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A SIMULATION MODELING APPROACH TO CENTRAL CITY DYNAMICS USING NEWARK, NEW JERSEY AS A PROTOTYPE

BY

LEONARD WILLIAM SCHAPER JR.

A DISSERTATION

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ABSTRACT

This dissertation describes a computer simulation model of a central city with emphasis on its application to Newark, New Jersey. The work begins with a review of the Forrester Urban Dynamics Model; the first attempt to simulate the entire system of the city. The objections to this model which have appeared in the literature are discussed, and the model is viewed in the light of other work in the field. A set of guidelines to aid the "second generation" model building effort is developed. The actual construction of a model which attempts to follow these guidelines is described. First, the logical basis for the inputs and outputs of the model is presented, and then the algorithms which make up the four sectors of the model are described in detail. These sectors include sub-models dealing with the city's Housing, Households, Jobs, and Government. Relevant data and appropriate connections with urban literature are presented. Next a "standard run" of the model is described. This run was made with data from Newark to achieve a partial model calibration, and to examine the future impact of existing policies. Various alternative programs leading to the arbitrary goal of "city stability" are examined. It is found that substantial changes in public policy would be necessary to achieve this goal. Finally, suggestions for the further development of large scale urban simulation models are made.

APPROVAL OF DISSERTATION

A SIMULATION MODELING APPROACH

TO CENTRAL CITY DYNAMICS

USING NEWARK, NEW JERSEY

AS A PROTOTYPE

BY

LEONARD WILLIAM SCHAPER JR.

FOR

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

BY

FACULTY COMMITTEE

APPROVED:____________________CHAIRMAN

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I. INTRODUCTION

Wherever American cities are going, Newark will get there first.

--Newark's Mayor Kenneth Gibson

Where are America's cities going? How will we know when they get there? And if we don't like where they are going, how can we alter their course?

Increasingly these questions vex many Americans who see the deterioration in the quality of city life, but feel powerless to do anything about it. Many programs instituted by the Federal government to aid cities have failed and are being phased out. Recent cutbacks in housing programs, Urban Renewal, and Model Cities underscore this failure.

Much of the problem in dealing with urban ills is that no one knows how a city operates as a system, a system filled with complex interactions among people and institutions. A program designed to alleviate a particular problem may, because of unforeseen effects, cause problems in other areas. Or even more likely, a program undertaken for its short term benefits may produce long range detriments never imagined. Slums unfit to live in are torn down to make room for high rise public housing which becomes unfit to live in. It is time for a thorough examination of this system called a city, time to find out why it works as it does and where it can be prodded to make it work better.

One tool which may help to achieve a better understanding of the workings of a city as a total system is the computer simulation model; a mathematical representation of the processes which make a city work using a computer as an instrument to carry out the laborious computations.

The use of the computer as a tool in urban problem solving is not new, but its use in the past has been mainly for models concerned with transportation planning and land use planning[1], in which the city was divided into many zones by a form of grid. These models were concerned with the strain put on transportation facilities by the movement of people and goods between zones and with the development of land use patterns in the different zones. None of these models was concerned with the city as an entity, and none included all of the important social and economic interactions which determine a city's course of history. In short, these models were designed to examine specific aspects of urban life, but they were not concerned with the larger problem of how the total city system operates.

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[1]See Kilbridge, et.al. (1970), for a discussion of previous modeling efforts in land use and transportation planning.

But it is possible to construct a simulation model which contains all of the important segments of urban life, at least at a highly aggregated level. Considering the city as one geographical unit and dividing the population into relatively few groups, for example, yields variables for which data can be collected. Behavioral characteristics can be determined, simply because groups with many similar members act in predictable ways, even though individual actions may not be predictable. Although a simulation model constructed with highly aggregated variables may not be as precise as would be desired, it can still give much information about the important interactions in the urban system.

The first such simulation model of a city was presented in 1969 by Dr. Jay Forrester of M.I.T. in his book Urban Dynamics. This work, although it has received wide criticism, stands as a landmark in the field of urban analysis. The Urban Dynamics model, the criticisms it received, and the lessons learned from it are discussed in Chapter II.

The remainder of this dissertation is concerned with the design, construction, and testing of a new computer simulation model of a city and its calibration with data from the city of Newark, New Jersey. Chapter III discusses the philosophy of the model and its development from the Urban Dynamics model and from the objections to the Urban Dynamics model. Especially important is the concept of a "modular" model: one in which the tasks of computation are divided into clearly delineated sectors which communicate with each other through a state variable matrix.

