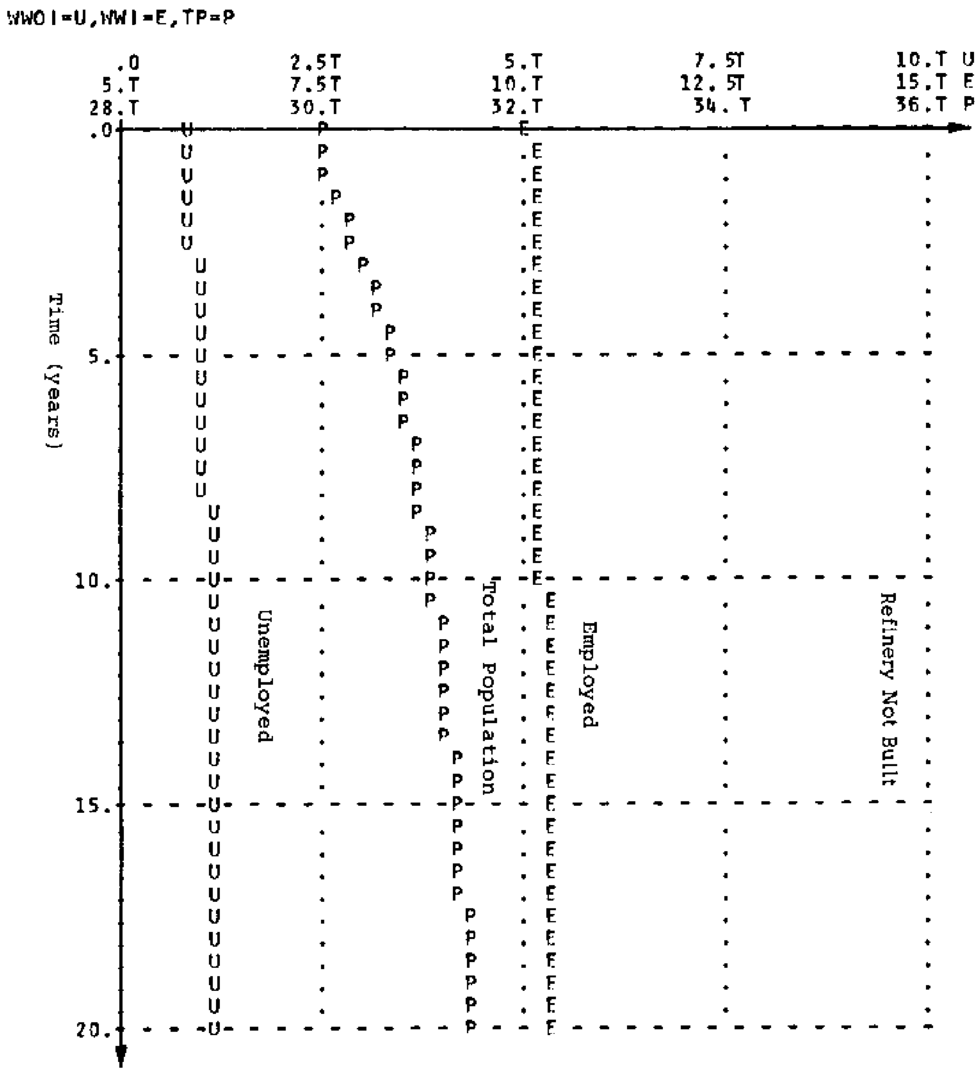

FIGURE 8.2. Twenty-Year Employment Predictions for Washington County Without a Refinery

resulting differential analysis minimizes concerns generated by the HEW variables.)

In spite of projected increases in tourist facilities (F8.4-T) and tourism over the twenty-year period covered by the model, the number of service jobs generated (F8.3-S) is not sufficient to absorb the influx of people

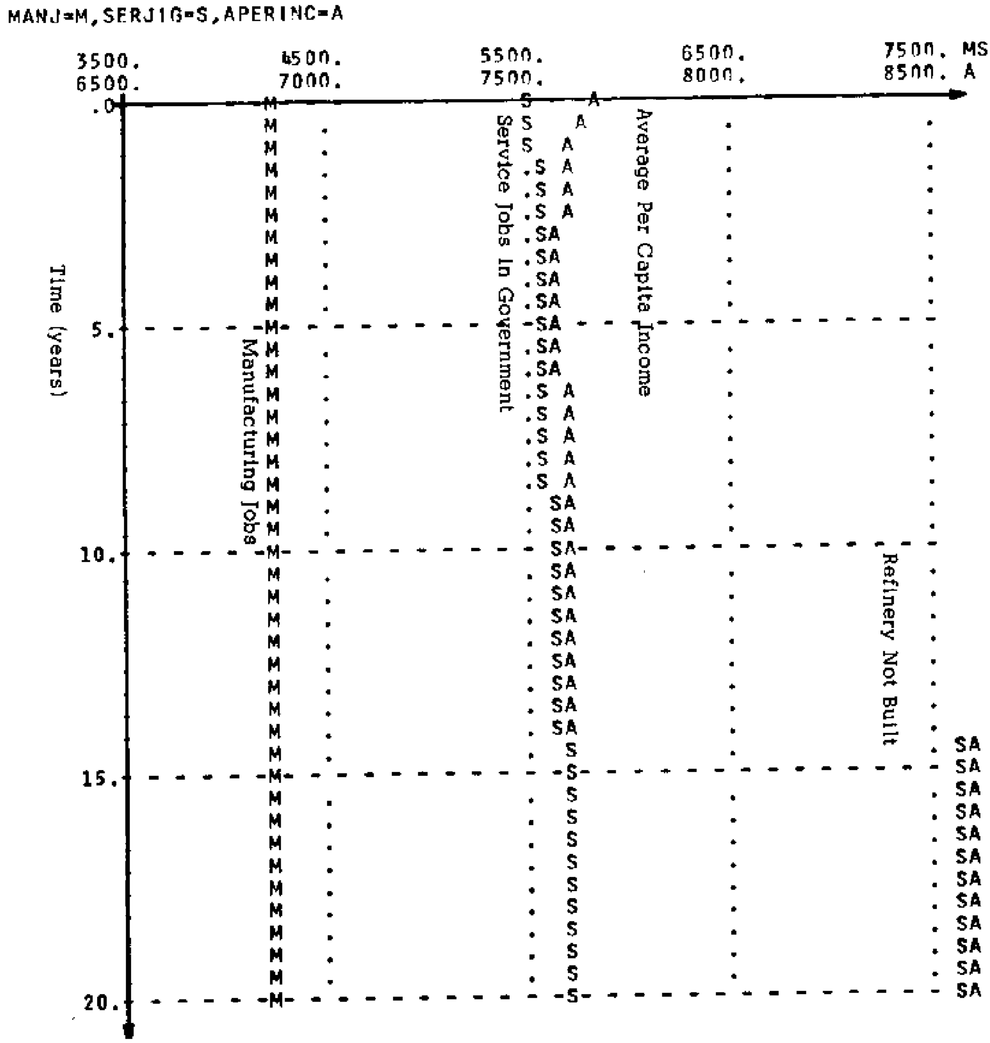

FIGURE 8.3. Twenty-Year Job and Income Predictions for Washington County Without a Refinery

(F8.2-P). The long-term trend is toward higher unemployment rates (F8.1-U); the absolute number of people employed, however, does go up. During the first few years, when activity in industrial support facilities is predicted (F8.4-I), the unemployment rate (F8.1-U) is much lower than it is later, when industrial support activity diminishes.

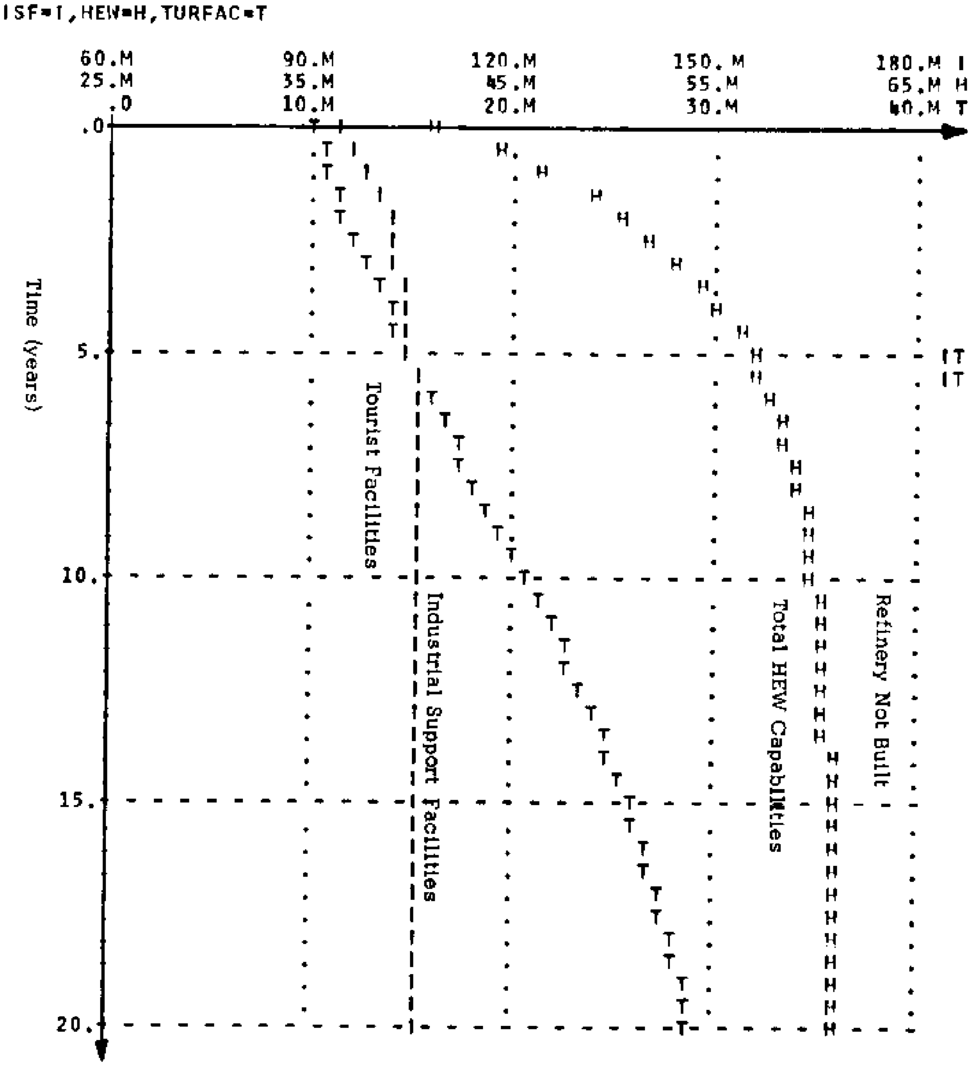

FIGURE 8.4. Twenty-Year Government Services Predictions for Washington County Without a Refinery

A final trend worth noting is a gradual decrease, followed by a stabilization, in the average wage earned by a worker (F8. 3-A). Because the model deals with dollars of constant value, this indicator masks the probable increase in income due to inflation. MAINE2 ignores the effects of inflation and the accompanying uncertainty in deriving the average wage in order to simplify the task of isolating the impact of building the refinery.

EFFECTS OF THE REFINERY

MAINE2 researchers found a major discrepancy in the literature with respect to the number of workers who might eventually be employed by the operating refinery. Therefore, to establish this parameter, two cases had to be examined. The first uses a figure of 300 workers for the permanent staff (Hammer, 1969); the second assumes only 124 workers (Governor's Task Force, 1972). All other parameters relating to the refinery's presence remain identical.

Three-Hundred Worker Operating Staff

County predictions for the 300-jobs case are presented in figures 8. 5 through 8. 8. Noticeable changes from the base case occur in all areas of the model.

Construction on the refinery begins between years 5 and 6 and causes marked changes in population (F8. 6-P) and unemployment (F8. 5-U). A large number of people move into the area both with and without their families, during this phase and then move out once the project is complete, leaving only a residual operating work force.

Employment (F8. 6-E) leads the extra population growth (F8. 6-P) as the sudden demand for workers gets an immediate response from slack in the local economy. The inverse effect on unemployment can be seen(F8. 6-U).

A noticeable change in industrial support facilities (F8. 8-I) occurs along with the new construction. Increased industrial activity in the county, along with an influx of people makes this change necessary. A minor shift upward in HEW facilities and expenditures (F8. 8-H) also results as the population level is altered from that of the base case.

Interesting data on the economic well-being of the county are shown in figure 8. 7. Manufacturing jobs (F8. 7-M) rise to a higher residual level than in the base case, indicating that more jobs are created by the refinery (in this sector) than are destroyed in the fishing-related industries. (Note: All fishing jobs are classified as secondary industry in this model to take advantage of model efficiencies.) Service jobs, including those serving tourists, follow the same trend (F8.7-S).

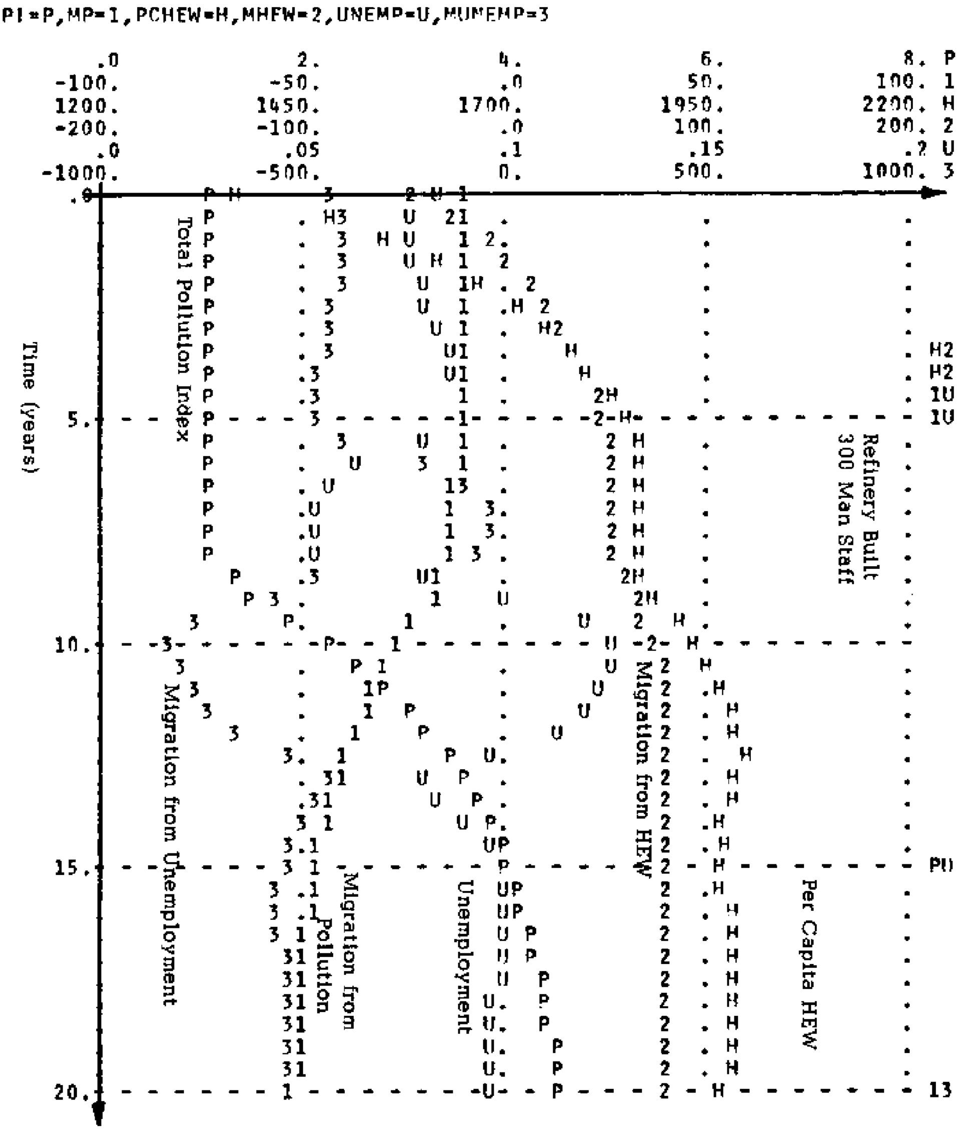

FIGURE 8.5. Migration Predictions for a 300-Worker Refinery

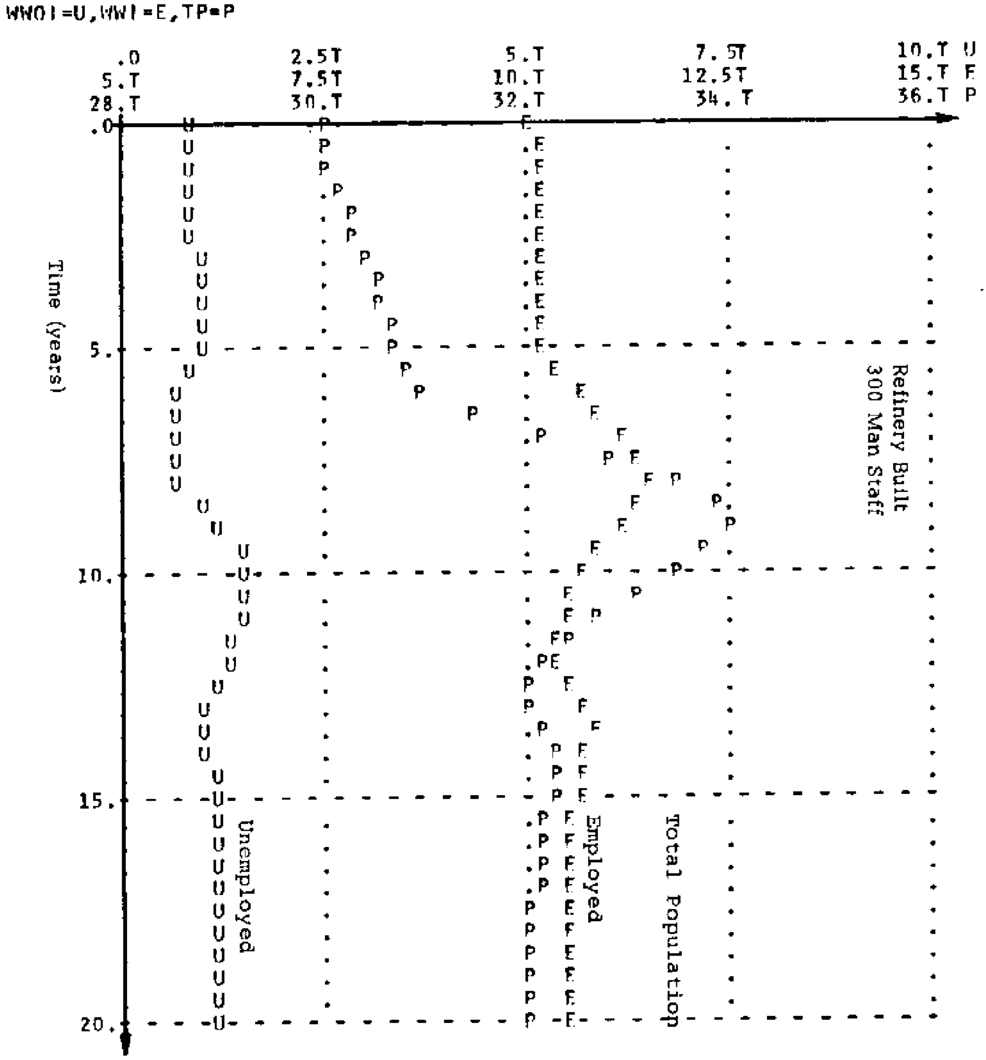

FIGURE 8.6. Employment Predictions for a Three-Hundred Worker Refinery

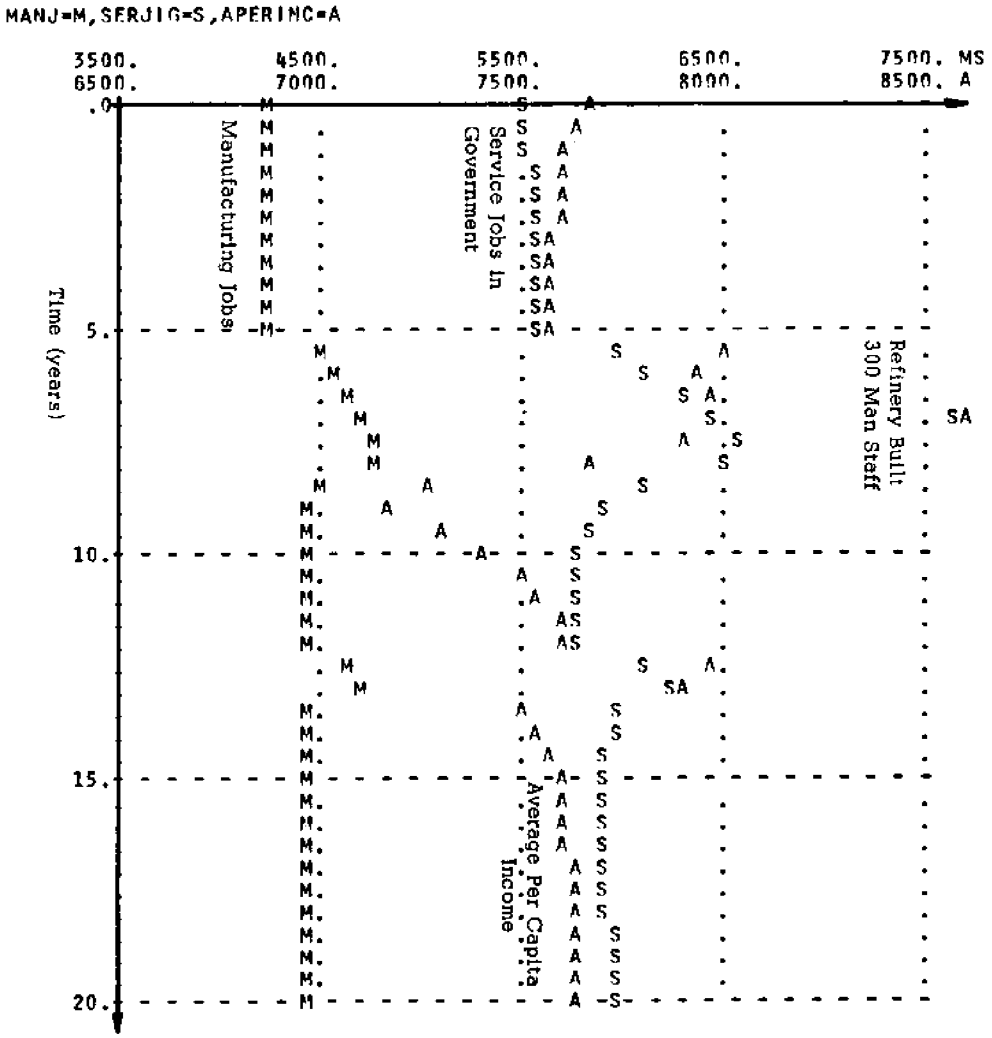

FIGURE 8.7. Job and Income Predictions for a Three-Hundred Worker Refinery

While more jobs become available in the area, little happens to the average wage (F8.7-A). A comparison of the residual values for average worker-income shows very little difference between the case in which no refinery is built and the case in which 300 people are employed by an operating

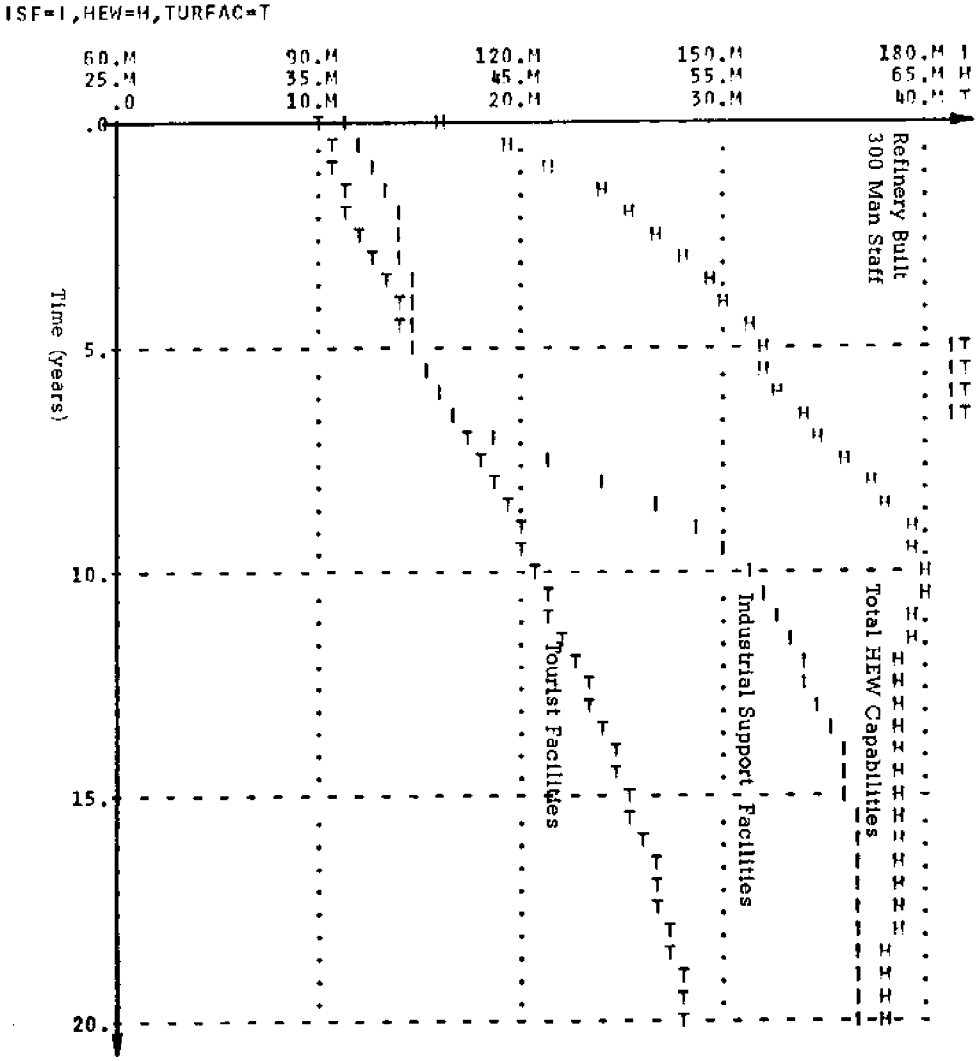

FIGURE 8.8. Government-Services Predictions for a Three-Hundred Worker Refinery

refinery. The only significant improvement is that more people are employed at the average wage when the refinery is operating. Thus, the county becomes more active economically and may be able to attract additional businesses.