Chapters IV through VII are concerned with the detailed descriptions of the algorithms which make up the four sectors of the model: Housing, Households, Jobs, and Government. Chapter VIII discusses the results of the standard calibration run of the model and the effects on the city of Newark of the present institutional structure. Alternative programs to impede urban decay are introduced in Chapter IX, and their simulated effects on Newark from 1975 until 1990 are presented. Chapter X deals with the limitations of the model as currently constructed, the general applicability of such models, and suggestions for further research. Program listings and certain computer outputs are included in Appendix I, and details of data collection are covered in Appendix II.

The model presented here is not intended as a finished product which can be used to definitively predict the future impact of proposed urban programs. It is only one step in the continuing evolutionary process of quantifying the factors which govern the growth and decay of cities.

The choice of Newark as a city on which to perform the simulation process is a logical one in light of Mayor Gibson's comment which began this chapter. Among the cities of America, Newark ranks near the highest in housing abandonments, crime, unemployment, venereal disease, property taxes, and a host of other urban ills. Thus Newark provides a wide range of data on which to base simulation relationships.

II. URBAN DYNAMICS

The Forrester Model

The publication in 1969 of the book Urban Dynamics by J. W. Forrester generated much interest and a great many book reviews, critiques, and analyses of the Forrester approach to the urban system. Some critics have condemned both Forrester's results and his system dynamics method. Others have questioned his results but hailed his method as a new approach to the solution of complex urban problems. This chapter will review Forrester's work in terms of the method used and the results achieved. It will also treat the criticisms of the work which have appeared in the literature as well as reported extensions of the original urban dynamics study.

The method used in Urban Dynamics is that developed at the Sloan School of Management at M.I.T. by Forrester and others in the 1950's and published in 1961 as the book, Industrial Dynamics (Forrester, 1961). The industrial dynamics method represents a business enterprise, with all of its component parts such as manufacturing, sales, warehousing, and retailing, as a system of interconnected feedback loops. All pertinent variables in the system are expressed as state or level variables whose values are influenced by flow rates into and out of the variable. An obvious physical analogy is that of pouring water into a leaky bucket. However, in Forrester's models the speed at which one is pouring and the size of the hole in the bottom of the bucket are determined by a complex system of interactions with other variables in the system. Because of these interactions the perturbation of one point in the system can influence the value of a variable at some other point in the system with which it has no apparent connection. In addition, because of non-linear relationships which can be built into the connections between system levels and flow rates, the value of one variable may not always affect the values of other variables in the same way.

Once the equations describing the system variables and flow rates are programmed and fed into the computer along with initial values for all variables, the simulation proceeds, usually on a yearly basis although any time period could be used as an increment. At each iteration a complete set of calculations takes place. New flow rates are calculated and the variables which they affect are updated by the appropriate amount. Outputs from the computer can be in the form of tables of variables or graphical outputs of variables as a function of time.

This is the method of simulating a real system used in Industrial Dynamics, Urban Dynamics, and even more recently, World Dynamics (Forrester, 1971b). This general method Forrester (1971a, p.53) has called "system dynamics", since it is a generalized technique for the analysis of any complex system. Most of the criticism of Urban Dynamics has not been concerned with the system dynamics method, but with the way in which the method was applied to the urban system.

The structure of Forrester's Urban Dynamics model is shown in Figure 2.1. All level variables and flow rates are indicated. Three sectors are apparent; the first is industry, the second housing, and the third people. In the industrial sector new enterprise is created. This new enterprise becomes mature business and then declining industry. Finally it ceases to exist.

In the housing sector, premium housing is created. Through age it becomes worker housing for a given time, and finally decays into housing for the underemployed which exists for some lifetime and then is demolished. In addition, worker housing can be created directly through a middle income housing program and underemployed housing can be created directly through a low income housing program.

The population sector is somewhat more complicated but is again divided into three classes: managerial-professional, labor, and underemployed. All three categories are influenced by their respective birth rates,