124-Worker Operating Staff

The second case, that of a 124-worker operating staff, provides interesting results when compared to the 300-worker case (figures 8.9-8.12). While in this case the construction phase of the refinery project causes swings in population (F8.10-P) similar to those in the first case, noticeable differences appear once operation begins. The eventual levels of population (F8.10-P) and employment (F8.10-E) are lower than in the case in which no refinery is built. The number of unemployed workers (F8.10-U), however, does not drop correspondingly.

COMPARISON OF THE ALTERNATIVES

Figures 8.3, 8.7, and 8.11 present information on how jobs and income are affected in the two different cases. By comparing this information the predicted economic effects of a refinery can be evaluated. With a staff of 300, the operating refinery would expand economic activity in the county. Higher levels of jobs in both the manufacturing and service sectors would result and would be accompanied by a stable constant-dollar wage (F8.7-A).

With the smaller staff, these trends would not hold. The number of manufacturing jobs (F8.11-M) would eventually drop below the initial level. Average wages would follow that trend (F8.11-A). Additional bad news is indicated by the fact that service-sector employment (F8.11-S) does not grow as fast in the base case (F8.3-S).

It would appear that the actual number of people eventually employed to operate the refinery is a critical factor in determining whether or not the refinery would benefit the county economically. Improvements do not automatically result from simply building and operating this facility. We have seen in the computer analysis that the refinery with the larger work force does increase the level of economic activity, whereas the refinery with a small staff has a tendency to depress economic activity.

THE SIGNIFICANCE OF THE RESULTS

As was advised in earlier chapters, readers should be cautious about accepting the validity and application of MAINE2. Once an output-producing model is in operation, it is very easy to become enchanted by the graphs and

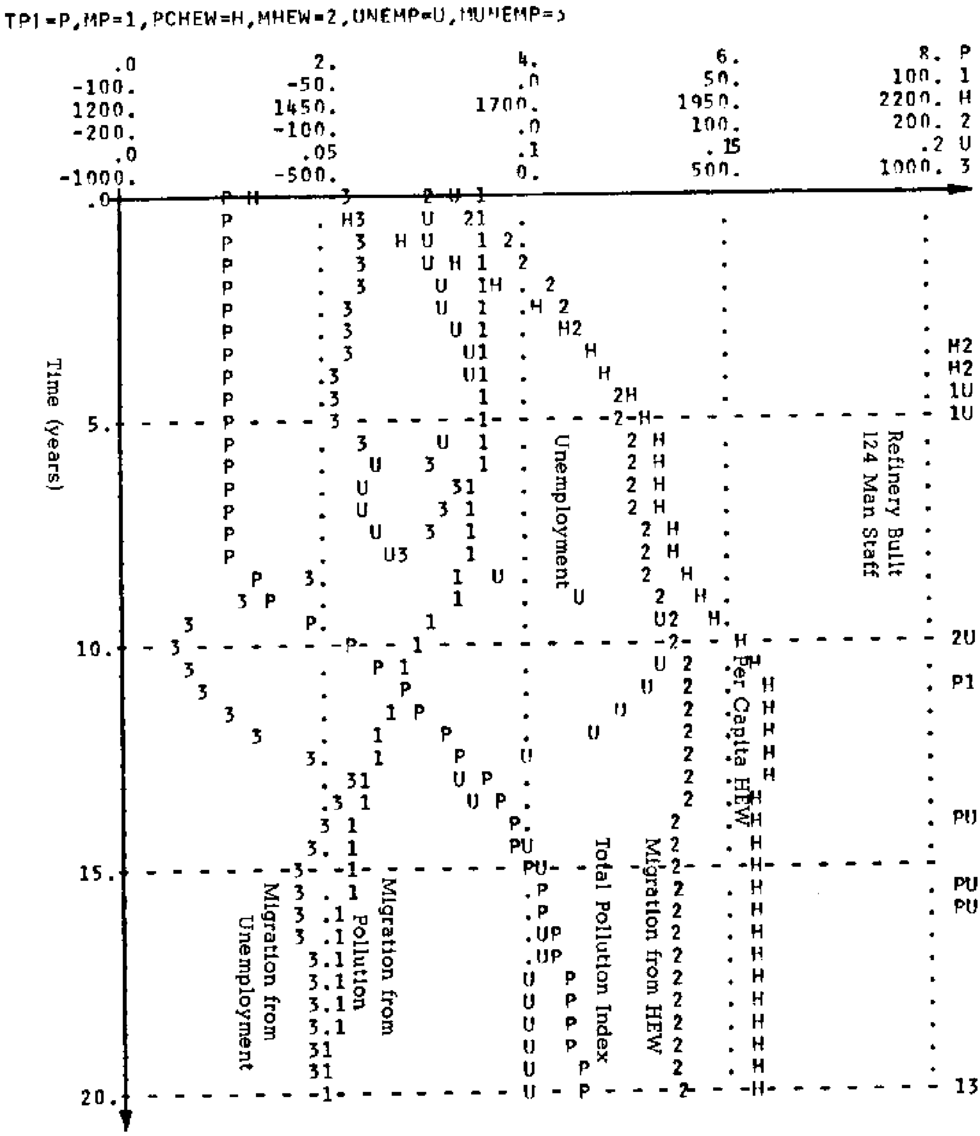

FIGURE 8.9. Migration Predictions for a 124-Worker Refinery

the precision of the numbers. It is very possible to carry the interpretation given in the last few pages to an extreme.

While much research preceded the development of the MAINE2 model, it was created without continuous interaction with state planners and representatives of the oil industry and other interested groups. Without the

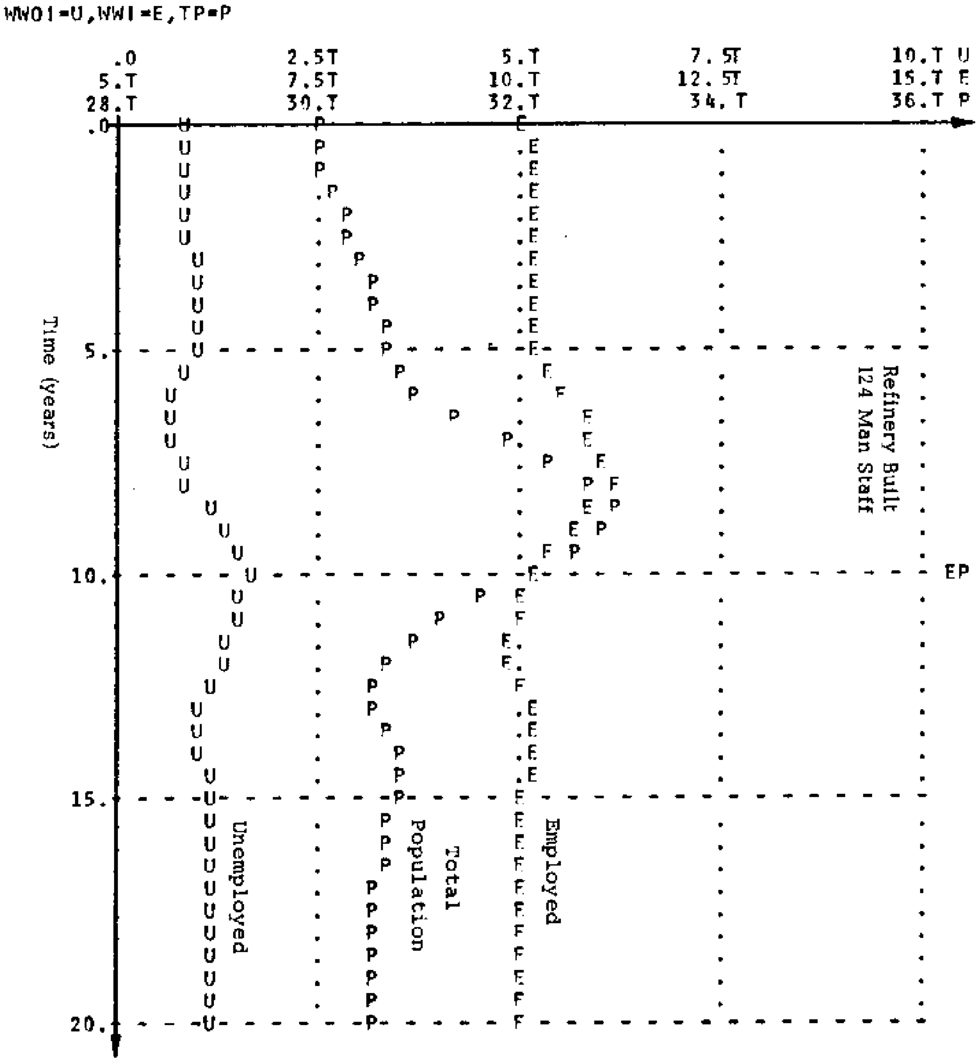

FIGURE 8.10. Employment Predictions for a 124-Worker Refinery

counsel of people with extensive experience, a fundamental structural oversight or misinterpretation could go unnoticed. Consequently, the system's dynamics may be misrepresented and the projections false.

Uncertainty in parameter values has not been addressed in MAINE2.

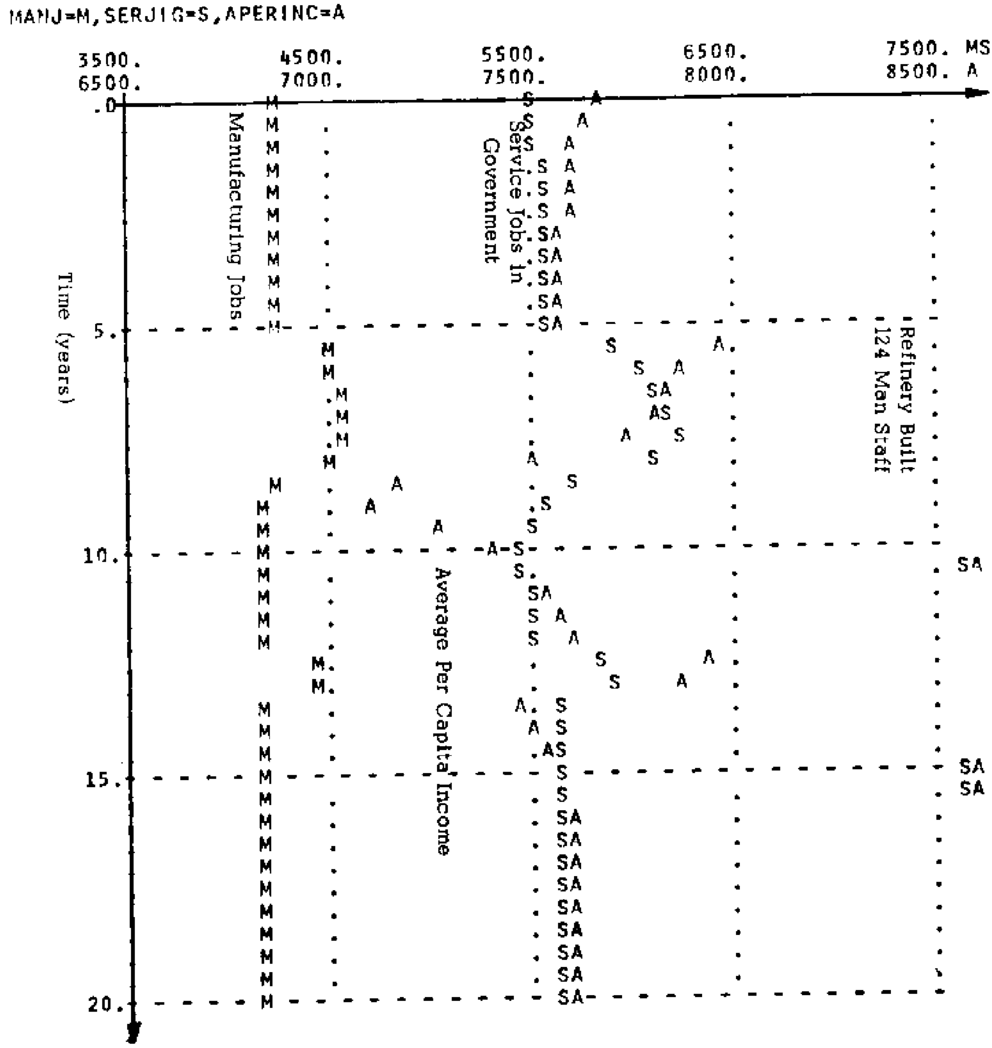

FIGURE 8.11. Job and Income Predictions for a 124-Worker Refinery

For that reason, it cannot be assumed that the values predicted in the computer outputs will exactly parallel reality, even if the model structure is correct. It is therefore futile to look for an expected change of, say, 0.1 percent in the value of a given indicator. The model can only show trends.

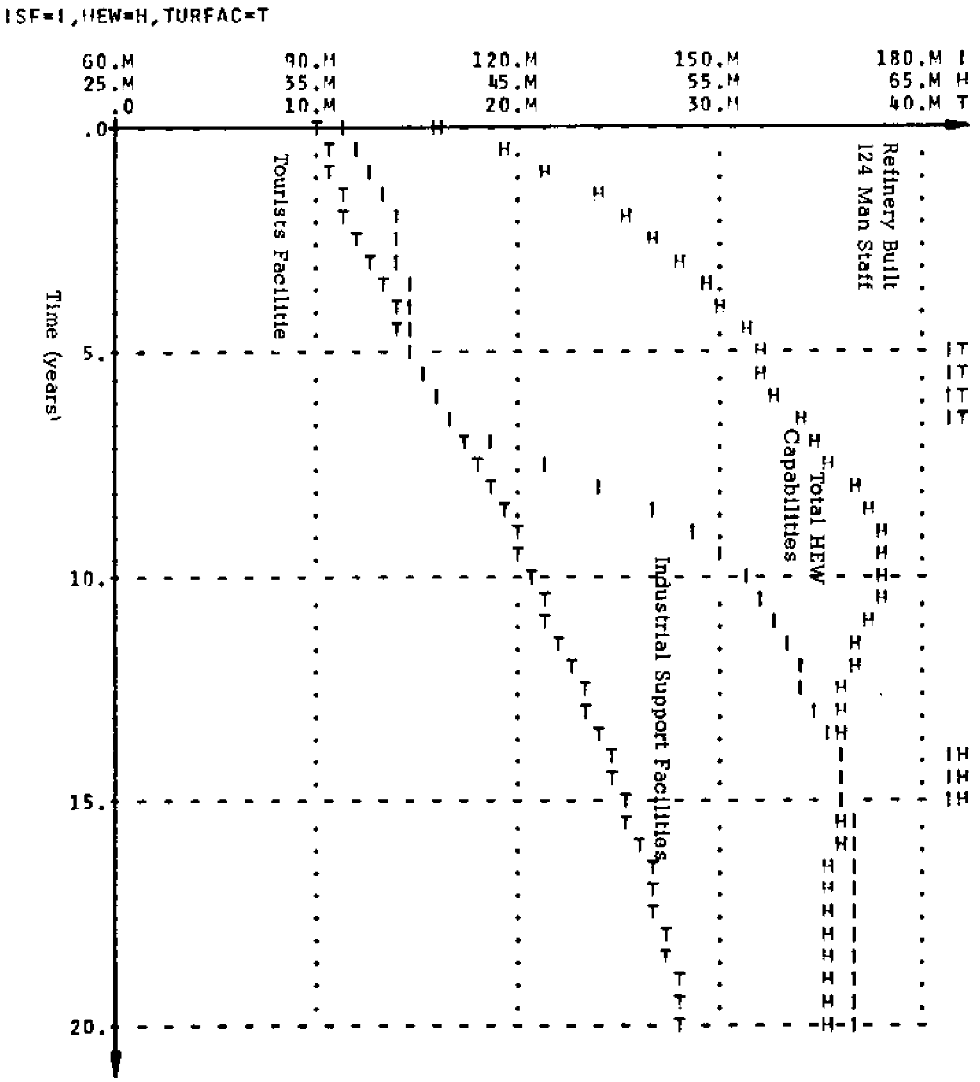

FIGURE 8.12. Government-Services Predictions for a 124-Worker Refinery

We have seen in this study that the total number of manufacturing jobs in the area can either increase or decrease as a result of building the refinery. We have an indication that the refinery at the low staffing level would not have significant positive effects on economic activity in the area. But if on the basis of this indication we projected a certain number of net jobs gained or lost, our findings would have no validity.

Economic activity has been the item stressed in this model, even though conditions such as pollution have been taken into account. A more realistic procedure for Maine residents might be to make the critical indicator a composite variable called "quality of life." Problems arise with this approach, though, because the components of such a variable and the weights given to them are open to much debate. Income, on the other hand, while not reflecting all aspects of life in Washington County, is an easily interpreted item -- X dollars.

MAINE2 was developed to study a particular situation -- an oil refinery in Washington County. It is not clear how useful it would be in studying other problems. This lack of transferability is a result of the editing process associated with constructing the model. For example, only those data associated with state taxes which were relevant to the original question were included. Had the focus of the study been the state tax policy, an entirely different structure for this section would have been developed.

A model of this type is a vehicle for information exchange on, and an understanding of the processes involved with, change. Uniformed or misguided use of a model will be counterproductive at best. Used as a tool in a knowledgeable manner, however, the model can prove valuable in helping the policy-maker perform his task.

Part III THE SIMULATION GAME

Chapter 9 GAMES

THE USES OF GAMES

There is much controversy over the benefits of playing games, especially explicitly educational games. Advocates contend that educational games actually make the learning process more efficient. Opponents argue that the only improvement brought about by introducing teaching games into the school curriculum is an observable increase in student enthusiasm. (Perhaps that benefit in itself, however, is enough to justify their use.)

Most people will agree, though, that games in general definitely do have very practical uses. The reasons why people play games include these:

1. to gain personal satisfaction
2. to reduce tension
3. to stimulate physical development
4. to provide a temporary leave of absence from reality
5. to use chance as a way of making decisions
6. to prepare for future experiences.

Games such as chess or poker can become almost incredibly involved. Each player has to make decisions, keeping in mind not only his own objectives and strategy, but also the strategy and disposition of the other player(s).

The sources for much of the information in this chapter are Barton (1970) and Avedon and Sutton-Smith (1971).

Complex interactions create a playing environment in which no one player ever has total control of the game. Games like these provide a splendid testing ground for the theories of behaviorists.

Studies have shown that half of the 95 most popular present-day games are based on acts of communication, transportation, or warfare. Surprisingly, purely recreational activities are the origin of only 15 percent. Religion can claim to be the source of another 10 percent. The remaining 25 percent have yet to be classified.

Military science based its early games on table games like chess. Business and industry games evolved from these war games and, like the war games, are intended primarily as a means of instruction. According to theoreticians, educational games have their roots in recreational games. The social and behavioral sciences games are derived from both channels.

A game can be characterized by ten basic elements:

1. purpose
2. physical setting
3. equipment needed
4. number of players
5. abilities and skills required
6. procedures for actions
7. rules governing actions
8. roles
9. interaction patterns
10. results.

Competitive factors and time constraints must also be kept in mind. The game becomes complete with the addition of the external element of strategy.

Modern nonathletic games take on a number of formats. Some games consist basically of analysis. Monte Carlo techniques are used in others in which random sampling is a central element. Another type, of which the Maine game presented in the next chapter is an example, is the simulation game that parallels a segment of the real world.

Many fields have adapted games for use in their operations. The military use of games goes back thousands of years. The first war games were concerned with strategy, but during the eighteenth century they became much more tactical. This century has seen a great expansion in the use of games for military purposes. Starting in September 1941, the Japanese played a game simulating a surprise attack on Pearl Harbor. Now, in the United States alone, over sixty organizations are interested in or are engaging in war games.

Business and industrial use of games started with a game by the name of Monopologs, developed by the RAND Corporation in the mid-1950s as part of an attempt to make the Air Force supply system more efficient.

In 1957 the American Management Association developed the first practical business game, Top Management Decision Simulation. Its purpose was "to provide a learning experience in which participants could increase their understanding of the decision-making process" (Greenlaw et al., 1962). Since that time many games have been devised to simulate the dynamics of various aspects of marketing, development, finance, and production.

Education, diagnosis, and therapy are other functions performed by games. Educational games foster communication skills and general development in a wide range of student activity. Crossword puzzles and spelling bees fit in this category. Diagnostic games have been used to study common interpersonal confrontations, marital problems being an example. Games have been designed to facilitate recovery from a physical ailment. These are especially useful in treating children.

THE PURPOSE OF A REGIONAL PLANNING GAME

We have seen that games can take on many different formats and serve many purposes. They can be fun, they can provide a means of keeping mentally or physically fit, and they can be instructive. It is the last attribute on which the Maine game will focus. In this context, a good answer to the question, Why a game? is provided by the following quotation (pertaining to war games):

> Gaming gives full scope to the enemy's actions and reactions, to his capability and his persistence. No staff planner writes a paper showing how his plan will fail and no engineer points out how the weapon system he has designed can be circumvented. These one-sided analyses, replete in the detailed calculations, assume a somewhat chuckleheaded and rather

> friendly enemy who seems quite vague about what he will do later on as the plan or weapon system moves smoothly to success. Gaming, on the contrary, supplies the most hostile of reviews (Paxson, 1963).

With this point of view in mind, the following goals for the Maine game were adopted:

1. to develop a simple but realistic model
2. to emphasize the importance of thinking of actions in terms of their net effects
3. to create a game that would be adaptable (so that parts of the game could be changed easily to suit the special constraints of particular projects) and versatile (so that many different goals and proposals could be studied within the constraints of the game).
4. to show the usefulness of gaming as a tool to aid decision-making in Maine.

Chapter 10 THE MAINE REGIONAL DEVELOPMENT GAME

Planning for regional development is replete with inherent difficulties. Its problems may be unwieldy, misperceived, or difficult in any number of ways. REDEV, the regional development game, provides a mechanism by which such problems can be approached in a reasonable manner and thus be made more manageable. The game has a loose format and permits much flexibility in pursuing elusive solutions to planning problems. It provides a means of focusing the knowledge and experience of the players on the actual problems of the area.

AN OVERVIEW OF REDEV

This chapter describes briefly the way REDEV is played. Succeeding chapters will offer a more complete discussion of the rules and an account of the actual play of the game.

The format of REDEV is in some ways similar to that of Monopoly. The participants in Monopoly, playing on a forty-block ring around a square board, wheel and deal to determine which of them will have the most money and property at the end of the game. The players have several strategic options. They can concentrate on buying as much property as possible or on developing the properties they own or, if they are lucky, on both.

The players must, however, work within a strict budget (their initial capital plus $200 for each complete trip around the board). In addition to being dependent on the throw of the dice, they are subject to further chance occurrences about 10 percent of the time, since landing on any one of four of the board squares results in either a Community Chest or a Chance card. Some of these cards help and others hurt the chances of the player who draws them. Property can be mortgaged to obtain emergency funds or can be sold or traded. As simple as the game of Monopoly is, it provides a method of studying the results of various strategies used to develop the property on the game map.

REDEV is also concerned with developing property. But the nature of the game, its actions and goals, are not defined until the players come together to study the particular problem or set of problems at hand. In REDEV, the players must analyze the region of interest and the nature of its problems or potential problems. Once the problems are defined, a set of conditions that the players agree would constitute a solution to the problems is adopted as the goal toward which game action is directed. The players work through a series of business and legislative programs developing, or not developing the region they have characterized on the game board.

As in Monopoly, a budget places constraints on the players, and chance events do occur. After five rounds of play, simulating, say, 25 years in real time, the game ends, and a careful analysis of the dynamics of the play by the participants completes the exercise.

The participants may choose to play the game more than once. Replaying allows different strategies to be tried and provides knowledge about the relative merits of alternative development plans.

REDEV is remarkably realistic when it is played seriously. It is not a magic device that will offer absolute truths or guarantee solutions with just a casual involvement of the participants. Rather, a rewarding, useful experience requires from the players not only an eager, committed effort to explore and understand the complex nature of regional development but also the conviction that by conscientiously playing the game they can actually achieve a usable result. Both serious planning and imaginative thinking are needed.

THE GAME MAP

A sample game map used during a play of REDEV appears in figure 10.1. It differs from the Monopoly board in that it does not have a fixed route around which players must move. It is, however, where property is

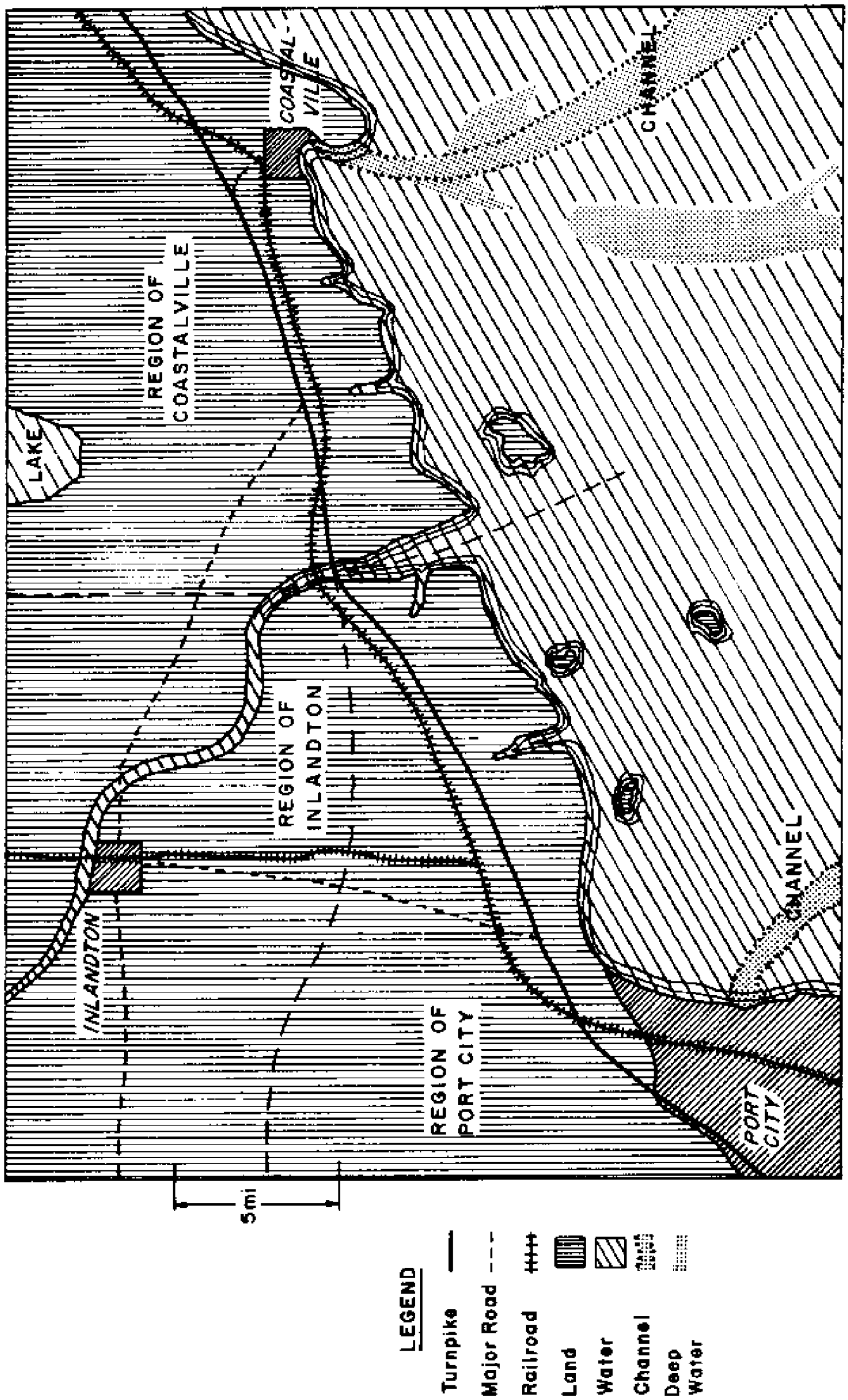

FIGURE 10.1. Game Map for REDEV

developed in accordance with the schedules given for projects. These schedules appear on project cards, REDEV's parallel to the deeds used in Monopoly. Like the Monopoly deeds, the REDEV cards also note the costs of developing the property.

The map incorporates the basic features of the area to be examined during the game. In the version of the game presented in this and the following chapters, it depicts a large coastal city (Port City), a small coastal town (Coastalville), and a small inland town (Inlandton), which are representative of the coastal area of Maine. Supporting geography and facilities have been included on the map.

GAME PERSONNEL AND PROCEDURES

The roles played by the participants in REDEV are those of two businessmen, two legislators, three social evaluators, and one controller.* One business player (BB) represents the business and industrial interests of Port City and the surrounding area, while the other (SB) represents those of Inlandton, Coastalville, and adjacent regions. (The first B and S in these designations simply stand for "big" and "small.") They command potentially equal resources. The limits of their resources, which are their budgetary constraints, are determined by the business climate in their region.

The business players can work individually or together. They can also enter into joint ventures with the legislators. Their primary concern is to take advantage of the assets of the region in such a manner that the interests of both new and old business are best served. This does not necessarily mean that the business players work to develop the region. They may choose to follow a no-growth, no-change policy.

The two legislators represent the needs and desires of the people of the area, especially those of the permanent residents. Like the business players, one legislator (BL) represents Port City and the outlying area, while the other (SL) represents the remaining territory. Unlike the business players, they operate from two different resource bases, which are a function of the number of people represented and the amount of money avail-

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* The role format can, of course, be changed if the game is based on a region better characterized by some other group of actors.

able from taxes. In this particular version of the game as developed for Maine, these two legislators together determine state priorities and implement as well as develop the state's plans for the area.

Rather than having their actions determined by throwing dice, the players in turn either choose a project from an existing pool of possibilities or make up a new project designed to bring conditions within their area of interest closer to their stated goals.

Descriptions of possible projects in the pool are written on project cards. Each card presents general information about the project, as well as its cost, the difficulties to be expected in getting the project accepted, and the anticipated effects of the project should it be implemented.

The existing set of projects is reviewed by all the participants before the start of the game. If the projects are inadequate for or irrelevant to the specific region, the players make up new project cards. And if, as the game proceeds, these projects in turn prove to be inadequate or irrelevant, the players have the option, as was stated before, of devising additional ones.

In order to model the uncertainties of real life, chance occurrences are also included in the workings of the game. Exogenous-event cards (paralleling Monopoly's Chance cards) are similar to project cards in content, but they are not introduced into the game by the player's choice. They are randomly chosen and immediately implemented after player projects have been determined.

As with the project cards, participants review the existing pool of exogenous-event cards, before play begins, to determine if the type and magnitude of surprise events are relevant to life in the region. If they are not, a realistic set is devised before the start of the game.

REDEV uses indicators in eleven areas to track conditions in the various subregions shown on the board:

1. education
2. medical care
3. business activity
4. quality of life
5. environment
6. government effectiveness
7. employment

8. transportation
9. recreation
10. crime prevention
11. population.

Initial conditions, goals, and changes resulting from the game are evaluated in terms of these indicators. All project and exogenous-event cards include suggestions as to how each indicator would be affected by the implementation of the project or the impact of the unplanned event.

The three participants who are social evaluators (SE) are essential to the game. They are the impartial judges who tell the players how they are progressing. They do this by translating the implemented projects and experienced chance events into changes in the values of the eleven indicator areas. Their other task is to make the probability-dependent decisions in the game, i.e., the acceptance of proposed projects and the determination of exogenous events.

The person who fulfills the remaining function is called the controller (CONT). This person handles all numbers, carries out the procedure for setting initial conditions and goals, determines player point allotments for each round, and has the final say on the point-cost and difficulty factors of project proposals. To expedite the play of the game, the controller has the final authority to interpret the rules and to settle disputes in any case not covered by the rules.

THE GAME FLOW

The general outline of play of the game can be best described by a flow chart. Figure 10.2 is a schematic diagram of the game flow.

As can be seen, the first task of the entire group of participants is to determine for each town the present values of the eleven indicators. The average of the town values as determined by the group is computed and is used as the initial condition of that indicator for the play of the game.

In the next phase of the game, the legislative and business players analyze these initial conditions to determine the level at which they would realistically like to see the region's indicators after five rounds of play (representing 25 years of real time). At the same time they are setting these goals, the controller determines the players' point allotments for the first round.

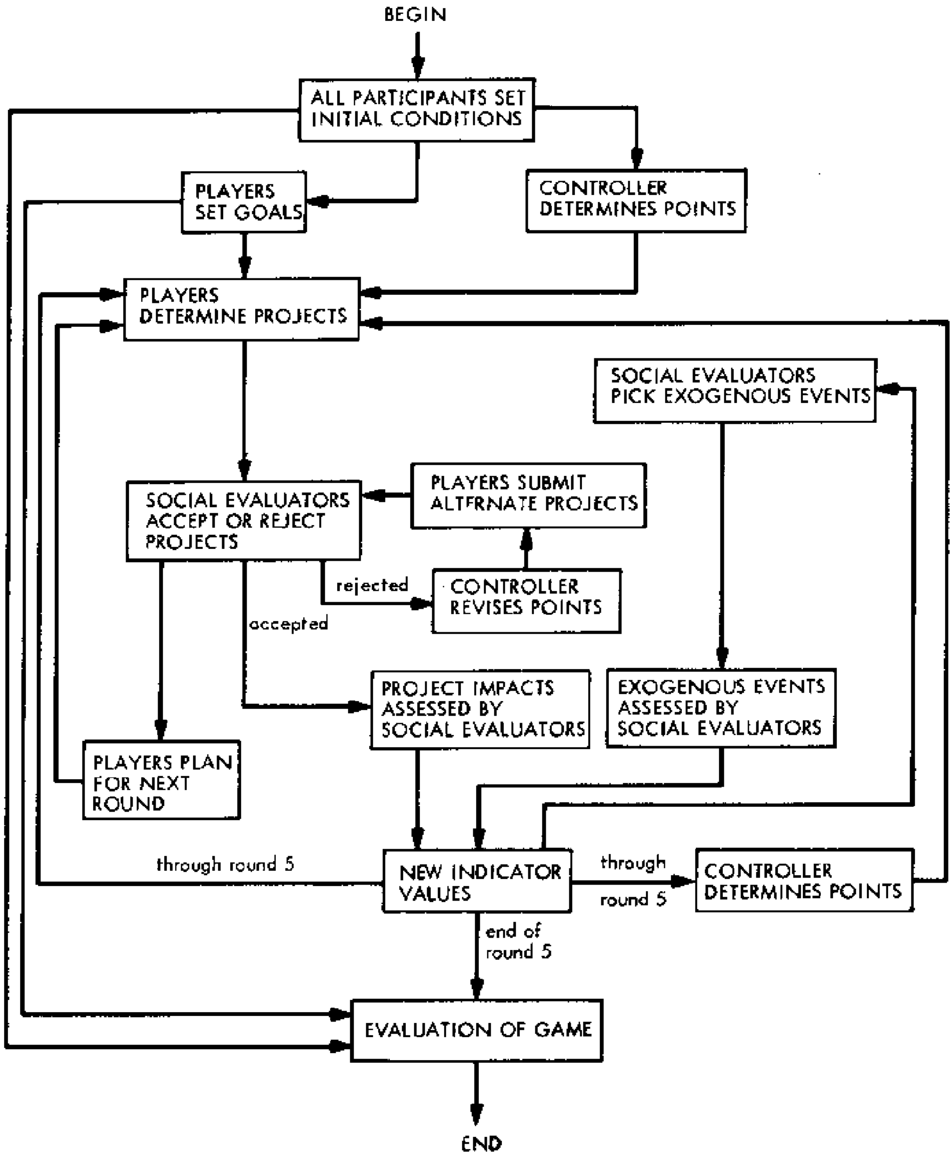

FIGURE 10.2. REDEV Game Flow

Next, the business and legislative players plan their projects for the first round of play. The players can converse, bargain, debate, or work together. Borrowing, joint actions, and exchanging points are encouraged. As each project is proposed, the social evaluators roll dice to determine if it is accepted. If it is not, the player proposing the rejected project will get back 90 percent of its point cost for use on other projects in that round. The social evaluators also decide what exogenous-event cards are to be used.

The effects of projects that have been accepted are determined by the social evaluators after careful discussion among themselves. Once all the projects have been evaluated, the exogenous events are introduced and similarly evaluated. Finally, the controller and the social evaluators modify the board and all supplementary charts and graphs used for bookkeeping so as to reflect the new conditions. The next round begins with the players returning to the planning stage.

EVALUATION

At the end of five rounds, play is stopped. All game personnel are requested to look at what happened to the region as a result of actions taken during the play of the game. During this post-play analysis, answers to questions such as the following should be forthcoming:

1. Were the original goals realistic?
2. What are the reasons for their being met or not met?
3. Is the outcome desirable?
4. If not, how could it be improved?

Chapter 11 GAME RULES

This chapter offers a detailed description of the Maine version of REDEV. Explanations of the various cards and graphs and how they are used in the game appear, in addition to an outline of instructions for the game participants.

THE GAME MAP

A map of a typical coastal area is included as a visual aid (see figure 10.1). It provides a consistent framework from which all players can work. Three cities are included: Port City, with a population of 60,000; Inlandton, population 3,000, and Coastalville, population 2,500. Its other features are

1. a turnpike roughly paralleling the coast
2. roads and railroads linking the cities
3. deep-water channels leading to Port City and Coastalville
4. a river bordering Inlandton
5. a lake in the region of Coastalville
6. islands off the coast.

The original game map was drawn to a scale of 2 1/2 miles to the inch. From the center of Port City it is roughly 22 miles to the center of Inlandton and approximately 30 miles to the center of Coastalville. Plastic overlays were included with the map so that project sites could be added or notes be made directly on the area of interest.

The game map is drawn so as to reflect the characteristics of the area to be studied. Placement and size of cities, scale factors, and other characteristics can be changed appropriately to model whatever area is under study.

SOCIAL INDICATORS

As explained earlier, the game uses eleven social indicators to note the state of affairs in each of the regions of interest shown on the map. This group is by no means the only combination of the many indices that could be used to describe the condition of a region. However, these indicators do represent a broad spectrum of interesting, informative parameters without being so numerous as to burden the gaming process unnecessarily.

The definition of each indicator is as follows:

1. Education:	the present quantity and quality of educational facilities and services, together with the residents' satisfaction with these.
2. Medical care:	the quantity and quality of medical facilities and personnel; satisfaction with these.
3. Business activity:	the ability of business and industry to grow and to implement new projects, a function of present prosperity, related to profits of existing business.
4. Quality of life:	the standard of living; the availability of various desired facilities and services.
5. Environment:	the quality of the physical environment of the area, including the negative effects of pollution.
6. Government effectiveness:	the ability of the government to continue to implement new projects, which is affected by both the availability of funds and the present and future levels of spending on existing facilities and services.

7.	Employment:	the level of employment.
8.	Transportation:	the level and quality of services on all modes of transportation; the availability of access routes and public transit facilities.
9.	Recreation:	the quality, availability, and attractiveness of recreational facilities and services in the area.
10.	Crime prevention:	the effectiveness of the police, the judicial process, and penal institutions in preventing criminal acts.
11.	Population:	the number of people living in the area.

All indicators are noted on a scale from 0 to 100, with the exception of those for employment and population. The scale values correspond to qualitative terms according to the following schedule:

0	-	the worst possible condition
25	-	critically poor
50	-	average
75	-	very good
100	-	perfection.

The employment scale is as follows:

scale value	percentage of unemployment
0	16
25	12
50	8
75	4
100	0

The population indicator is the actual population level.

The vagueness of the terms is intentional; it is very hard to rate these indicators accurately. However, relative size and direction of change are more important to the game than are absolute values and can be clearly shown by the social indicators.

INDICATOR SCORE CARDS

Two score cards dealing with the social indicators are used in the game. The first is an initial-condition and goal card. Players use this card as a quick reminder of where they started and where they want to go (figure 11.1). For example, in one play of the game the participants determined that the initial condition (IC) for education for the town of Coastalville was 25. The legislator (SL) and businessman (SB) dealing with this area set their twenty-five-year goals for education to be 75 and 50, respectively.

The second indicator card notes trends in the social indicators as the game progresses (see figure 11.2). Once again the eleven indicators associated with a 0-100 point scale are shown, but another dimension, time, has been added so that the results of all five rounds can be graphically presented. An enlargement of a section of the card shown in figure 11.2 appears in figure 11.3. The initial condition and goals that appeared in figure 11.1 are indicated:

initial condition (IC)	-	25
businessman's goal (SB)	-	50
legislator's goal (SL)	-	75

Horizontal lines have been drawn at these three levels to allow players to ascertain the status of the area quickly.

As results of the various rounds are determined, changes in the indicators are noted. For example, if education in Coastalville should rise 10 points after the first round of play and another 5 after the second, the chart would then take on the appearance shown in figure 11.4. Effects of the last three rounds would be entered in the remaining space.

THE PROJECT RATING SYSTEM

A dual rating system is used to categorize all actions in a standard reference frame. By using a point system, the necessary budget constraint mechanism and its associated dynamics are included. A receptiveness factor determines the probability of the project's being implemented once the constraint prerequisites are met. It represents the uncertainty associated

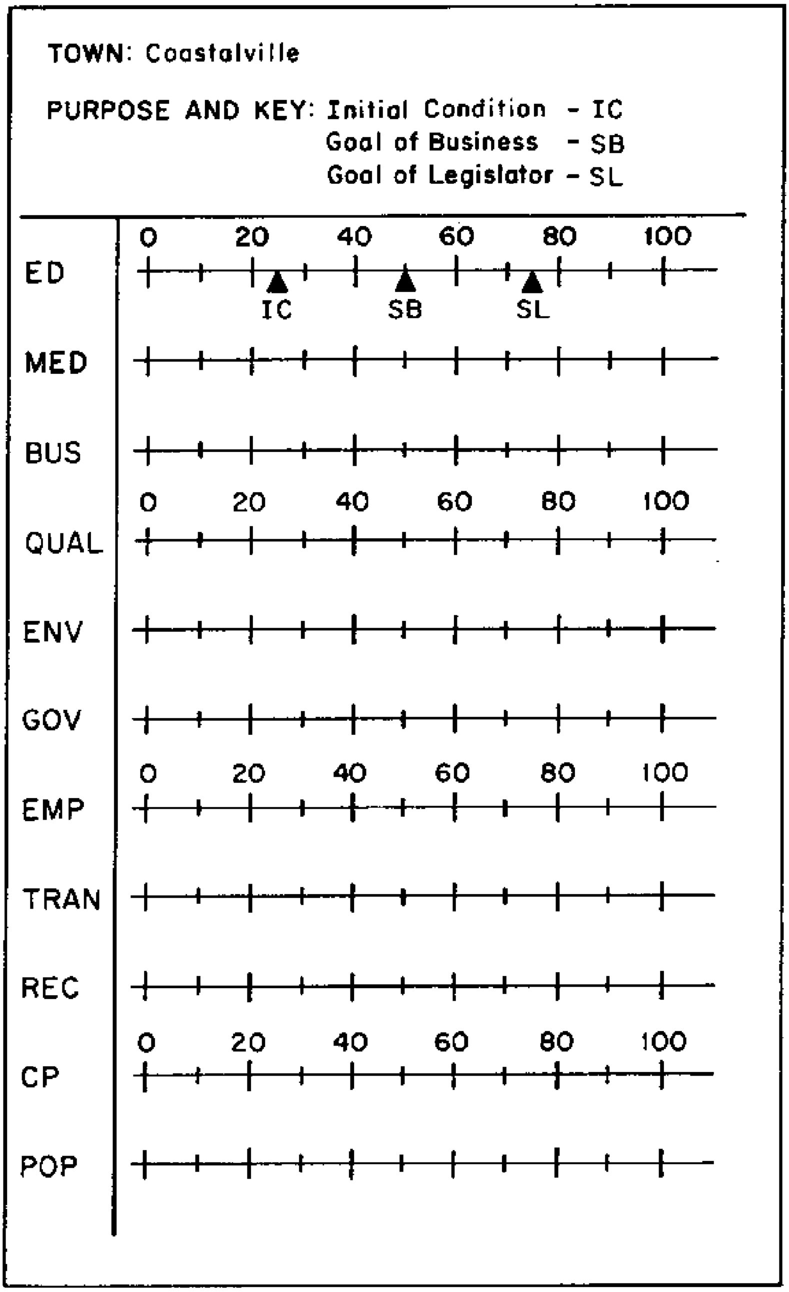

FIGURE 11.1. Initial Condition and Goal Card

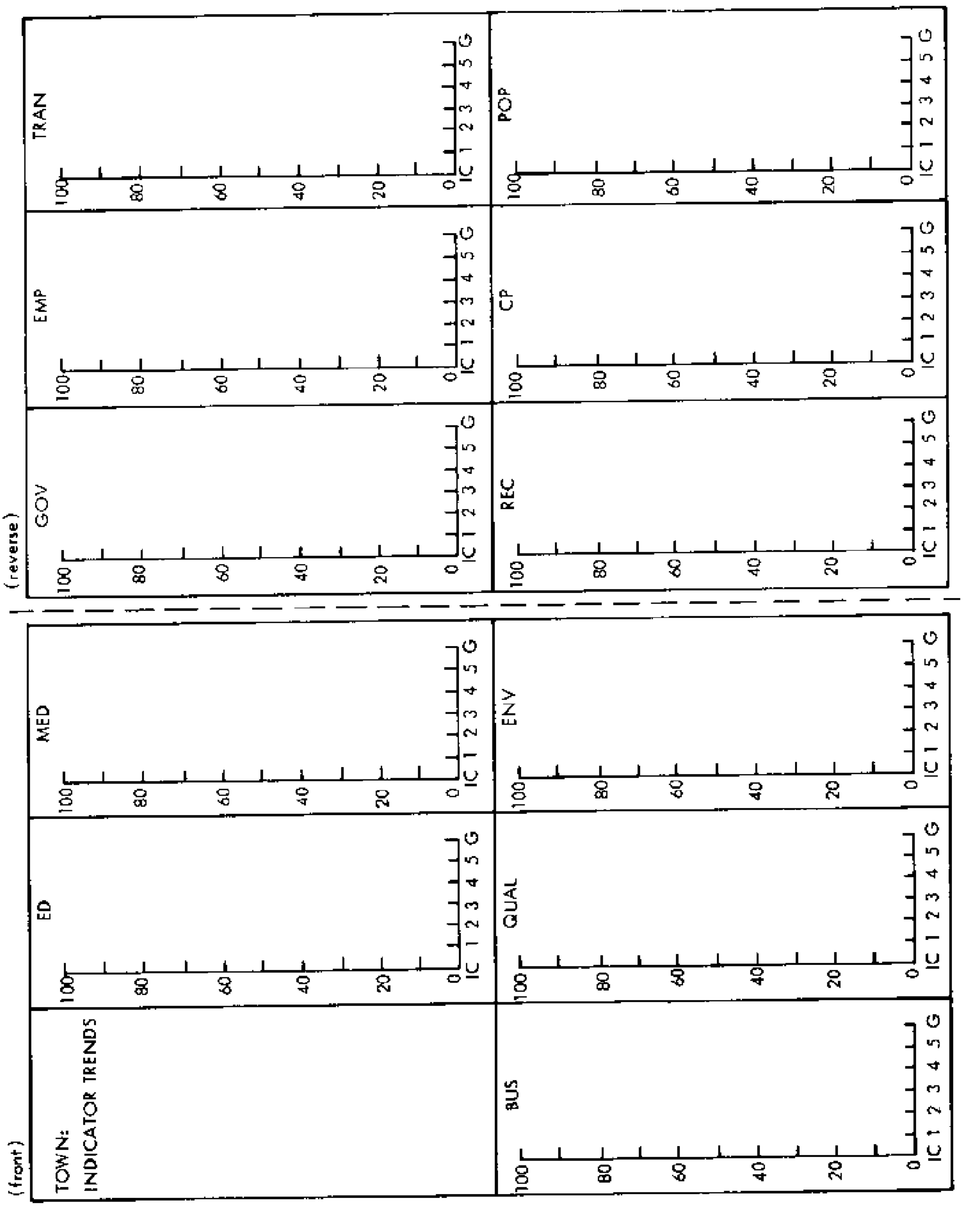

FIGURE 11.2. Indicator Trends Card

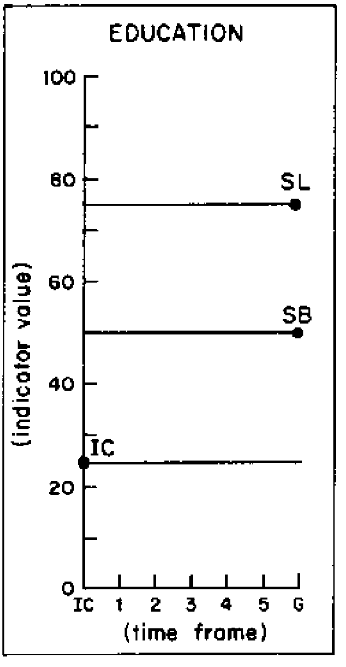

FIGURE 11. 3. Education Section of Indicator Trends Card

with successfully bringing a project from conception to completion.

Mechanics of the Point System

The first rating given to a project reflects the money cost to the player initiating the project. Because of such financial sources as federal subsidies, which are not included in these net costs to the players, the cost of many projects is rated very low. The point cost of the projects implemented in a round by a player must be no greater than the budget allotted to him for that round, unless he borrows from another player.

Cost points are determined by use of the business and government indicators and a point allotment chart (figure 11. 5). The relevant index is used as the "present condition," and the budgeted points are read from the appropriate vertical scale.

For example, to obtain the budget for the legislator from Port City,

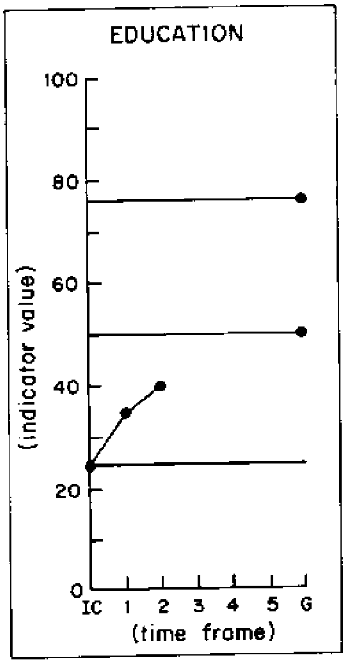

FIGURE 11.4. Education Section After Two Rounds of Play

the government index for Port City (40) would be used as the "present condition." A vertical line would be drawn from this point on the Present Condition scale. A horizontal line drawn from the point at which the vertical line crosses the curve to the City Government scale indicates the budget for Port City for the next round.

The shape of the curve is arbitrary. If the players want to change it they do so at the beginning of play. The same is true of the specific value of points on the vertical scales. If the players feel that different scales would make the simulation more realistic for their situation, they then make the appropriate changes.

To obtain the index value for the state government points, an average value of the government index of the three cities is used. The state's point scale should reflect the size of allocations to the area which could be reasonably expected from the total state budget, considering the importance of the three areas in the game relative to the state as a whole.

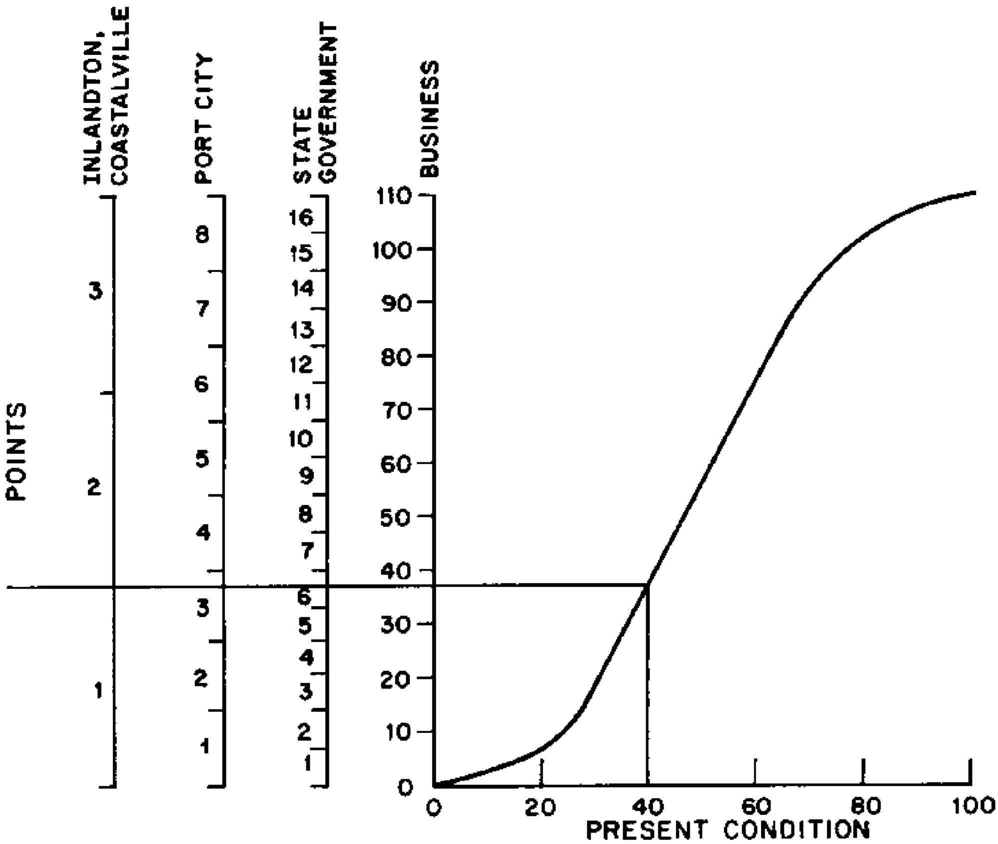

FIGURE 11.5. Point Allotment Chart

The index for the business player dealing with Inlandton and Coastalville is an average of business indices for the two towns.

The range of points on the government scales reflects the amount of funds that are uncommitted to present or future programs.

The range of points on the business scale reflects the amount of capital available for new project implementation. The shape of the curve given earlier assumes that little capital will be available until the area becomes economically attractive.

Points are allotted round by round. They can be used, given away, borrowed, or lent. However, they may not be saved for action in succeeding rounds. The only manner by which points can be transferred from one round to another is by the repayment of a loan. The terms of the loan will be set by the principals involved. Note that loans can be taken in the fifth round, but repayment must be considered when evaluating the outcome of the simulation.

In order to facilitate the paperwork associated with keeping track of points, the controller uses a standard form for each round. All point allotments, transactions, and expenditures for each player can be neatly kept on a form such as the one shown in figure 11.6.

Receptiveness Rating

A second rating deals with a receptiveness factor. It accounts for such things as the possibility that even though the monetary costs of a project are low and the project is strongly desired by one group, the opposition of another group may make the project hard to implement.

The receptiveness rating assigned to each project appears as a letter code. An "A" project is likely to be accepted, while a "C" project is not. Chance, however, finally determines acceptance. A social evaluator makes the determination by throwing dice. Any roll of two dice totalling from 2 to 11 points means acceptance for a project rated A. A project rated C is accepted only if the dice total 2, 3, or 4. For a B-rated project to be accepted, the throw can total any number of points from 2 through 8.

If a project is accepted, it is put aside until all projects for that round have been rated. Accepted projects are then evaluated together. Should a project be rejected, points are returned to the initiator according to the procedure described in a following section dealing with the controller.

PROJECT CARDS

Associated with every project is a set of conditions that must be met before the project can be implemented. Also, certain consequences follow from every project once it is implemented. The project card presents information on these conditions and consequences in a concise manner.

For ease of handling and for clarity in presenting information, a formatted 5" x 8" card was developed (figure 11.7). It is compact, but yet has enough space to contain the information needed for the game.

POINT SHEET

ROUND

	BB	SB	BL	SL_I*	SL_C**	2L***
Prior to Round 1. Debts and interest from previous round						
2. Points from graph						
Total of 1 and 2						
3. State point split						
4. Points given freely						
5. Points received freely						
6. Points loaned out						
7. Points borrowed						
Debt schedule						
8. Balance for round (sum of 3,4,5,6,7)						
9. Total spent (sum of projects)						
10. Point difference 8-9						
11. Points left after refusal of action (90% of project cost)						
Balance of 10 and 11						
Total spent						

* Points derived from Inlandton

** Points derived from Coastalville

*** State government

FIGURE 11.6. Controller's Record Form

PLAYER: PROJECT# : RECEPTIVENESS:

PROJECT AND OBJECTIVES:

REMARKS:

MINIMUM POINT SCHEDULE						
Round	1	2	3	4	5	
Suggestion						
Player						

	ED	MED	BUS	QUAL	ENV	GOV	EMP	TRAN	REC	CP	POP
Suggestion											
Player											

FIGURE 11.7. Project Card

Along the top of the card the player, project number, and receptiveness rating are listed. All players may not be able to or, for that matter, may not want to implement a given project. Therefore, the player who is most interested in the project and would probably introduce it is listed. As projects are coded onto project cards they receive a sequential number. It appears as "Project #" and is used only as a bookkeeping aid. The third heading notes the probability of acceptance, A, B, or C.

The main body of the project card contains a description of the project and a brief statement of its primary objectives and expected effects. Any special conditions for implementation or unique consequences of implementation are included under "Remarks." The remainder of the card deals with costs and effects.

The "Minimum Point Schedule" lists the number of points that are required to implement the project. These points are listed in the "Suggestion" row. More than the listed minimum can be used, and it is up to the social evaluators to judge the appropriateness of such an action.

The schedule has space for five rounds, but most projects will show expenses for only the first round. For the sake of simplicity, it will be assumed that the points available in each round are new and uncommitted. New projects will require an initial outlay and continuing commitment in subsequent rounds. The effects of inflation and existing budget expenditures are excluded; consequently the only cases in which point costs occur other than in the round of implementation are those in which the project is multistaged or expanding.

Should the players disagree with the suggested point schedule, space has been provided for their judgments on point costs.

The bottom part of the project card lists the expected effects on the indicators in the region where the project is implemented. Once again, values are given in the "Suggestion" row, and there are spaces in which the players can add their input. A positive number in one of the boxes means that the particular indicator would be increased by that amount, should the project be implemented. A negative number decreases the indicator's value. Should a plus or a minus appear with no number, it means that the direction of the effects of the project are known but their size is unknown. A blank indicates that no effect is expected.

An immediate change in indicator values after implementation is the primary effect of a project. It is then carried for the rest of the game. However, the project may not continue to be effective over a long period of time, or, on the other hand, its effectiveness may actually increase with time. Should changes in the effects of a project be felt in ensuing rounds, an asterisk will appear in the box or boxes of the indicator(s), and an explanation will appear on the reverse side of the card. Also, should a project affect geographical areas other than the one in which it is located, the effects would be noted in the same manner.

An example of an actual project card is shown in figure 11.8. It describes the objectives, costs, and expected effects of starting a trucking company in one of the three regions shown on the game map.

Specifically, the following information is contained on the card:

1. Players SB or BB are most likely to initiate such a project.
2. The project number assigned is 1.
3. The project has a B receptiveness rating.

PLAYER: SB or BB PROJECT # : 1 RECEPTIVENESS: B

PROJECT AND OBJECTIVES:

Start a trucking company to serve the three regions shown on the game map as well as adjacent areas.

The firm will, it is hoped, not only meet existing needs for highway shipping but also make the area more attractive to other companies because of better transportation at a lower cost.

REMARKS:

MINIMUM POINT SCHEDULE

Round	1	2	3	4	5	
Suggestion	15					
Player						

	ED	MED	BUS	QUAL	ENV	GOV	EMP	TRAN	REC	CP	POP
Suggestion			+2			+1	+1	-2			
Player											

(reverse)

BUS: + trend expected in next two seconds.

FIGURE 11.8. Project Card for Proposed Trucking Company

4. The proposed firm would serve all three regions of the game map, as well as adjacent areas.
5. The firm not only would meet existing needs, but would also, it is hoped, make the area more attractive.
6. The project would cost 15 points in the first round. It is assumed that the firm would not require any further input of points in succeeding rounds.
7. The expected changes to indicators affected by such a project at the end of the first round would be these: business +2,

government +1, employment +1, transportation -2.

8. It is expected that the project would augment the business indicator in the two succeeding rounds as well.

Players may introduce their own projects, rather than choosing them from the established pool. Should they desire to do so, a blank project card is filled out following the pattern just described. Point schedules as well as the general feasibility of the project are subject to review by the controller.

EXOGENOUS-EVENT AND AUXILIARY CARDS

Some method of introducing the unexpected and unpredictable must be included in the game if it is to parallel real life. By such a method, the way that uncertainty about the future affects planning can be shown.

Like the project cards, the exogenous-event cards specify external or chance events in a standard format (figure 11.9). Basic information appears

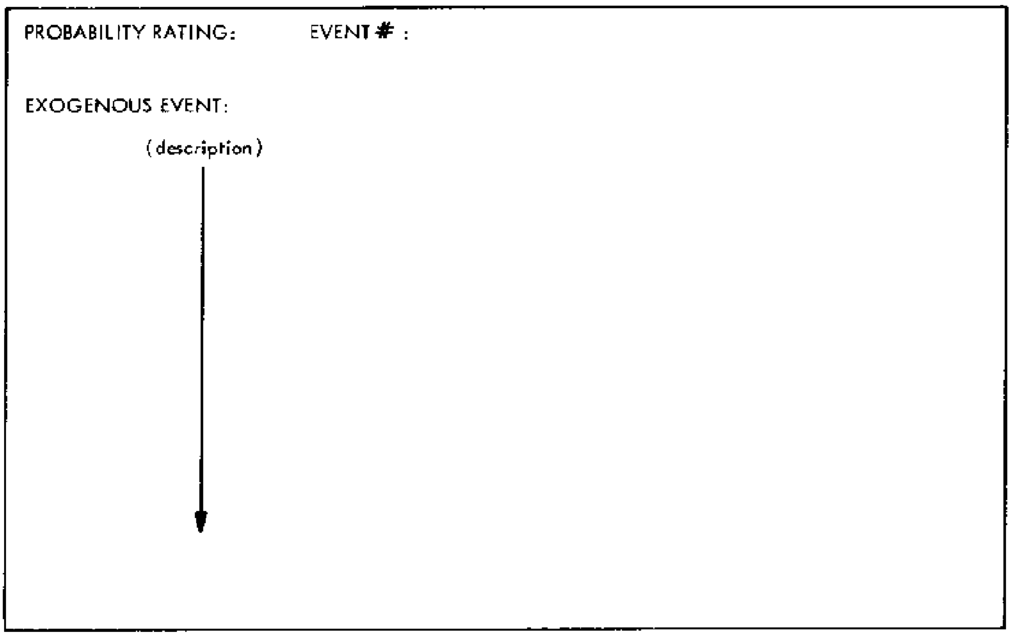

FIGURE 11.9. Exogenous-Event Card

at the top of the card: (1) probability of occurrence, (2) title of the event, and (3) an identification number. The main body of the card contains a description of the event and its probable impact.

Three ratings are used: (1) Very Probable, (2) Probable, and (3) Unlikely. These ratings are derived from the number of auxiliary cards related to the event. The auxiliary cards are simply a device for determining the probability of exogenous events and have no content of their own. From one to three such cards are made up for each event. Each card carries only the number of one of the exogenous events and an indication of whether it is the first, second, or third card associated with the event. The cards are shuffled and combined into a deck.

An exogenous event rated Very Probable would have three auxiliary cards in the deck, an event rated Probable would have two, and one rated Unlikely would have only one.

For an exogenous event to be considered as having occurred in a round of play, one of its auxiliary cards must be drawn during that round. So that the game is not overloaded with exogenous events, only three auxiliary cards are drawn during each round. Should two auxiliaries from the same event be chosen, the second is disregarded and a replacement is drawn.

An example of an exogenous-event card appears in figure 11.10. It is event #21 in the listing of exogenous events provided with the Maine version of REDEV and is entitled "Megalopolitan Spread."

The text has several parts. First, a brief explanation of the megalopolitan spread northward is offered. Next, the primary effects of such an event are given, along with further explanation. The text continues with suggestions as to what secondary effects might be important. Finally, a suggestion is made as to how the social evaluators might extend the scope of the exogenous event should they desire to do so.

The event is adequately described for the purposes of this game. Details necessary for evaluation are explicitly stated. Participant-initiated exogenous-event cards introduced during the game would follow this pattern.

The upper left-hand corner of the Megalopolitan Spread card contains its probability rating -- Probable. According to the guidelines described earlier, it would have two cards in the auxiliary deck, one of which would have to be drawn for the event to occur.

PROBABILITY RATING: EVENT # : 21

Probable

EXOGENOUS EVENT: Megalopolitan Spread

Because of increases in national population and changes in lifestyles, the megalopolis that now encompasses Boston, New York, Baltimore, and Washington is spreading northward.

This expansion is first felt in a five-year increase in tourist trade (and a decline in quality of recreation, unless other events intervene). The population of Port City begins to grow, and the business index leaps upward some 15 points this period.

If transportation to the south is improved, commerce will increase and business will improve still further. There is pressure for this action. Land speculation is rampant, and Port City is becoming a boom town. Pollution and crime increase. Firms are looking for new sites.

The social evaluators will determine whether and how this trend will continue through the rest of the game. Pay attention to the changing demographic base and the secondary effects of the population increase. You may wish to simulate some national actions.

FIGURE 11.10. Exogenous-Event Card for Megalopolitan Spread

GAME PERSONNEL

The minimum number of participants required to play this version of the game is eight. They play the following roles: two representatives of business interests, two legislators, three social evaluators, and one controller.

The Business Players

Territories. One player (BB) represents the business and industrial interests of Port City and the surrounding region. The other player (SB) represents those of Inlandton, Coastalville, and their surrounding regions.

Points. The business players are alloted points from the graph used by the controller. The point allotment of player BB is a function of the business index for Port City. Player SB's allotment is a function of the average of the business indices for Inlandton and Coastalville.

Duties. The duties of the business players are to serve the interests of business in the regions (1) by implementing projects designed to improve the business climate and the economic well-being of the people and (2) by taking whatever additional steps are necessary to preserve the status of business.

Actions. The business players can (1) create new project cards, (2) create new exogenous-event cards, and (3) implement projects from project cards either by direct funding from points delegated to that region by the controller or by making arrangements with the other businessman or with one or both of the legislators to borrow, lend, give, or receive points at a rate set by the players involved. These players may also perform any other function necessary to complete the game, given the arrangements settled upon by the players.

The Legislative Players

Territories. One legislative player (BL) represents Port City and the surrounding region; the other player (SL) represents Inlandton, Coastalville, and their surrounding regions. Together (2L) the players represent the state legislature.

Points. The legislative players are allotted points from a graph used by the controller. The point allotment of player BL is a function of the government index for Port City. Player SL receives two separate grants of points, based on the government indices for Inlandton and Coastalville. The two players acting together as the legislature receive a point allotment that is a function of the average of the three government indices.

Duties. The duties of the two legislators are to serve the people of their regions (1) by implementing projects to meet the needs of the people in the three regions, in accordance with their budgetary constraint, and (2) by taking whatever steps are required to safeguard the region from uncontrolled development, again in accordance with their budgetary constraint.

Actions. The legislative players (1) create new project cards, (2) create new exogenous-event cards, and (3) implement projects from project cards by direct funding from points delegated to the region by the controller, by using state points for a project, or by making some arrangement with the other legislator or with one or both of the business players to borrow, lend, give, or receive points at a rate set by the players involved. They also perform any other function necessary to complete the game, given the arrangements settled upon by the players.

The Social Evaluators

Duties. The three social evaluators (SE) are of equal status. Their duties are (1) to evaluate the effects of all projects and exogenous events, (2) to determine which exogenous events occur, and (3) to determine which projects are accepted.

Actions. The social evaluators use auxiliary cards to determine the occurrence of exogenous events. (Exogenous events occur after the projects for each round have been implemented.) The evaluators determine the acceptance of projects by throwing dice, as described earlier in this chapter. If a project is accepted, the social evaluators notify the proposer. The effects of the project are assessed when all proposals for that round have been made by the players. A project is considered implemented upon its acceptance. If a project is rejected, the social evaluators notify the proposer. The controller is alerted so he or she can make adjustments in point allotments. The rejected project cannot be resubmitted in the round in which it was rejected.

In assessing the impacts of projects, the social evaluators use the indicator change suggestions on the project cards as guides in adjusting the affected indicators. Should the social evaluators feel that the suggested values of indicator adjustment are wrong or inadequate they may (1) make the appropriate changes and explain their action to the players, (2) include additional changes, and (3) alter any of the indicators of regions other than the one in which the project appears, should such a move seem necessary.

It should be remembered that one round of the game is equivalent to an elapsed time of five years. Transient effects are not considered in this simulation unless they are of great magnitude. It is the net effects that are of prime importance.

The Controller

Duties. The controller acts as game moderator. He or she has the final say on rule interpretation and may settle any disputes that arise. In particular, the controller (1) carries out the evaluation of initial conditions,

(2) sets points for players, (3) revises points when projects are rejected, (4) makes sure that budgets are not exceeded, (5) makes sure that any inter-player bargaining is legal, (6) handles all chart modifications, and (7) over-sees the entire game.

Actions. The controller evaluates initial conditions in the following way: All participants (the controller included) are given indicator cards for the three regions on which they indicate what they believe the present conditions of the area to be. The controller averages the eight values obtained. These averages become the initial conditions for each of the eleven indicators in the three areas. (A calculator would be helpful to the controller here.) New indicator cards with the initial conditions are then distributed, and the players are charged with setting their goals for values of the eleven indicators at the end of five rounds of play.

Using the appropriate government or business index, the controller determines the points each player will have for the next round using (1) the initial conditions to determine points for the first round and (2) repositioned indicators from the previous round for rounds 2 through 5.

The controller returns to players whatever points are owing to them after rejection of a project. Should a project be rejected, not all points originally committed to it are available for other projects. In the game version described in this book, the points returned to a player whose project is rejected are 90 percent of the original number, but this rule may be changed at the will of the participants. For projects with expenses in more than one round, points scheduled during the round in which the project is proposed are the only ones that are reduced.

After all projects and exogenous events are evaluated, the controller receives from the social evaluators a list of the total changes to each indicator. The controller makes the appropriate modifications in indicator levels on the indicator cards, according to procedures outlined earlier.

THE SEQUENCE OF PLAY

For play to be efficient the workload of the participants must be balanced. Tasks are scheduled in such a manner as to keep all participants busy during all phases of the game while at the same time not compromising the verisimilitude of the dynamics. The following format is suggested as a means of keeping the length of the game to five hours (figure 11. 11).

Time Slot 1

During the first phase, all participants determine the initial values for the eleven indicators used to describe the status of the three regions. While the controller carries out the formalities associated with determining the actual initial conditions and filling out the appropriate forms, all other participants should be familiarizing themselves with the projects included with the game. This is also a good time to make up new project and exogenous-event cards.

Time Slot 2

Once the controller hands the initial-condition and goal cards to the four players, they can mark their goals for the various indicators. Meanwhile, the controller determines point allotments for the round. This shouldbe a very quick process.

Time Slot 3

Much happens in the third time slot. After the players receive their points, they work out their project proposals and submit them to the social evaluators who in turn either accept or reject them. Should any project be rejected, the controller makes the necessary point adjustments. Players then work with the returned points on other courses of action. Accepted projects are held for evaluation in the next time slot. The social evaluators choose the exogenous events for the round and these, too, are kept for evaluation in the next time slot.

Time Slot 4

The brunt of the work during the fourth slot falls on the social evaluators. They tell the players what exogenous events have occurred in that round. They evaluate the impacts of all implemented projects and exogenous events. When finished, they hand the controller a list of the total effects. The controller then modifies the indicator charts and determines point allotments for the next round. While the evaluators and the controller are at work, the players have time to plan their efforts for the next round. Some

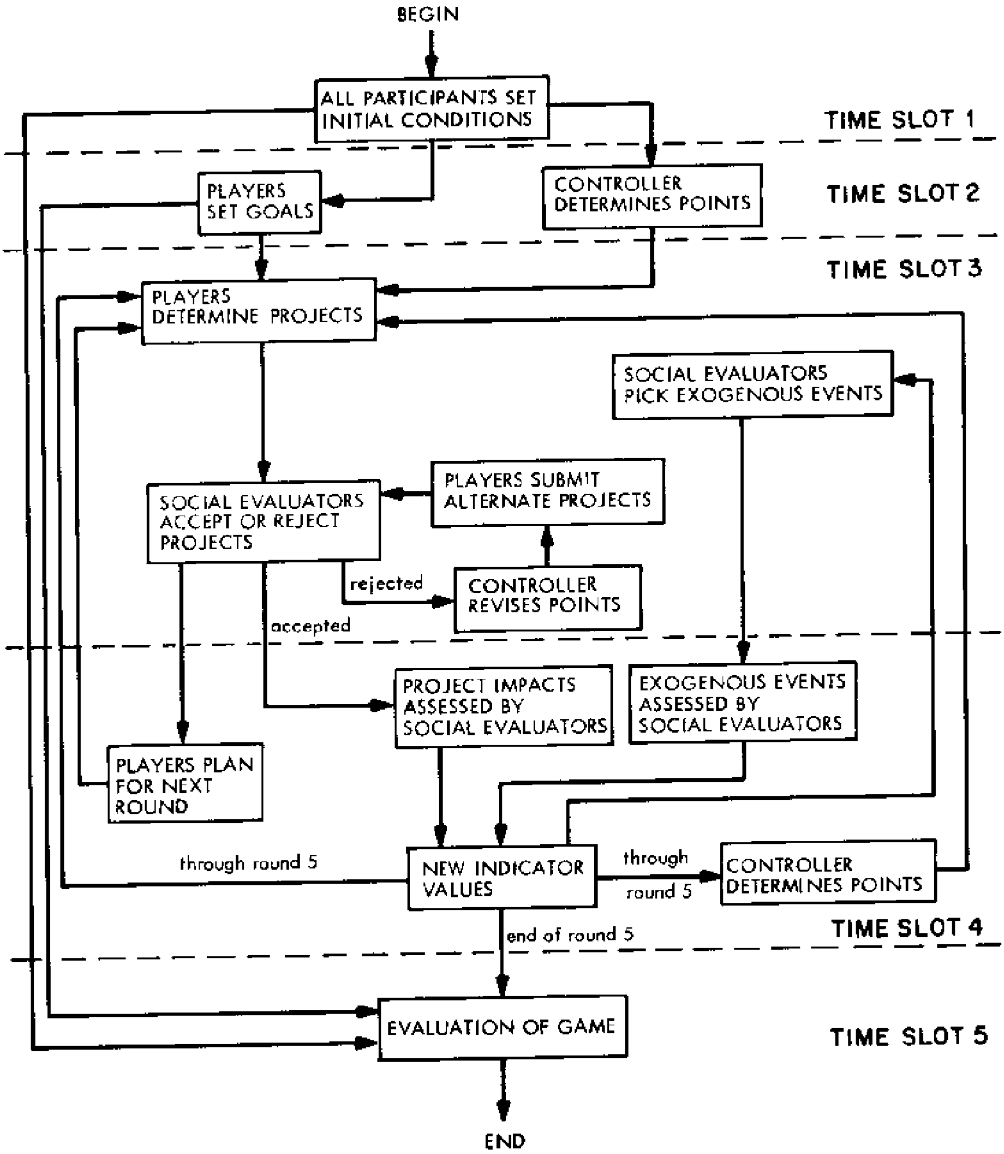

FIGURE 11.11. Format for Five-Hour Play of REDEV

adjustments to these plans will be necessary in the next round, when the effects of the first round are known. Play is continued by returning to the actions of the third time slot.

Time Slot 5

Once five rounds have been played, the action enters the last phase, evaluation of the game as a whole. Analyzing what occurred during the game is perhaps the single most important aspect of the entire simulation. By referring to the initial conditions, goals, and final conditions of the indicators, together with a list of events, all participants should be able to retrace the entire simulation and, through discussion, come to understand why things -- expected and unexpected -- happened as they did.

Chapter 12 A PLAY OF THE GAME

This chapter reports on actual play of the Maine version of REDEV. The session at which this play took place was the last of a series carried out to develop the best possible format for the game, before it was released for use by planners and policy-makers in Maine.

PRE-PLAY DECISIONS

After discussing the rules and format of the game, the participants addressed the task of determining specific policies for this particular play. The following specifications were decided upon:

1. The game personnel would consist of eight participants (BB, SB, BL, SL, 3 SE, 1 CONT).
2. Point graphs and acceptance probabilities would be those given in the original set of rules (See chapters 10 and 11).
3. Returned points from rejected projects would be discounted at 10 percent and rounded off to the next whole point.
4. Projects and exogenous events would be evaluated according to the suggested effects noted on the appropriate cards. Where the amount of the expected effect was not known, the social evaluators were to be instructed to use their judgment.
5. No modifications would be made on the game map.
6. One round would represent five years in real time.
7. Critical points (indicated by numbered circles) would be added to the indicator scales (figures 12.1, 12.2, 12.3).

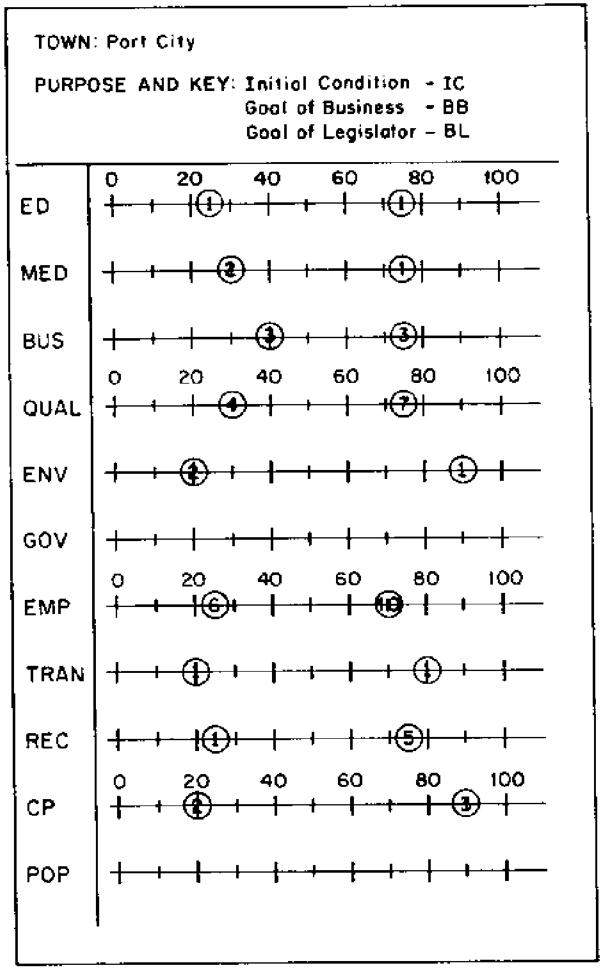

FIGURE 12.1. Critical Points for Port City

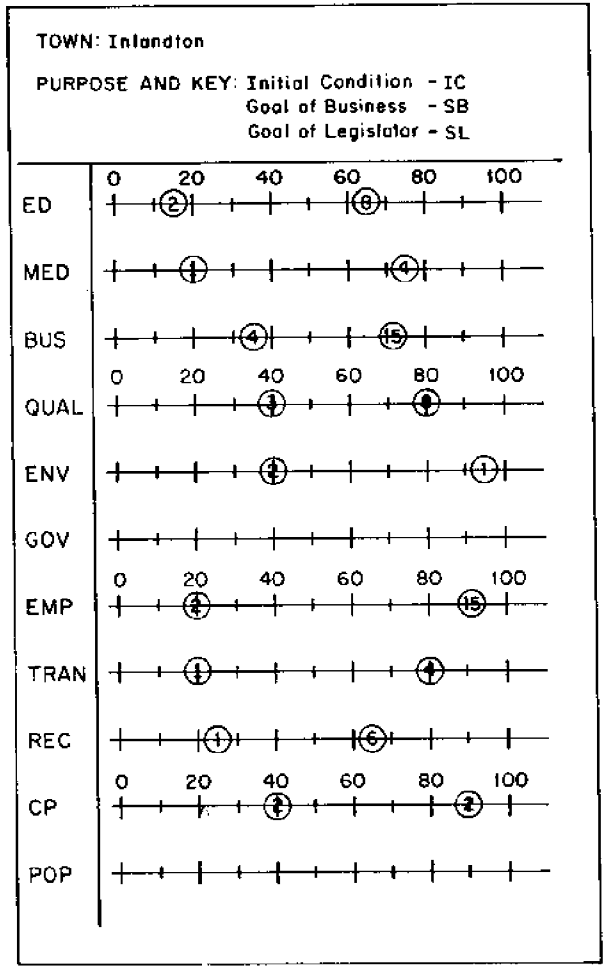

FIGURE 12.2. Critical Points for Inlandton

> Nine of the eleven indicators would have two circles placed on the scales -- one at the high end and one at the low end. When an indicator value reached or passed one of these critical points, a shift in the population of the area would be assumed to have occurred. If the lower point were reached or passed, the population would be lowered to reflect disappointment with life in that area. If the high critical point were met or exceeded, the population would be increased because of the heightened attractiveness of the area. The size of the change would be determined by multiplying the number inside the circle by 1,000 for Port City or 100 for Inlandton and Coastalville. Care would have to be exercised not to let any secondary effects from the changes in population go unnoticed. For example, a jump in population made mandatory when an indicator passed a high critical point could lower the education indicator because more people would have to be educated with the existing facilities.

INITIAL CONDITIONS

Before the participants could set initial conditions for the eleven indicators, research had to be done on the real-life areas that were models for the three cities and regions on the game map. Portland, Gray, and Machias were the basis for the game's framework.

Port City modeled the basic characteristics of Portland, which is located on Casco Bay in Cumberland County. Sixty-five thousand people inhabit its 22.4 square miles, and in the decade from 1960 to 1970 the city experienced a drop in population of 10.3 percent, most of which was due to out-migration. Educational expenses per pupil for Portland public schools are higher than the average for the state.

Gray, the model for Inlandton, is approximately 17 miles north of Portland and occupies 42.8 square miles. Lakes and skiing areas are nearby. During the 1960-1970 decade, the population jumped by more than a third to 2,939 people. This small community provides police and fire protection to its inhabitants in spite of its relatively low tax rate. Its public education expenditures are $550 per pupil.

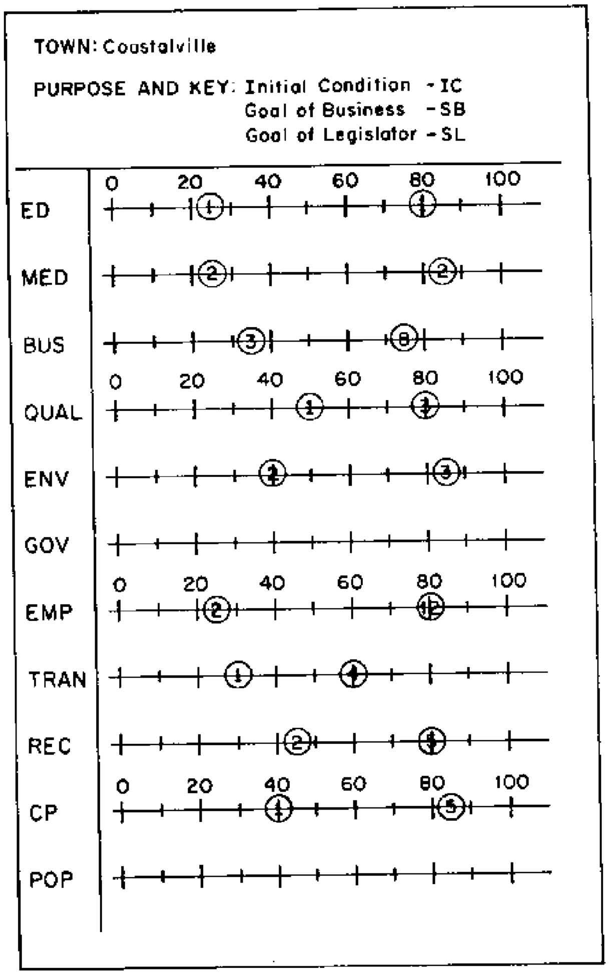

FIGURE 12.3. Critical Points for Coastalville

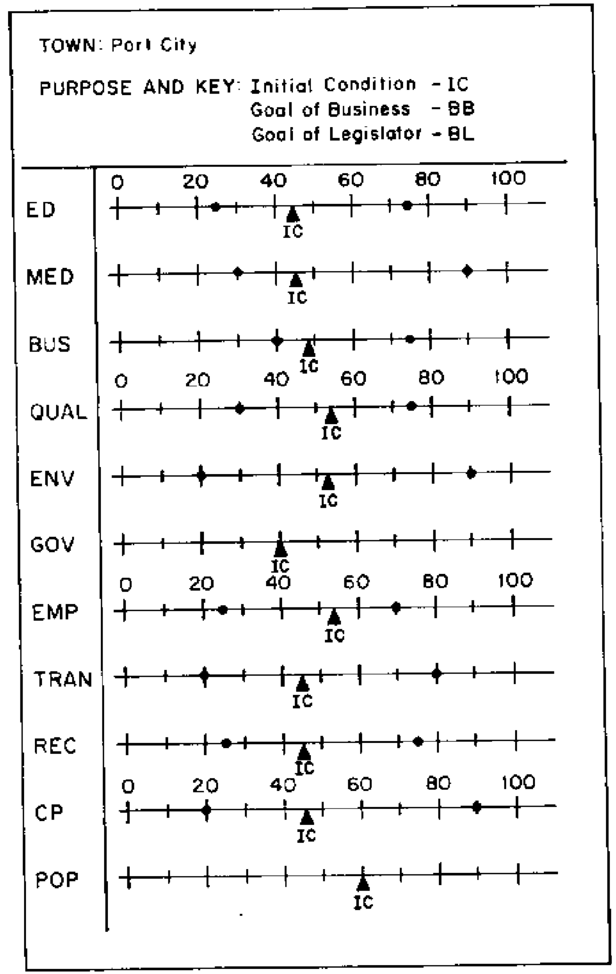

FIGURE 12.4. Initial Conditions for Port City

Gray offers great possibilities for development. Its location, topography, and community facilities are excellent. The extensive recreational assets of the area add to its attractiveness.

The third city modeled in the game is located in the easternmost region of the state. Machias and its neighbor, Machiasport, are located in one of the most economically depressed areas in all New England. The effective buying power of income in this region is 33 percent below the New England average and 15 percent below the state average. As might be expected, unemployment is high.

There are 2,441 people living in the 15.2 square miles of Machias, and the town experienced a 6.6 percent drop in population during the last decade. School expenditures stand at $504 per pupil.

The region is basically undeveloped but offers great potential in at least one regard. Land and sea formations would allow for building a deepwater port and oil refinery. Many think that such a project would be of great economic value not only to Machias but also to the entire New England region.

Machias is much further from Portland than its game counterpart, Coastalville, is from Port City on the game map. This disparity between the game and the real world was not considered to be an important issue. If the distance factor had been considered important, another game map could have been drawn to reflect the true distance.

Following the method outlined in the rules, all eight participants selected initial values for the eleven social indicators in the three regions. The averages of these values are shown in figures 12.4, 12.5, and 12.6.

The ten qualitative indicators for Port City deviated very little from the midpoint of the 0-100 scale. Nine of the ten were within five points of 50 and the tenth, the government index, was only ten points below it. For all practical purposes, Port City's initial condition was that of an average city. The eleventh indicator, population, was set to show a population of 60,000.

The participants determined that Inlandton was in below-average condition. The levels of education and medical care were close to the critically poor points, while those of business, government, and transportation were not much higher. Quality of life and the environment were rated average.

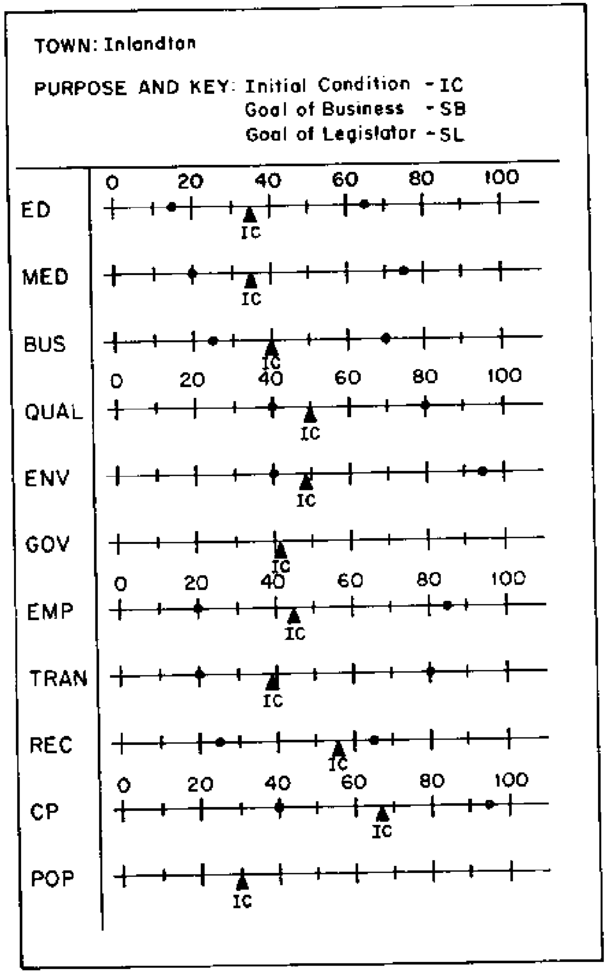

FIGURE 12.5. Initial Conditions for Inlandton

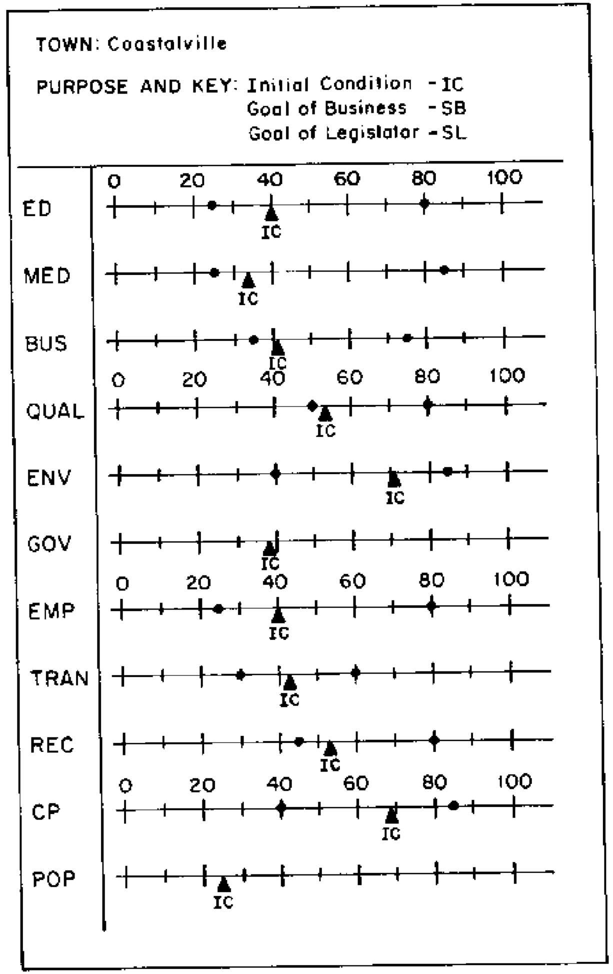

FIGURE 12.6. Initial Conditions for Coastalville

The two indicators that were on the favorable side of average were recreation and crime prevention. The area provided good possibilities for outdoor activity and had not experienced the problems of crime as much as the big cities had. Inlandton, however, could use help.

Coastalville had ratings almost identical to those of Inlandton. It experienced the same problems and for approximately the same reasons. Coastalville's environmental indicator, however, was higher because much of the area surrounding the town was still untouched by development.

GOALS

Figures 12.7, 12.8, and 12.9 show the values chosen by the players as goals for the social indicators at the end of five rounds of play (equivalent to approximately 25 years in real life). For the most part, the goals were set at a level higher than the initial conditions, and in some cases ambitious jumps were desired, e.g., the environmental indicator goal of the legislator for Inlandton and the same legislator's education indicator goal for Coastalville.

FIRST POINT ALLOTMENT

Using the initial conditions set by all participants, the controller released the following schedule of available points:

Player	Index	Points
BB	48	58
BL	40	3
SB	40	36
SL		
Inlandton	41	2
Coastalville	40	2
2L (SB and SL, acting as the state legislature)	40	5

The list seems to indicate that business interests were heavily favored in point allotments; however, that is not quite the case. Business, as a general rule, has to put up or borrow all the money for a project, whereas many state and local government projects are subsidized in one form or another and their cost to their proponents therefore is less.

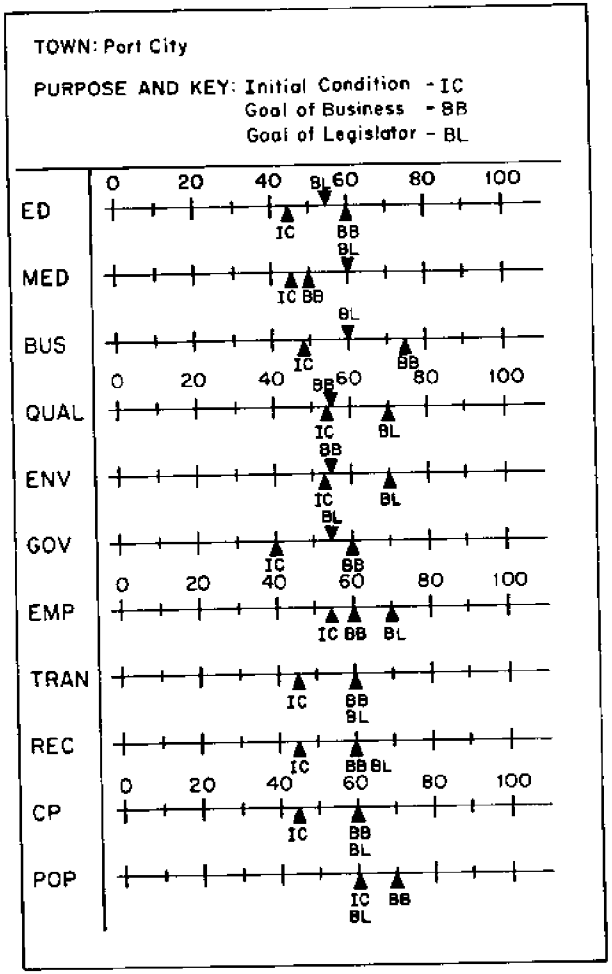

FIGURE 12.7. Goals for Port City

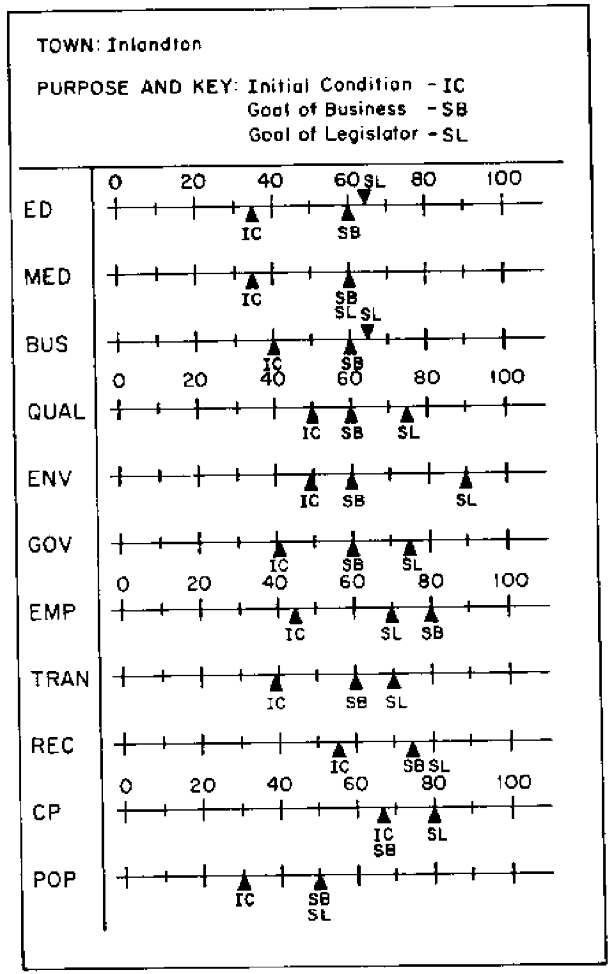

FIGURE 12.8. Goals for Inlandton

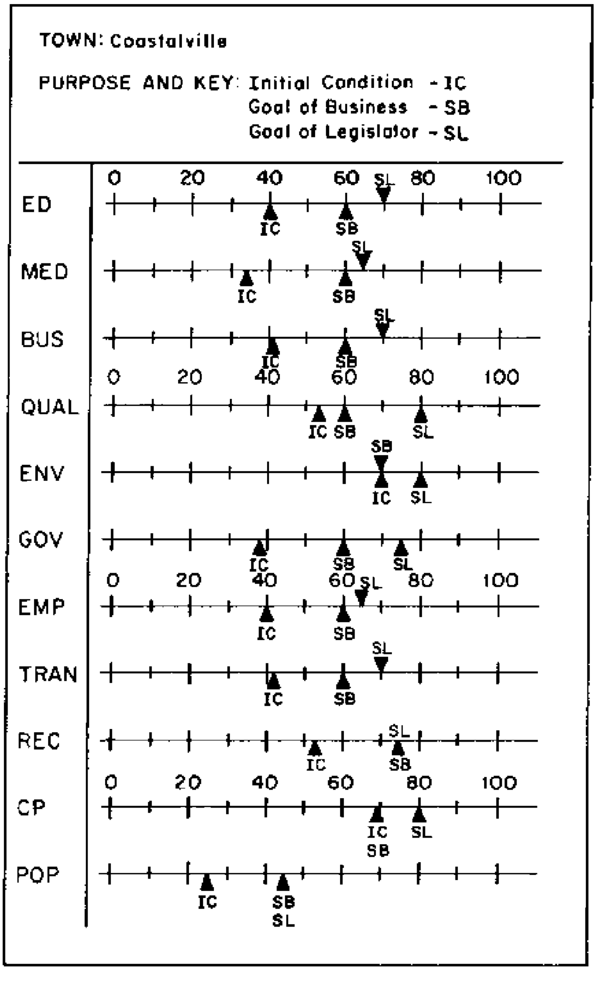

FIGURE 12.9. Goals for Coastalville

ROUNDS 1 AND 2

Inputs

The intention of all players was to choose or create projects that would move the values of their social indicators from the initial conditions to the goals they had set. They had to implement projects in the face of uncertainty and within a budgetary constraint.

All participants, especially the social evaluators, attempted to plan and evaluate in terms of long-range net effects. The simulation would have been of dubious value if any other basis of evaluation had been used.

A list of projects proposed for the first two rounds appears in Table 12.1. The table also indicates exogenous events that occurred.

TABLE 12.1. Projects and Exogenous Events

ROUNDS 1 AND 2

Round	Player	Location	Project
1	BB	PC	Restaurant-motel-theater complex
1	BB	PC	Eight indoor tennis courts
1	BB	PC	Trucking company*
1	BB	PC	Soft-drink bottling plant
1	SB	C	Aquaculture study
1	SB	C	Lake recreation facilities
1	SB	I	Commercial park
1	SB	I	Low-cost housing for elderly and poor
1	BL	PC	New hospital
1	BL	PC	Improvement of mass transit and routes to city
1	SL	I, C	Advertising for tourism
1	SL	I, C	Upgrading the road between Coastalville and Inlandton
1	exogenous event	PC	Megalopolitan spread

(Continued)

Round	Player	Location	Project
2	BB	PC	Shoe-manufacturing company
2	BB	PC	Aquaculture company
2	BB	PC	Marina
2	BB	PC	Trucking company*
2	SB	C	Motel, restaurant
2	SB	C	Sailing pavilion, youth club, marina
2	BL	PC	New school
2	SL	I	Improving education, hiring more teachers
2	SL	C	Public park, playground, picnic area

*Project was rejected

Results

Figure 12.10 shows the indicator card for Port City after two rounds of play. Much has happened. According to the social evaluators the education indicator has surpassed both the legislator's and the businessman's goals because of the primary effects of building a school in the second round and the secondary effects of all other projects and events during both rounds. Medical care also noticeably improved with the building of a new hospital.

The most striking change, however, came in the business index. In addition to the tendency for the index to increase with the improvement in the quality and quantity of business in the area, a great shift took place as a result of the megalopolitan spread, which occurred as an exogenous event (see figure 11.10). As was suggested by the exogenous-event card, the business index improved fifteen points because of the development boom (actual and potential); this increase resulted in a greatly expanded point budget for player BB.

Education and medical care improvements increased the quality-of-life index also. The environment indicator suffered, however, but only slightly, because the negative effects of the boom in business had not yet been strongly felt. The marina, tennis courts, and theater caused a jump in the recreation index. People, it was assumed, began to look upon the

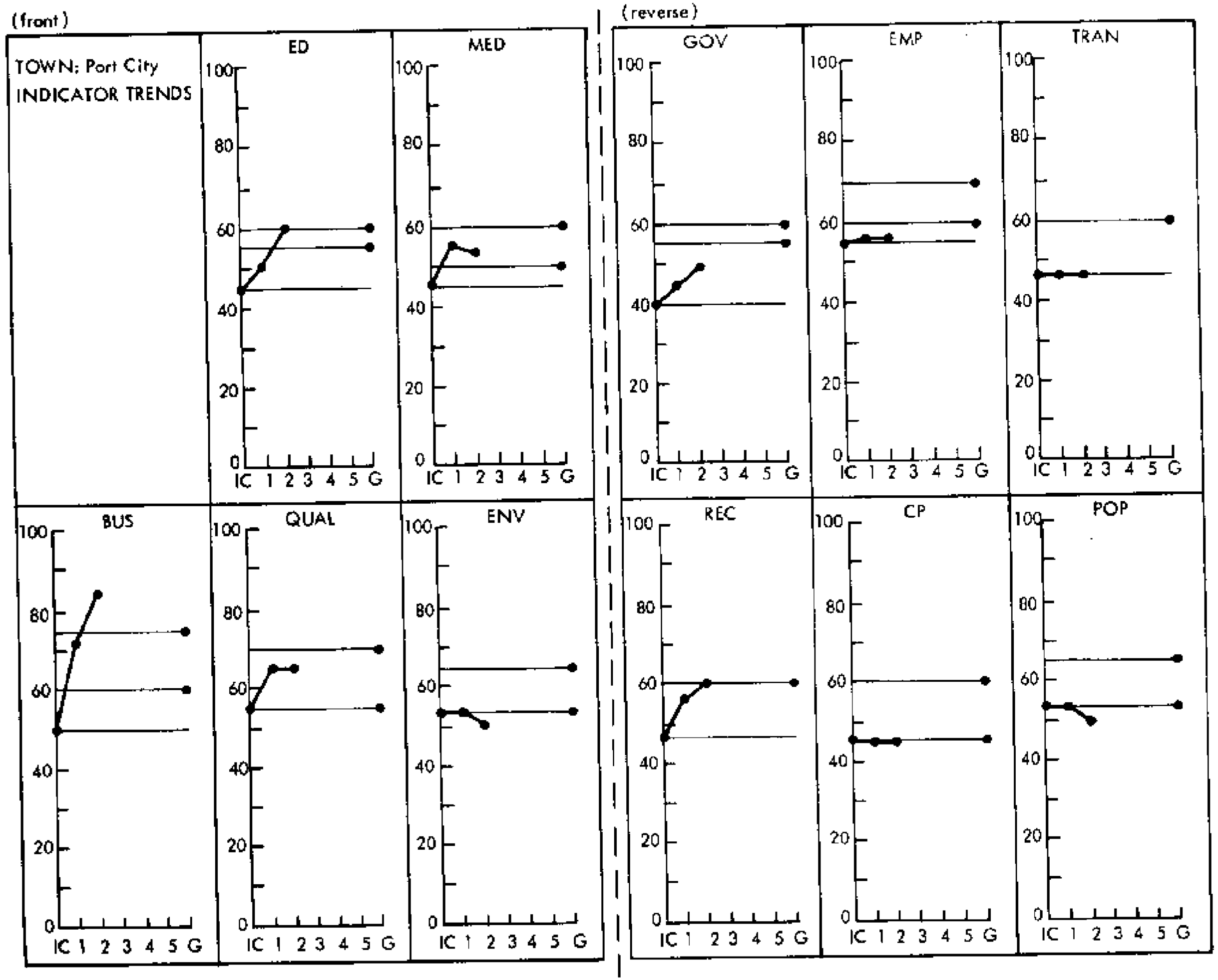

FIGURE 12.10. Indicators for Port City After Round 2

government more favorably because the net effect of changes in these indicators was desirable. The remaining indicators showed no significant movement.

Up to this point, the Port City players were doing well. Impressive strides toward the goals put forth at the beginning of the game had been taken. The Port City players either planned well or unknowingly chose those projects that the social evaluators favored.

ROUNDS 3, 4, AND 5

Inputs

The remaining rounds of play were carried out with the same goals and methods in mind. As noted, some indicators had improved in round 2. Others, however, did not, and some actually dropped slightly. These indicators would need attention in the later rounds if there was to be balanced growth in the areas.

Table 12.2 lists the projects and exogenous events of the last three rounds. From the third round on, a number of projects not included in the original game set were originated. Apparently, the players felt that the projects in the existing selection were inadequate to move the indicators from their second-round values to the goals set at the beginning of the game.

TABLE 12.2. Projects and Exogenous Events

ROUNDS 3, 4, AND 5

Round	Player	Location	Project
3	BL	PC	Sewage-treatment plant
3	BB	PC	Expanded commercial aquaculture
3	BB	PC	One wholesale and two retail health-food stores
3	BB	PC	Closing of paper plant because it is old and pollution control costs too much
3	exogenous event	PC	Strict enforcement of air and water pollution laws
3	SL	I	Purchase of wildland (making use of the Federal Open Spaces Act)

(Continued)

TABLE 12.2. (Continued)

Round	Player	Location	Project
3	SL	I	Better cooperative school/ industry programs for high school students
3	SB	I	Large private housing development on the river
3	SB	I	Golf course
3	exogenous event	I	High water, with consequent damage to water-table purity and sewage-treatment facilities
3	SB	C	Potato-processing plant
3	SB, SL	C	Port facility*
3	SL	C	Zoning for port
4	BL	PC	Advertising for new industry; the offer of a five-year tax incentive
4	BL	PC	Outpatient clinic
4	BL	PC	Reorganization of the city government to reduce inefficiency, corruption, and spending
4	BL	PC	Transfer of ownership of city mass-transit to private firm
4	BB	PC	Health clinic with exercise facilities and staff for weight-reduction
4	BB	PC	Two new large fast-food concerns
4	exogenous event	PC	Departure of three large industries because of strict pollution controls
4	SL	I	Legal controls on facilities near water
4	SL	I	Outpatient clinic (partially state-funded)
4	SB	I	Shutdown of waterfront paper mill because of expense of pollution controls
4	exogenous event	I	Tourism boom

* Project was rejected.

(Continued)

TABLE 12.2. (Continued)

Round	Player	Location	Project
4	exogenous event	I	Federal funds available for historic restoration
4	SB	C	Oil refinery*
4	SB	C	School funding, as a concession for oil refinery
4	SL	C	Tax concession to oil company
4	SL	C	Road upgrading
4	SL	C	Sewage-treatment facility
5	BB	PC	Large recreation facility
5	BL	PC	Renovation of penal institutions, including rehabilitation programs
5	BB	PC	Solid-waste commercial recycling facility, along with small industries that use the reclaimed materials
5	BB	PC	Large shopping center
5	BB	PC	Small electric steel mill
5	SL	I	Zoning ordinance for river area
5	SL	I	Police force upgrading
5	SL	I	Historic river fort rebuilt, with local workers educated in techniques of eighteenth-century craftsmanship
5	SB	I	Restaurants, hotels, and other tourist facilities built to take advantage of fort renovation
5	SL, SB	C	Port facility for oil
5	SL	C	Police force increase

*This facility, together with the port-zoning project of round 3, resulted in a change in the receptiveness factor of the oil refinery from C to B for remaining rounds.

Results

The completed indicator cards appear in figures 12.11, 12.12, and 12.13. A quick glance reveals that Port City fared better in this simulation than either Inlandton or Coastalville.

Port City. Education in Port City rose from a below-average value of 45 to 60. This new value is above average and is the higher of the two goals chosen. Medical care made almost the same move. While it did not reach the Port City legislator's goal, its rise of more than ten points was certainly substantial.

Because of an unexpected event (megalopolitan spread), the business index received a tremendous boost in round 1. As a result, it not only passed both goals but also passed the high critical point. This movement brought a mandatory increase in population of 3,000 people. This increase represented half the expected rise in population over the 25 years.

Surprisingly the quality-of-life and environment indicators rose 15 and 10 points respectively in spite of the increased population. These rises were made possible by adequate controls and protective measures limiting the disadvantages of urban growth and general economic development and, perhaps, by the city's achievement of its recreation goals.

Other indicators fared less well. The government index climbed more than 10 points, but still fell short of both goals. The legislators did not prove themselves as effective as they would have liked. Transportation and crime prevention showed movement in the right direction, but did not meet the goals of either the legislators or the businessmen. Employment did not move at all. Apparently, the increase in population offset any gains made in the total number of people employed.

On the whole, however, Port City did very well. When goals were not actually met, they were closely approached. If the population indicator is excluded, the city was 232 points short of the goals at the beginning of the game. * It finished only 59 points short of all goals (any movement beyond a goal was not counted). At the beginning, the average value of the ten qualitative indicators was 49. By the end of the game that figure had risen to a respectable 60, significantly above average.

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* This point figure is determined by subtracting the initial conditions from the goals and summing the differences.

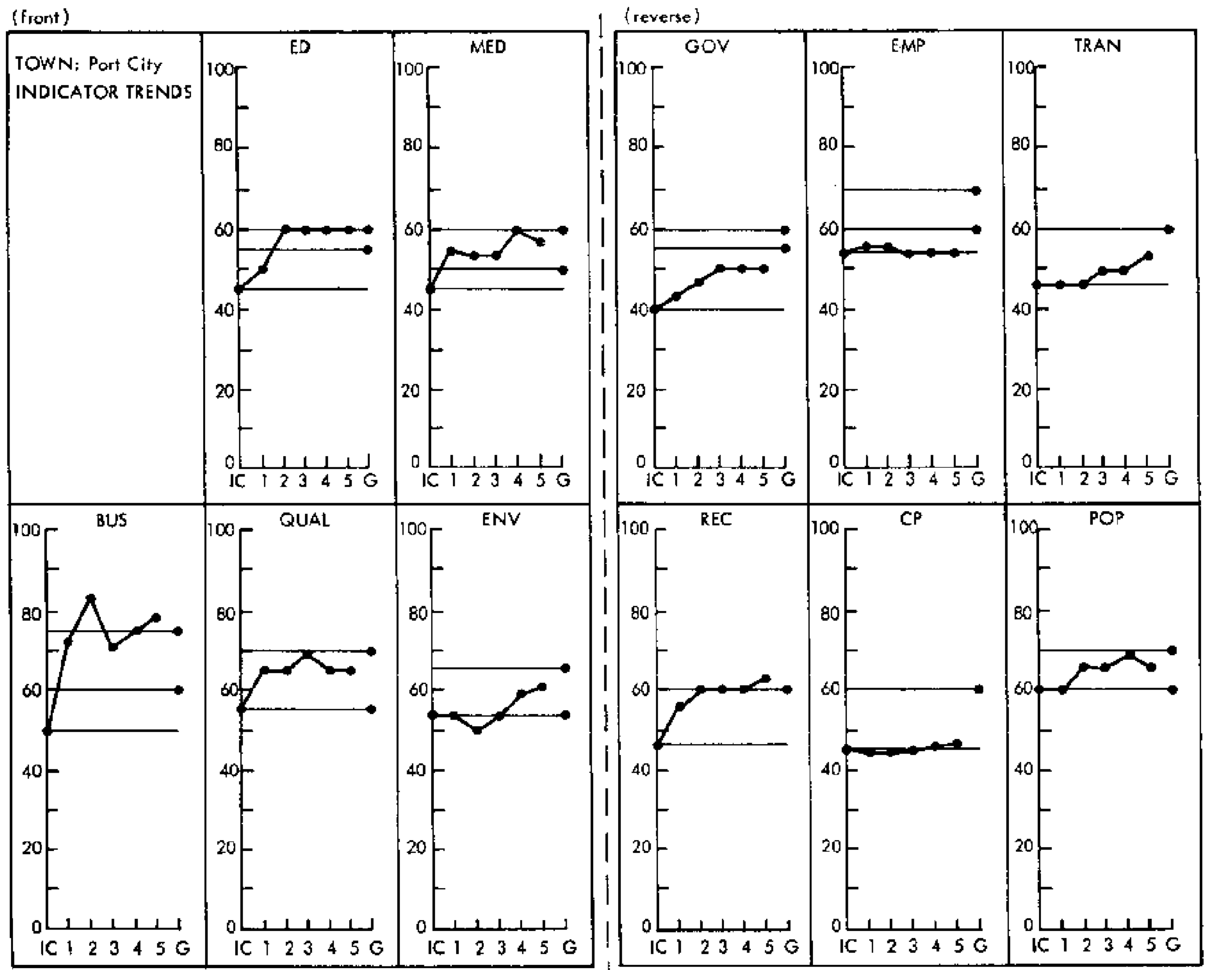

FIGURE 12.11. Indicators for Port City After Round 5

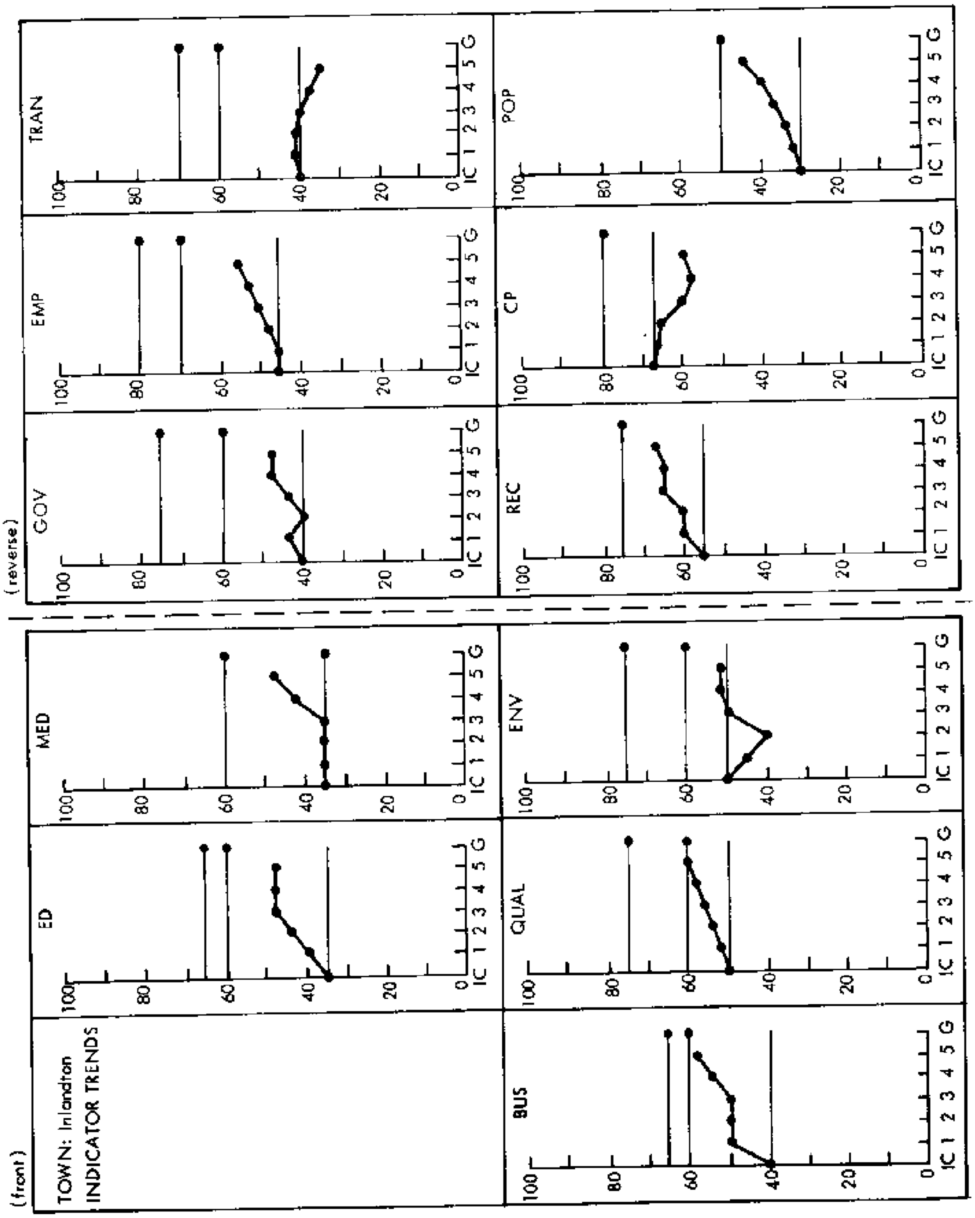

FIGURE 12.12. Indicators for Inlandton After Round 5

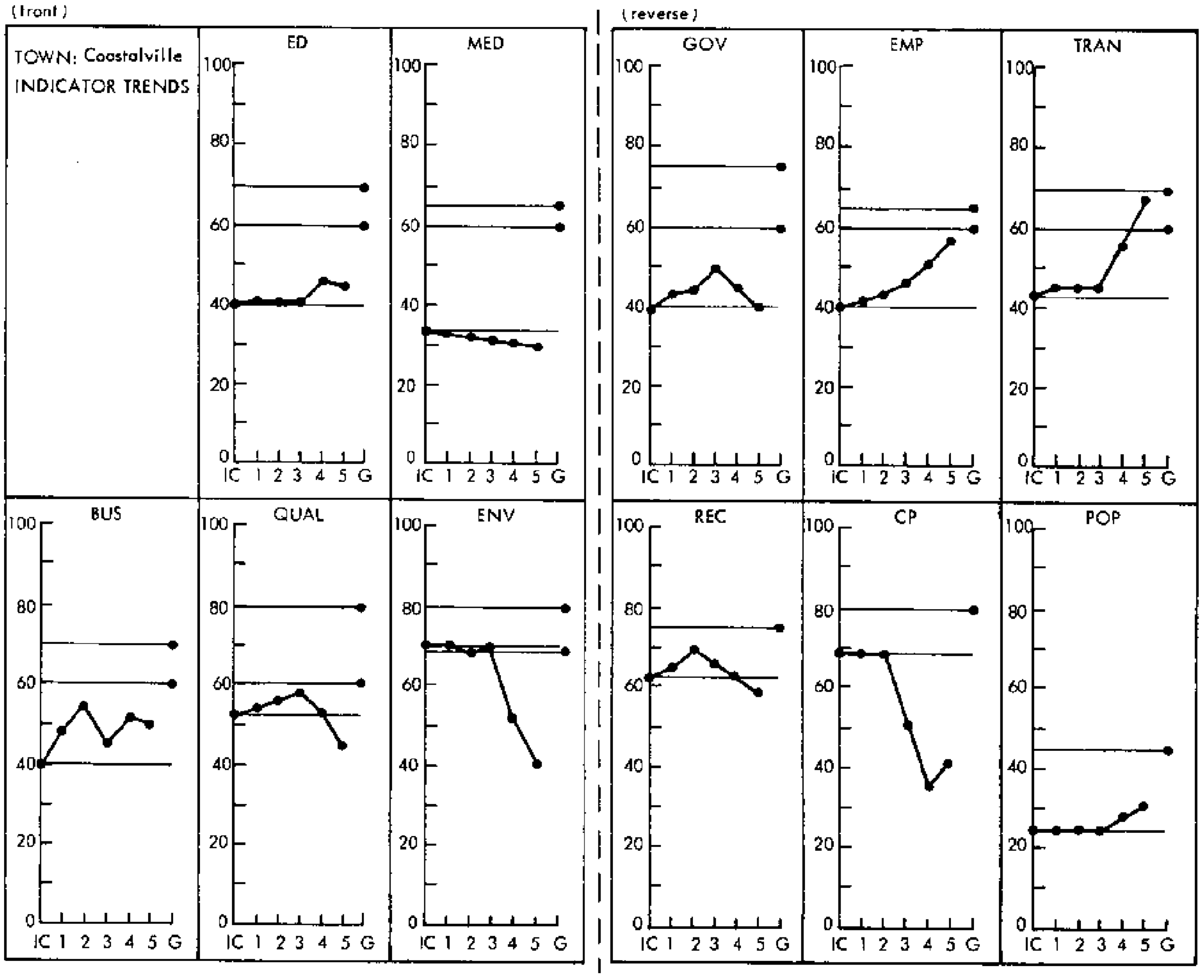

FIGURE 12.13. Indicators for Coastalville After Round 5

Inlandton. Although Inlandton made progress, it did not do as well as Port City. The initial conditions were short of goals by 430 points, indicating more ambitious plans for this town than for Port City. Operating constraints hindered development, however, and resulted in a 307-point deficit at the end of play. Nevertheless, the 123-point movement led to an increase from 47 to 53 in the ten-indicator average.

Education, medical care, and the business index followed the pattern set in Port City, but fell short of goals in all cases. Although the goals were the same as Port City's, Inlandton started with a bigger deficit and did not experience immediate benefits from the Port City boom.

The quality-of-life rose slightly, reflecting the small positive movements in related indicators with only a slight drop in environmental quality. The government index improved to almost average, and employment rose 9 points, putting it above average.

The effects of the renovated fort and the resulting tourist trade served to lower the transportation index because nothing was done to improve the routes to the southwest, where most of the increase in traffic would originate. Recreation, however, gained as a result of the fort and additional tourist facilities. Because of the influx of visitors, crime prevention deteriorated slightly.

Coastalville. Coastalville suffered. It actually experienced a deterioration in the average value of its indicators.

Education remained below average in spite of improvements. Medical care dropped almost to the critical level. The government and recreation indices showed hardly any movement, but the evaluators felt that crime prevention suffered tremendously.

One of the few improvements over initial conditions came in the business index, owing to the strong influence of the new oil facilities. Quality-of-life and environmental indicators suffered because of the same influence. The quality-of-life value dropped below its critical population-change level. The environment value came close to doing the same. Not only bad results stemmed from the implementation of oil facilities, however. Unemployment dropped considerably in this small town. Much better transportation resulted from improvements made during the construction and start-up phases of the new industry.

Coastalville started with a 409-point total goal deficit. Unfortunately, it finished 421 points below its goals, for a net change of -12 points. The average indicator value dropped from 48 to 47.

A combination of events led to Coastalville's problems. In the first place, the social evaluators in this game gave heavy weight to the detrimental effects of the new oil facilities. The other main problem of the town was the apparent lack of enthusiasm or initiative on the part of the town's players. With the exception of the oil industry, the projects implemented in or near Coastalville during the game were without inspiration. Perhaps it would fare better in another simulation.

Chapter 13 LIMITATIONS AND POTENTIAL BENEFITS

REDEV is not a perfect game. No gaming simulation can hope to parallel the real world exactly. Nevertheless, REDEV is a prototype of a game that can simply and flexibly model the dynamics of a region -- in this case, part of Maine's coast.

LIMITATIONS

Mechanics

The overriding problem of the game is establishing a satisfactory trade-off between the realism of the game and the difficulty of playing it. If this game is to be useful as a tool for planners, it must not be so difficult that people will refuse to play it. However, a game of this kind is more interesting if it simulates actual life, which is extremely complex.

By necessity, some shortcuts were taken in this version. For example, some decisions were left to chance rather than being determined by discussion and vote of the players. It was felt that a discussion on whether or not to implement each project would have required too much game time.

Interdependencies

As can be imagined, it is practically impossible to include all the interdependencies that might exist between projects. In the game, only the social evaluators' judgment can determine the degree to which these effects must be taken into account.

Quantitative Judgments

Another difficulty with the simulation is that of obtaining quantitative results from qualitative planning. In other words, much of the true worth of the game comes directly from the experience, thoughtfulness, and insight of the social evaluators in determining the likely quantitative changes of the indicators.

It is possible that an exact effect on the indicators could be specified for each project, but this predetermination would destroy the flexibility of the game and would also be unrealistic, since all the consequences of an action cannot be completely predetermined. Thus, although we must accept the fact that a problem exists, we can provide enough information so that, if the players are serious about the game and put forth enough effort to play it properly, they will obtain valuable results.

VARIATIONS AND IMPROVEMENTS

Because of the time restrictions for the play of the game, an implicit limit on the number of projects each player may submit per round has been imposed through the point system. This restriction is partially unrealistic and limits the variety of changes that can be effected in each round. However, it has been necessary in order to allow the social evaluators time to consider all of the consequences of the ten or twelve projects proposed in each round.

Instead of doing all of the bookkeeping of the game by hand, however, participants could use a computer to keep account of the clerical processes of the game. It would allow a relaxation of some of the game constraints.

Evaluation of proposed projects could be carried out by using a model similar to MAINE2 but developed specifically to deal with the situations that would be likely to arise in the game. A thorough analysis of projects could be performed if this were feasible from a cost/availability standpoint.

An enlarged, more detailed game map, which would allow land use to be explicitly included as a game concept, could be worthwhile in some situations. Additional expansions of the game, such as the inclusion of players serving as project lobbyists or the addition of different age-group satisfaction indicators, might also prove worthwhile in future game models.

POTENTIAL BENEFITS

Playing the game many times would provide planners with information of great value. Replaying would allow different scenarios to be played in an attempt to analyze the sensitivity of the indicators to alternative approaches. This analysis would give insight into the merits of various trade-offs in projects and create a reasonable knowledge base from which to plan.

Another possible use of the game would be to resolve differences created by a lack of understanding of the "opposition's" needs and goals. In a game played for this purpose, real-life legislators would, for example, play as businessmen, businessmen as social evaluators, and evaluators as legislators.

Participants would be asked to take on, during the game, the attitudes and desires appropriate to their new roles. This role-play might well have real-life benefits in helping those involved in planning decisions become sensitive to points of view other than their own.

In summary, the game does have limitations and some problems. Yet it is useful, too. Within limits, it meets the goals of providing a stimulating, compressed-time simulation laboratory that gives insights into the problems of planning for regions such as Maine's coast.

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Appendix C MAINE2 PROGRAM LIST AND DOCUMENTATION

0001 L WWOI.K=WWOI.J+(DT)(MP.JK+MHEW.JK+MUNEMP.JK-DR.JK+
MAT.JK-CINJ.JK)
WORKERS WITHOUT INCOME

0002 L WWI.K=WWI.J+(DT)(CINJ.JK)
WORKERS WITH INCOME

0003 A TP.K=(WWOI.K+WWI.K)(AFS)
TOTAL POPULATION

0004 N WWOI=(UNEMPC)(WWI)
WORKERS WITHOUT INCOME INITIAL CONDITION

0005 C UNEMPC=.089
UNEMPLOYMENT CONSTANT
Average 1960-1970 levels as a percent of workers rather than total available work force. (Maine Pocket Data Book 1971 Section 8.13.)

0006 N WWI=10033
WORKERS WITH INCOME INITIAL CONDITION
Derived from the summation of initial values for industry groups' jobs.

0007 R MP.KL=(TABHL(MPT,TPI.K,0,20,20))(TP.K/AFS)
MIGRATION FROM POLLUTION

0008 R MHEW.KL=(TABHL(MHEWT,PCHEW.K,5E2,27E2,22E2))
(TP.K/AFS)
MIGRATION FROM HEW

0009 R MUNEMP.KL=(TABHL(MUNEMPT,UNEMP.K,0,.20,.025))
(TP.K/AFS)
MIGRATION FROM UNEMPLOYMENT

0010 R DR.KL=(DRC)(TP.K/AFS)
DEATH AND RETIREMENT RATE

0011 R MAT.KL=DELAY1((MATC)(TP.K),15)
MATURATION RATE
There is a delay of 15 years between births and maturation into the labor force.

0012 A UNEMP.K=WWOI.K/(WWOI.K+WWI.K)
UNEMPLOYMENT

0013 R CINJ KL=(JBS.K-PJBS.K)
CHANGE IN NUMBER OF JOBS

0014 C AFS=2.74
AVERAGE "FAMILY" SIZE
State averages for the number of jobs divided by the number of people.
Maine Pocket Data Book 1971, Section 8.
This multiplier is a constant because it is assumed that there will be little incentive for the percentage of housewives employed to significantly change over the life of this model because of the effects of the oil refinery on the economy.

0015 T MPT=0/-.0196
MIGRATION FROM POLLUTION TABLE
This figure was chosen so that if the pollution index goes up to twenty times its present level a migration of 1.96 percent per year of the total population will occur.

0016 A TPI.K=TPOL.K/POLNF
TOTAL POLLUTION INDEX

0017 T MHEWT=-.0196/.0196
MIGRATION FROM HEW TABLE
These values were chosen such that the relationship shown in figure C.1 holds.

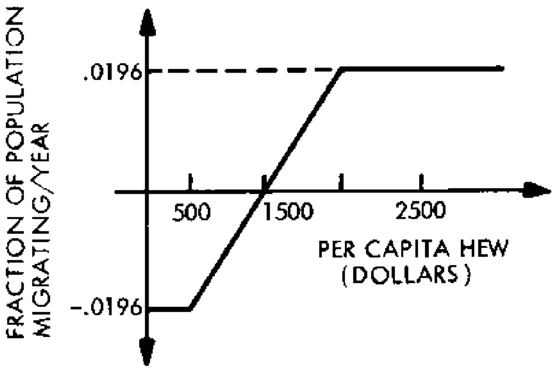


FIGURE C.1.

0018 A PCHEW.K=HEW.K/TP.K
PER CAPITA HEW

0019 T MUNEMPT=.196/.039/0/-.035/-.047/-.066/-.085/-.124/-.173
MIGRATION FROM UNEMPLOYMENT TABLE
The values were chosen to reflect the increased attractiveness of the area with decreasing unemployment rates in the manner shown in figure C.2.

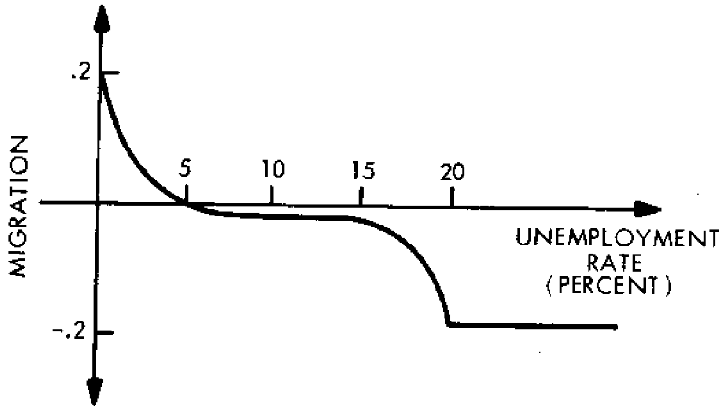


FIGURE C. 2.

0020 A TPOL. K=(POLN. K)(AFFOR)+POLOI. K+POLP. K
TOTAL POLLUTION

0021 C POLNF=2. 8E6
POLLUTION NORMALIZATION FACTOR
Pounds of pollutants is a measure chosen to be consistent with other parameters dealing with pollution generation and absorption.

0022 L HEWP. K=HEWP. J+(DT)(MTHEW. JK*. 5-DHEW. JK)
LEVEL OF HEW FACILITIES

0023 C DRC=. 011
DEATH RATE CONSTANT
(Maine Pocket Data Book 1971, Section 1. 9, state average.)

0024 C MATC=. 02
MATURATION CONSTANT
Derived in the following manner: 65 > work age range
16
49 yrs ∴ 1 yr ≈.02

assuming no gradient in the number of people.

0025 A JBS. K=FARMJ. K+MANJ. K+SERJIG. K-SERRRPL. K
JOBS

0026 A PJBS. K=DL1. K
PREVIOUS JOBS

0027 C AFFOR=. 30
AREA OF WASHINGTON COUNTY AFFECTED BY OIL REFINERY

Estimate of the fraction of Washington County that actually experiences the adverse effects of the oil refinery operations.

0028 A HEW.K=HEWP.K+HEWY.K
TOTAL HEW CAPABILITIES

0029 A HEWY.K=MTHEW.JK*.5
HEW OPERATING BUDGET

0030 L DL1.K=DL1.J+(DT)(DR1.JK-DR2.JK)
DUMMY LEVEL ONE

0031 N DL1=WWI
DUMMY LEVEL ONE INITIAL CONDITION

0032 R DR1.KL=JBS.K
DUMMY RATE ONE

0033 R DR2.KL=DL1.K
DUMMY RATE TWO

0034 L NI.K=NI.J+(DT)(CAPINVN.JK+REINVN.JK-DEPRN.JK)
LEVEL OF NEW INDUSTRY

0035 N NI=O
LEVEL OF NEW INDUSTRY INITIAL CONDITION
All existing industry at the beginning of the model is classified as old; therefore, no new industry can exist at that point.

0036 R CAPINVN.KL=(STEP(S1,ST1)+STEP(S2,ST2)+STEP(S3,ST3)+STEP(S4,ST4)+STEP(S5,ST5)+STEP(S6,ST6))
CAPITAL INVESTMENT IN NEW INDUSTRY

0037 R REINVN.KL=(PROFAC)(NI.K)(DEPRNC)
REINVESTMENT IN NEW INDUSTRY

0038 R DEPRN.KL=(NI.K)(DEPRNC)
DEPRECIATION OF NEW INDUSTRY

0039 C S1=25E6 DOLLARS

0040 C ST1=5 YEAR

0041 C S2=30E6 DOLLARS

0042 C ST2=6 YEAR

0043 C S3=-20E6 DOLLARS

0044 C ST3=7 YEAR

0045 C S4=-35E6 DOLLARS

0046 C ST4=8 YEAR

0047 C S5=10E6 DOLLARS

0048 C ST5=12 YEAR

0049 C S6=-10E6 DOLLARS

0050 C ST6=13 YEAR
Equations 0039 through 0050 represent a schedule of how funds are spent when building an oil refinery of the size projected in the model. (Governor's Task Force, 1972b, p. 101.)

0051 A BPDO.K=(1E5)(STOLFUN.K)
BARRELS PER DAY OUTPUT

0052 C PROFAC=1
PROFIT FACTOR
This assumes that the refinery will operate profitably.

0053 C DEPRNC=.07
DEPRECIATION CONSTANT
This form denotes an exponential decay with an initial slope of fourteen years.
(Atlantic World Port Inc., n.d.)

0054 R PGRN.KL=(YBO.K)(POLPB)(1/BCPBO)
POLLUTION GENERATION RATE OF NEW INDUSTRY

0055 C POLPB=.23
POLLUTION PER REFINED BARREL
(SCEP, 1970, p. 262.)
SO_x pollution per thousand metric tons = 0.053 tons.
8.5 bbl equals approximately one metric ton.
SO_x equals approximately 5.5 percent of total pollution.
These conversions produce the figure of .23 pounds of "pollution" per barrel of oil refined.

0056 L POLN.K=POLN.J+(DT)(PGRN.JK-POLABSN.JK)
POLLUTION LEVEL FROM NEW INDUSTRY

0057 N POLN=0
POLLUTION LEVEL FROM NEW INDUSTRY INITIAL CONDITION

0058 R POLABSN.KL=(PAC)(POLN.K)
POLLUTION ABSORPTION RATE

0059 C PAC=.25
POLLUTION ABSORPTION CONSTANT
It is assumed that for the given size of the refinery and the characteristics of the area pollution dissipates exponentially with an initial rate of one-fourth per year. It is further assumed that no permanent damage occurs.

0060 A STOLFUN.K=STEP(STF1,8)+STEP(STF2,9)
ON-LINE FUNCTION

0061 C STF1=.5

0062 C STF2=.5
STEP FUNCTION VALUES
On the assumption that the refinery will gradually be brought up to full capacity, these factors were included to parallel the situation.

0063 C BCPBO=.98
BARRELS OF CRUDE TO BARRELS OUTPUT EFFICIENCY
(Garman, 1963.)

0064 C PACO=.33
POLLUTION ABSORPTION CONSTANT FOR OLD INDUSTRY
Refer to equation 0059. The starting slope is one-third decay/year, assuming that existing industries are not as taxing on the environment as the oil refinery.

0065 R POLABSO.KL=(PACO)(POLOI.K)
POLLUTION ABSORPTION RATE FOR OLD INDUSTRY

0066 R PGRO.KL=(PACO)(POLOI.K)
POLLUTION GENERATION RATE FOR OLD INDUSTRY

0067 L POLOI.K=POLOI.J+(DT)(PGRO.JK-POLABSO.JK)
LEVEL OF POLLUTION FOR OLD INDUSTRY

0068 N POLOI=2.8E6/2
LEVEL OF POLLUTION FOR OLD INDUSTRY INITIAL CONDITION

0069 A CWN.K=(CAPINVN.JK)(FCITCW)
CONSTRUCTION WAGES FROM NEW INDUSTRY

0070 C FCITCW=.20
FRACTION OF CAPITAL INVESTMENT TO CONSTRUCTION WAGES
(Governor's Task Force, 1972b, p. 14.)

0071 A POLP.K=48.28*TP.K
POLLUTION FROM PEOPLE
This figure (48.28) was derived assuming that half the present pollution level in Washington County comes from people.

0072 A CJN.K=CWN.K/PWCWN
CONSTRUCTION JOBS FROM NEW INDUSTRY

0073 C PWCWN=8600
WAGE ON NEW INDUSTRY CONSTRUCTION JOBS
(Governor's Task Force, 1972b, p. 14.)

0074 A CJNL.K=MIN(CJN.K, LSP.K)
CONSTRUCTION JOBS FROM NEW INDUSTRY TO LOCALS

0075 A LSP.K=260
LOCAL SKILL POOL
(Governor's Task Force, 1972b, p. 14.)

0076 L CIDL1.K=CIDL1.J+(DT)(CAPINVN.JK)
CAPITAL INVESTMENT DUMMY LEVEL

0077 N CIDL1=0
CAPITAL INVESTMENT DUMMY LEVEL INITIAL CONDITION

0078 A FRACOM.K=CIDL1.K/TCIP
FRACTION OF CONSTRUCTION COMPLETE

0079 C TCIP=115E6
TOTAL COST INITIAL PHASE

0080 A PJNL.K=(FRACOM.K)(STAFF)
PERMANENT JOBS FROM NEW INDUSTRY TO LOCALS

0081 C STAFF=350 C STAFF=124
OPERATING STAFF OF THE REFINERY
(Hammer, 1969, p. 20; Governor's Task Force, 1972b, p. 20.)

0082 A PJNLW.K=(PJNL.K)(PWPWN)
WAGES FROM NEW LOCAL PERMANENT JOBS

0083 C PWPWN=8.6E3
PER WORKER WAGE FROM NEW PERMANENT JOB
(Governor's Task Force, 1972b, p. 14.)

0084 A YBO.K=(BPDO.K)(365)
YEARLY BARRELS OUTPUT

0085 A SERRRPL.K=(.04)(SERJIG.K)(STOLFUN.K)
LOSS OF PERMANENT SERVICE JOBS RELATED TO RECREATION.

0086 L FARMJ.K=FARMJ.J+(DT)(EFC.JK)
FARM JOBS

0087 N FARMJ=420
FARM JOBS INITIAL CONDITION
(Maine Pocket Data Book, Section 8.13.)
46.5 percent of 900 Note: assume 46.5 percent holds from county population figures.

0088 A MANJ.K=4224-AMC.K+CJNL.K+PJNL.K
MANUFACTURING JOBS
(Maine Pocket Data Book, Sections 7.5, and 8.13.)

0089 A SERJIG.K=(DDL1.K)(FARMJ.K+MANJ.K+SERJT.K)
SERVICE JOBS IN GOVERNMENT

0090 L DDL1.K=DDL1.J+(DT)(DDR1.JK-DDR2.JK)
DUMMY DELAY LEVEL ONE

0091 N DDL1=1.15
DUMMY DELAY LEVEL ONE INITIAL CONDITION

0092 R DDR1.KL=SJTSSJ.K
DUMMY DELAY RATE ONE

0093 R DDR2.KL=DDL1.K
DUMMY DELAY RATE TWO

0094 T SJTSSJT=1.05/1.15/1.35/1.55
SERVICE JOBS TO SERVE PRIMARY SERVICE JOBS TABLE
(Maine Pocket Data Book, Section 8.13.) It is assumed that that as per capita income rises per capita service (demanded) also rises.

0095 A SJTSSJ.K=TABHL(SJTSSJT,APCINC.K,1900,3850,650)
SERVICE JOBS TO SERVE PRIMARY SERVICE JOBS

0096 A APCINC.K=AREAWGS.K/TP.K
AVERAGE PER CAPITA INCOME

0097 A AREAWGS. K=FARMJ. K+FARMW. K+MANJ. K+MANW. K+
SERJIG. K*SERWIG+SERJT. K*SERJTW-SERRRPL. K*SERWIG
AREA WAGES

0098 R EFC. KL=EFCC
EXOGENOUS CHANGE IN FARM JOBS

0099 C EFCC=0
EXOGENOUS CHANGE IN FARM JOB CONSTANT

0100 A AMC. K=(163)(STOLFUN. K)
SEA-RELATED LOSSES IN JOBS
(Maine Pocket Data Book, Sections 7.44, 7.36.)

7930 total Maine fishermen
3972 fishermen who derive less than half their income from fishing (assume .4)

3958 full-time fishermen

3958(1) + 3972(.4)=5547 effective full-time fishermen

1970 value landed=\$30.67 M =) $\frac{\$30.67M}{5547}$ =\$5529/fisher-man/yr

\$900,000/\$5529 = 163 loss in fishing jobs due to refinery as proposed

0101 C SERJTW=800
SERVICE WAGES GENERATED BY TOURISM
(Veazie, 1971.)
\$110,000/140 ≈ \$800

0102 C SERWIG=7560
SERVICE WAGES INCLUDING STATE AND LOCAL GOVERNMENT EMPLOYEES
These, along with other full-time job wages, were derived from total income and population figures.

0103 A FARMW. K=7560
FARM WAGES

0104 A MANW. K=(4224*MANWC-AMC. K*MANWC+CJNL. K*PWCWN
+PJNL. K*PWPWN)/MANJ. K
MANUFACTURING WAGES

0105 C MANWC=7560
MANUFACTURING WAGE CONSTANT

0106 A SERJT. K=(TOURDW. K)(140/1.1E6)
SERVICE JOBS GENERATED BY TOURISM
(Veazie, 1971, p. xiv.)
One hundred forty extra employees are needed to handle service jobs during the summer peak; 1.1 million tourist days comes from STNDTD.

0107 A TOURDW. K=(STNDTD. K)(TURFACI. K)(1-(.04*STOLFUN. K))
TOURIST DAYS IN WASHINGTON COUNTY

0108 A TURFACI. K=((TURFAC. K/TFNF. K)-1)(.5)+1
TOURIST FACILITIES INDEX

0109 A TFNF. K=(STNDTD. K)(10E6/1.1E6)
TOURIST FACILITIES NORMALIZATION FACTOR

0110 A TOURPOL. K=TABHL (TPOLT, TOURDW. K, 2E6, 3.5E6, .5E6)
TOURIST POLLUTION (CROWDING)

0111 L STNDTD. K=STNDTD. J+(DT) (ITD. JK-DTD. JK)
STANDARD NUMBER OF TOURIST DAYS

0112 N STNATD=1.1E6
STANDARD NUMBER OF TOURIST DAYS INITIAL CONDITION
(Maine Coastal Resources Renewal, State Planning Office, 1971b, p.26.)
Assume 10 percent of total figure.

0113 R ITD. KL=.09E6
INCREASE IN TOURIST DAYS
(Maine Coastal Resource Renewal, State Planning Office, 1971b, p.26.)
Statewide growth on annual basis for the last decade.

0114 R DTD. KL=TOURPOL. K
DECREASE IN TOURIST DAYS

0115 T TPOLT=0/.07E6/.15E6/.3E6
TOURIST CROWDING TABLE

0116 L TURFAC. K=TURFAC. J+(DT) (MTURFAC. JK-DTURFAC. JK)
TOURIST FACILITIES

0117 N TURFAC=10E6
TOURIST FACILITIES INITIAL CONDITION

0118 R MTURFAC. KL=MFTF. K+MSTF. K+MLTF. K
MONEY TO TOURIST FACILITIES

0119 R DTURFAC. KL=TURFAC. K*TURFDC
DEPRECIATION OF TOURIST FACILITIES

0120 C TURFDC=.07
TOURIST FACILITY DEPRECIATION CONSTANT
Exponential decay with an initial decay rate of 1/14 per year.

0121 A DLTF. K=TOURDW. K*DRTFTD. K
DESIRED LEVEL OF TOURIST FACILITIES

0122 A DRTFTD. K=(13)(1+DLG. K)
DESIRED RATIO OF TOURIST FACILITIES TO TOURIST DAYS

0123 A DIITF. K=DLTF. K-TURFAC. K
DESIRED INCREASE IN TOURIST FACILITIES

0124 C FITFTY=.3
FRACTION OF DESIRED INCREASE IN TOURIST FACILITIES
REQUESTED THIS YEAR

0125 A TYDIITF. K=FITFTY*DIITF. K
THIS YEAR DESIRED INCREASE IN TOURIST FACILITIES

0126 A DLISF. K=(DRISF. K)(NI. K+OI. K)
DESIRED LEVEL OF INDUSTRIAL SUPPORT FACILITIES

0127 A OI. K=208E6
OLD INDUSTRY
(<u>Census Of Maine Manufacturies 1970.</u>)
1965--1969 total industry capital investment=\$69.4 M ⇒ 13.9M/yr
assume 15 years depreciation ⇒ 15x\$13.9M=\$208M

0128 A DRISF. K=(.60)(1+DLG. K)
DESIRED RATIO OF INDUSTRIAL SUPPORT FACILITIES

0129 L ISF.K=ISF.J+(DT)(MISF.JK-DISF.JK)
INDUSTRIAL SUPPORT FACILITIES

0130 N ISF=94E6
INDUSTRIAL SUPPORT FACILITIES INITIAL CONDITION

0131 R MISF.KL=MFISF.K+MSISF.K+MLISF.K
MONEY TO INDUSTRIAL SUPPORT FACILITIES

0132 R DISF.KL=(ISF.K)(DISFC)
DEPRECIATION OF INDUSTRIAL SUPPORT FACILITIES

0133 A DIISF.K=DLISF.K-ISF.K
DESIRED INCREASE IN INDUSTRIAL SUPPORT FACILITIES

0134 C FIIDTY=.3
FRACTION OF DESIRED INCREASE IN INDUSTRIAL SUPPORT FACILITIES REQUESTED THIS YEAR

0135 A TYDIISF.K=FIIDTY*DIISF.K
THIS YEAR DESIRED INCREASE IN INDUSTRIAL SUPPORT FACILITIES

0136 A SSBIISF.K=SISFF*TYDIISF.K
STATE SHARE OF BURDEN OF INCREASE TO INDUSTRIAL SUPPORT FACILITIES

0137 A LSBIISF.K=LISFF*TYDIISF.K
LOCAL SHARE OF BURDEN OF INCREASE TO INDUSTRIAL SUPPORT FACILITIES

0138 A MFISF.K=MSISF.K/(1-FISFF)
ACTUAL MONEY RECEIVED FROM FEDERAL GOVERNMENT FOR INDUSTRIAL SUPPORT FACILITIES

0139 A MSISF.K=(SSBIISF.K/TWCDS.K)(MATWC.K)
ACTUAL MONEY RECEIVED FROM STATE GOVERNMENT FOR INDUSTRIAL SUPPORT FACILITIES

0140 A MLISF.K=(LSBIISF.K/TWCDL.K)(LMA.K)
ACTUAL MONEY RECEIVED FROM LOCAL GOVERNMENT FOR INDUSTRIAL SUPPORT FACILITIES

0144 C DISFC=.07
INDUSTRIAL SUPPORT FACILITY DEPRECIATION CONSTANT
Chosen so as to begin exponential decay at 1/14 per year.

0145 A SSBITF.K=STFF*TYDIITF.K
STATE SHARE OF BURDEN OF INCREASE IN TOURIST FACILITIES

0146 A LSBITF.K=LTFF*TYDIITF.K
LOCAL SHARE OF BURDEN OF INCREASE IN TOURIST FACILITIES

0147 A MFTF.K=MSTF.K/(1-FTFF)
ACTUAL MONEY RECEIVED FROM FEDERAL GOVERNMENT FOR TOURIST FACILITIES

0148 A MSTF.K=(SSBITF.K/TWCDS.K)(MATWC.K)
ACTUAL MONEY RECEIVED FROM LOCAL GOVERNMENT FOR TOURIST FACILITIES

0149 A MLTF. K=(LSBITF. K/TWCDL. K)(LMA. K)
ACTUAL MONEY RECEIVED FROM LOCAL GOVERNMENT FOR TOURIST FACILITIES

0153 N MEWP=30E6
LEVEL OF HEW FACILITIES INITIAL CONDITION

0154 R MTHEW. KL=MLHEW. K+MSHEW. K+MFHEW. K
MONEY TO HEW FACILITIES

0155 R DHEW. KL=HEWP. K*DHEWC
DEPRECIATION OF HEW FACILITIES

0156 A DLHEW. K=DLHEWPP. K*TP. K
DESIRED LEVEL OF HEW

0157 A DLHEWPP. K=(2420)(1+DLG. K)
DESIRED LEVEL OF HEW PER PERSON

0158 L DLG. K=DLG. J+(DT)(DLGR1. JK)
GROWTH DUMMY LEVEL

0159 R DLGR1. KL=(DLGRC)(DLG. K)
GROWTH RATE

0160 C DLGRC=0
GROWTH RATE CONSTANT
Chosen so as to reflect no increase in demand as a function of time only.

0161 N DLG=0
GROWTH DUMMY LEVEL INITIAL CONDITION

0162 C DHEWC=.10
DEPRECIATION FACTOR FOR HEW FACILITIES
Chosen so as to reflect an exponential decay with the initial drop being 10 percent per year.

0163 A DIIHEW. K=DLHEW. K-HEWP. K
DESIRED INCREASE IN HEW

0164 C FIHEWTY=.5
FRACTION OF DESIRED INCREASE IN HEW REQUESTED THIS YEAR

0165 A TYDIHEW. K=DIIHEW. K*FIHEWTY
THIS YEAR DESIRED INCREASE IN HEW

0166 A SSBIHEW. K=SHEWF*TYDIHEW. K
STATE SHARE OF BURDEN OF INCREASE TO HEW

0167 A LSBIHEW. K=LHEWF*TYDIHEW. K
LOCAL GOVERNMENT'S SHARE OF BURDEN OF INCREASE OF HEW

0141 C FISFF=.287 FEDERAL INDUSTRIAL SUPPORT FACILITIES FRACTION

0142 C SISFF=.485 STATE INDUSTRIAL SUPPORT FACILITIES FRACTION

0143	C	LISFF=.228	LOCAL INDUSTRIAL SUPPORT FACILITIES FRACTION
0150	C	FTFF=.150	FEDERAL TOURIST FACILITIES FRACTION
0151	C	STFF=.425	STATE TOURIST FACILITIES FRACTION
0152	C	LTFF=.425	LOCAL TOURIST FACILITIES FRACTION
0168	C	FHEWF=.463	FEDERAL HEW FRACTION
0169	C	SHEWF=.326	STATE HEW FRACTION
0170	C	LHEWF=.211	LOCAL HEW FRACTION

Equations 0141--0143, 0150--0152, 0168--0170 were derived in the manner shown in Table C.1.

TABLE C.1.

Federal money to Washington County	HEW	$9.8E6
	TF	.196E3
	ISF	1.79E6
Federal money to state	HEW	$273E6
	TF	5.8E6
	ISF	39.9E6
O.E.O., 1970, pp. 16-17		
State expenditures	HEW	$192.6E6
	TF	$16.5E6
	ISF	$67.5E6
(State of Maine, Financial Report 1970, p. b.)		
Local expenditures	HEW	$124.6E6
	TF	$ Assumed to be the same as for state
	ISF	$ 31.7E6
(Maine Legislative Research Committee, 1967, p. 35)		

(Continued)

TABLE C. 1 (Continued)

	HEW	TF	ISF
(11) = (7) ÷ (8)	.211 LHEWF	.425 LTFF	.228 LISFF
(10) = (5) ÷ (8)	.326 SHEWF	.425 STFF	.485 SISFF
(9) = (1) ÷ (8)	.463 FHEWF	.150 FTFF	.287 FISFF
(8) = (1) + (5) + (7)	21.17E6	1.308E6	6.73E6
(7) = (3) x (6)	4.47E6	.556E6	1.42E6
(6) Local $	124.6E6	16.5E6	31.7E6
(5) = (3) x (4)	6.9E6	.556E6	3.02E6
(4) State $	192E6	16 5E6	67.5E6
(3) WC Fed$/State Fed$ (1 ÷ 2)	.0359	.0337	.0448
(2) Federal $ to State	273E6	5.8E6	39.9E6
(1) Federal $ to Washington County	4.8E6	.196E6	1.79E6

Note: It is assumed that federal cooperative spending is a function of the state's ability to come up with its share of the money.

0171 A MFHEW.K=MSHEW.K/(1-FHEWF)
ACTUAL MONEY RECEIVED FROM FEDERAL GOVERNMENT FOR HEW

0172 A MSHEW.K=(SSBIHEW.K/TWCDS.K)(MATWC.K)
ACTUAL MONEY RECEIVED FROM STATE FOR HEW

0173 A MLHEW.K=(LSBIHEW.K/TWCDL.K)(LMA.K)
ACTUAL MONEY RECEIVED FROM LOCAL GOVERNMENT FOR HEW

0174 A MPCIA.K=3257
MAINE'S AVERAGE PER CAPITA INCOME
(Maine Pocket Data Book 1971, table 6.3.)

0175 A DPCIF.K=((AREAWGS.K/TP.K)-MPCIA.K)/MPCIA.K
DIFFERENTIAL PER CAPITA INCOME FRACTION

0176 T NFT=2/1/.95
RELATIVE NEED FUNCTION TABLE

0177 A FMTS.K=85E6
FEDERAL MONEY TO STATE
(State Of Maine Financial Report 1971.)

0178 A STABUD.K=STSLSTW.K+STPERTW.K+STCORTW.K+MUNFISW.K+SMOVEHW.K+SGLCTW.K+SIFOC.K+FMTS.K
STATE BUDGET

0179 A STSLSTW.K=(SSTPTD)(TOURDW.K)+(SSTPLP)(TP.K)
STATE SALES TAX FROM WASHINGTON COUNTY

0180 A STPERTW.K=(WWI.K)(SPERIT.K)
STATE PERSONAL INCOME TAX FROM WASHINGTON COUNTY

0181 A STCORTW.K=(CORINC.K)(SCORIT)
STATE CORPORATE INCOME TAX FROM WASHINGTON COUNTY

0182 A MUNFISW.K=(LCPTD)(TOURDW.K)+(LCPLP)(TP.K)
HUNTING AND FISHING LICENSE REVENUES FROM WASHINGTON COUNTY

0183 A SMOVEHW.K=(NVPLP.K)(STPV)(TP.K)+(NLPR)(2.50)(TP.K)
MOTOR VEHICLE TAXES FROM WASHINGTON COUNTY

0184 A SGLCTW.K=(GLCTGPT)(TOURDW.K)+(GLCTGPL)(TP.K)
GAS, LIQUOR, CIGARETTE TAXES FROM WASHINGTON COUNTY

0185 A SIFOC=238E6
STATE REVENUES FROM OTHER COUNTIES
(State of Maine, Maine Handbook, p. 295; Financial Report 1970.)

$$\frac{\text{Washington County}}{\text{Maine}} = \frac{1.116}{51.880} = .0215 \therefore \frac{\text{other counties}}{\text{Maine}} = 97.85\%$$

\$327.9M total
85.3M from federal government ⇒ 97.85%x\$242.6M=\$238E6
\$242.6M

0186 C LCPTD=.153
LICENSE COST PER TOURIST DAY
(Maine Pocket Data Book 1971, Section 12.12.)

$\frac{\$1.149M}{994K}$ $\frac{\text{resident }\$}{\text{population}}$ => \$1.15/Licenses

$\frac{\$1.884M}{12.6E6 \text{ tourist days}}$ = \$.153/tourist day

0187 C NLPR=.49
NUMBER OF LICENSES PER RESIDENT
(Maine Pocket Data Book 1971, Section 11.22.)
491E3=Number of driver's licenses $\frac{491E3}{994E3}$ = .49

0188 C LCPLP=1.15
LICENSE PER LOCAL PERSON
See equation 0186.

0189 A NVPLP.K=.40+.005*TIME.K
NUMBER OF VEHICLES PER LOCAL PERSON
(Maine Pocket Data Book 1971, Section 11.22.)

$\frac{396E3}{994E3}$ $\frac{\text{vehicles}}{\text{population}}$ = .4. It is assumed that this figure will grow to .5 by 1990.

0190 C STPV=15
STATE TAX PER VEHICLE
(State of Maine, Maine Handbook, p. 289.)

0191 C GLCTGPT=.51
GAS, LIQUOR, AND CIGARETTE TAXES PER TOURIST DAY
(State of Maine, Financial Report 1970, p. 6.)

$\frac{\$6.3M6}{\$12.3E6}$ $\frac{\text{tourist related}}{\text{tourist days}}$ = \$ .51/tourist day

0192 C GLCTGPL=77.60
GAS, LIQUOR, AND CIGARETTE TAX PER LOCAL PERSON
(State of Maine, Financial Report 1970, p. 6.)
\$83.2E6- 6.07E6=\$77.13E6 \$77.13E6/994E3=\$77.60

0193 C SSTPTD=.49
STATE SALES TAX PER TOURIST DAY
(State of Maine, Financial Report 1970, p. 6.)
607E6/12.3E6 = \$.49/tourist day

0194 C SSTPLP=63.58
STATE SALES TAX PER LOCAL PERSON
(State of Maine, Financial Report 1970, p. 6.)
\$63.2E6/994E3=\$63.58/resident

0195 A SPERIT.K=TABHL(SPERITT, APERINC.K=0,11E3,1E3)
STATE PERSONAL INCOME TAX

0196 C SCORIT=.04
STATE CORPORATE INCOME TAX RATE
(State of Maine, Taxation and Laws, p. 5.)

Before federal tax ⇒ .04

0197 A TWCDS.K=SSRIHEW.K+SSBIISF.K+SSBITF.K+TYRFOSW.K
TOTAL WASHINGTON COUNTY DEMAND

0198 A TYRFOSW.K=(.15)(SSBIHEW.K+SSBIISF.K+SSBITF.K)
THIS YEAR REQUESTS FOR OTHER SERVICES-WASHINGTON COUNTY
(State of Maine, Financial Report 1970, p. 6.)

$\frac{\$41.3\text{M other}}{\$276.7\text{M HEW, TF, ISF}} = 15\%$

0199 A TDOS.K=TWCDS.K+TDBOC.K
TOTAL DEMAND ON STATE

0200 A TDBOC.K=308E6
TOTAL DEMAND BY OTHER COUNTY
The $318M total is assumed to be proportional to population.
(State of Maine, Financial Report 1970, p. 6.)

0201 A MATW1.K=MIN(TWCDS.K,(SPPFTWC.K)(STABUD.K))
MINIMUM ALLOCATION TO WASHINGTON COUNTY

0202 A MATWC.K=MAX(0,MATW1.K)
NON-NEGATIVE CONSTRAINT

0203 A SPPFTWC.K=(WCSTG.K / STABUD.K) (SMABDF.K)(SMABNF.K)
STATE POTENTIAL PAYMENT TO WASHINGTON COUNTY FACTOR

0204 A SMABDF.K=1
STATE MONEY ALLOCATED BY DEMAND FUNCTION
For this simulation it is assumed that there is no special demand from any one area.

0205 A SMABNF.K=TABHL(NFT,DPCIF.K,-.2,.2)
STATE MONEY ALLOCATED BY NEED FUNCTION

0206 A WCSTG.K=STABUD.K-SIFOC.K
WASHINGTON COUNTY STATE TAX GENERATOR

0207 A CORINC.K=10650E3
CORPORATE INCOME
(Maine Pocket Data Book 1971, Section 7.4.)

Volume = $71E6. A profit of 15 percent before taxes is assumed.

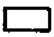
0208 A APERINC.K=AREAWGS.K/WWI.K
AVERAGE PERSONAL INCOME FOR WORKERS

0209 T SPERITT=0/10/20/40/60/80/110/140/170/200/230/250
STATE PERSONAL INCOME TAX TABLE
(State of Maine, Taxation and Laws.)

```
0210  A     LCLBUD.K=PRTX.K
            LOCAL BUDGET
0211  A     PRTX.K=(PTXR)(PRESPRO.K+NPROPV.K)
            PROPERTY TAX
0212  A     PRESPRO.K=76.7E6
            PERSONAL PROPERTY
            (Maine Pocket Data Book 1971, Section 4.23.)
0213  C     PTXR=.05
            PERSONAL PROPERTY TAX RATE
            (State of Maine, Report of The Bureau of Taxation.)
0214  A     TWCDL.K=LSBIISF.K+LSBITF.K+LSBIHEW.K+ODFLTM.K
            TOTAL WASHINGTON COUNTY DEMAND FOR LOCAL MONEY
0215  A     ODFLTM.K=(.20)(LSBIISF.K+LSBITF.K+LSBIHEW.K)
            OTHER DEMAND FOR LOCAL TAX DOLLARS
0216  A     LM1.K=(LCLBUD.K)(MIN(1,TWCDL.K/LCLBUD.K))
            LOCAL MONEY ALLOCATION FACTOR
0217  A     LMA.K=MAX(0,LM1.K)
            NON-NEGATIVE CONSTRAINT
0218  A     OPD.K=(76.7E6/29.9E3)(TP.K)-76.7E6
            OTHER PROPERTY DEVELOPMENT
0219  A     NPROPV.K=NI.K+OPD.K
            NEW PROPERTY TAX BASE
0220  PLOT  WWOI=U(0,1E4)/WWI=E(5E3,15E3)/TP=P(28E3,36E3)
0221  PLOT  TPI=P(0,8)/MP=1(-100,100)/PCHEW=H(1200,2200)/MHEW=2
            (-200,200)/UNEMP=U(0,.2)/MUNEMP=3(-1000,1000)
0222  PLOT  ISF=I(60E6,180E6)/HEW=H(25E6,65E6)/TURFAC=T(0,40E6)
0223  PLOT  MANJ=M(3500,7500)/SERJIG=S(3500,7500)/APERINC=
            A(6500,8500)
0224  SPEC  DT=.25/LENGTH=20/PRTPER=0/PLTPER=.5
```

Appendix D GUIDE TO DYNAMO SYMBOLS AND EQUATIONS

There are four basic types of equations in DYNAMO: (1) level, (2) rate, (3) auxiliary, and (4) constant. Each has its own symbol and format.

The level equation is designated by the letter L. The equation format is L LEVEL.K=LEVEL.J+(DT)(RATES.JK), and its symbol is a rectangle: 

The rate equation starts with the letter R. It takes the form: R RATE.KL=EXPRESSION. Its symbol is the valve: 

Auxiliaries have two forms. The first is a combination of rates, levels, and other auxiliary variables. The other can be the first part of a two-equation set describing a table function. The forms are

A AUXILIARY.K=EXPRESSION
A TABLE FUNCTION.K=TABLE FUNCTION SPECIFICATIONS
T TABLE=VALUES

The symbol for auxiliaries is a circle,  ; its identification letter is A.

Constant terms are introduced by initial-value or constant equations. Their formats are

N LEVEL=INITIAL VALUE
C CONSTANT = VALUE.

GUIDE TO DYNAMO OUTPUT GRAPHS

DYNAMO graphs are printed according to the standard format shown in figure E.1.

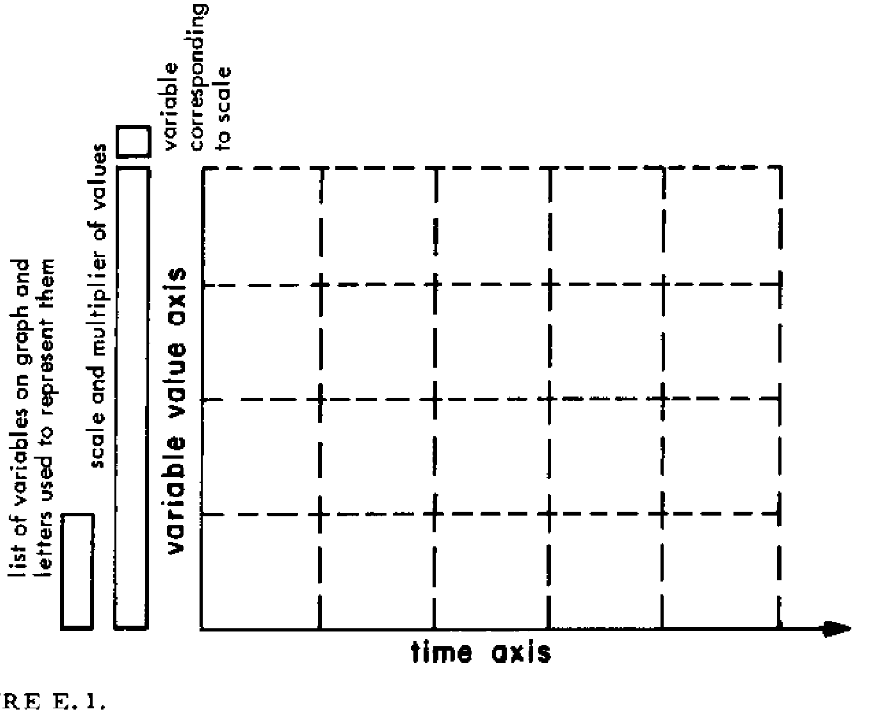


FIGURE E.1.

Graphical output uses a code for power of ten multipliers which appears immediately after the scale value. The most frequently used symbols are:

$$F = 10^{-9}$$
$$E = 10^{-6}$$
$$A = 10^{-3}$$
$$T = 10^{3}$$
$$M = 10^{6}$$
$$B = 10^{9}$$

Should further information about DYNAMO be desired, see Alexander Pugh III, DYNAMO II User's Manual (Cambridge, Mass.: The M.I.T. Press, 1970).