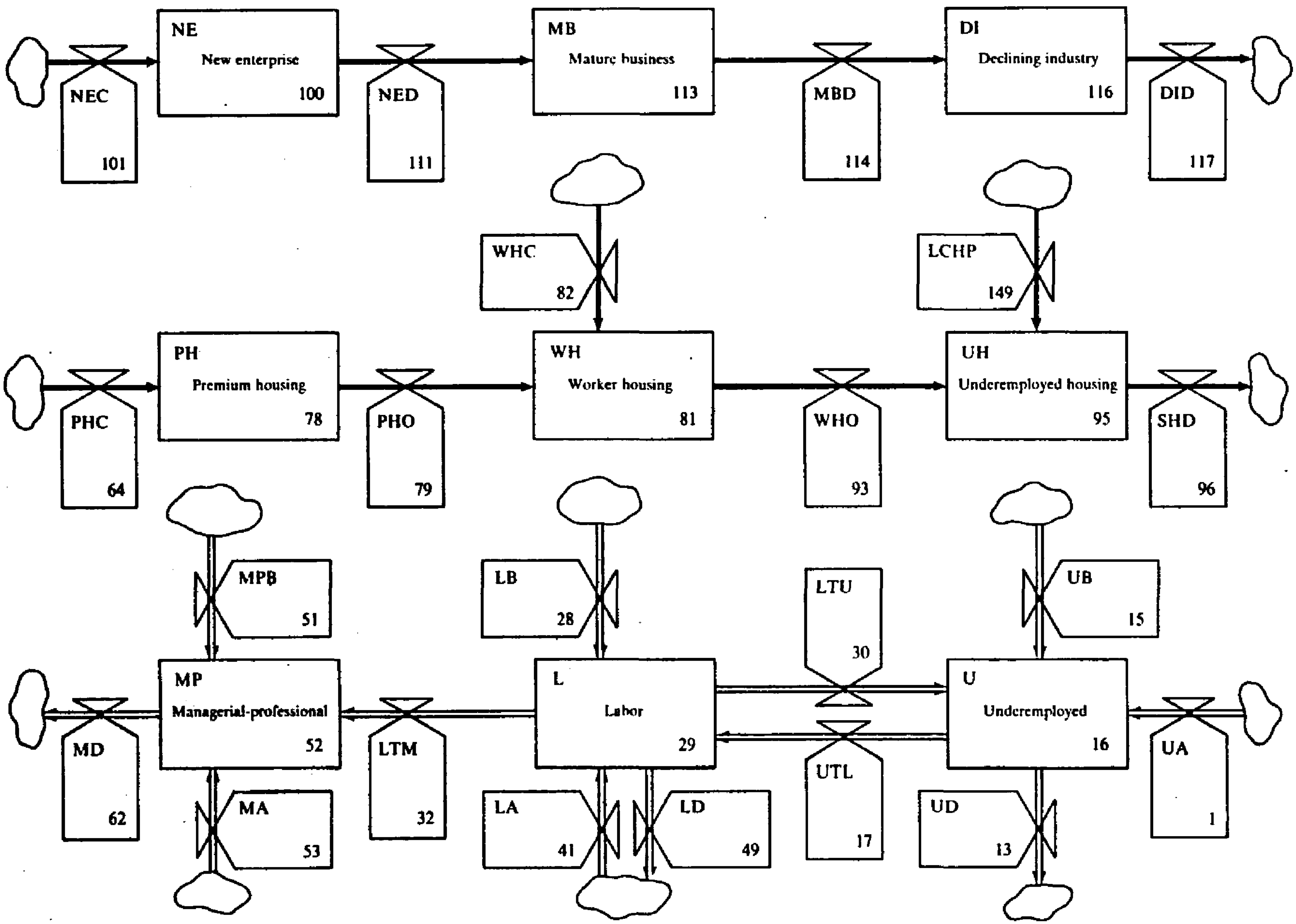

Figure 2.1 The Forrester Urban Dynamics Model (Forrester,1969,p16)

expressed as the difference between birth rate and death rate, and by arrivals from and departures to the outside world. In addition, paths are provided for labor to become underemployed, for underemployed to become labor, and for labor to become managerial-professional. In all cases the amorphous blob symbol in Figure 2.1 represents either a creation or dissolution or a migration to or from the surrounding environment.

For the present discussion, it is not relevant to go into the detailed interactions among variables in the model. However, one example of the calculation of a flow rate in the Forrester model may be instructive. The small circles in Figure 2.2 represent mathematical relationships between level variables and the underemployed arrival rate. The influences on this rate include the underemployed arrivals mobility multiplier (UAMM) which describes how readily the underemployed are moving into the skilled labor class; the underemployed per housing multiplier (UHM) which determines the availability of underemployed housing in the city; the public expenditure multiplier (PEM) which determines how much tax money is being spent per capita in the city; the underemployed per job multiplier (UJM) which determines how many jobs are available for underemployed people; and the underemployed housing program multiplier (UHPM) which reflects the influence of the existence of a construction program for low cost housing. All of these

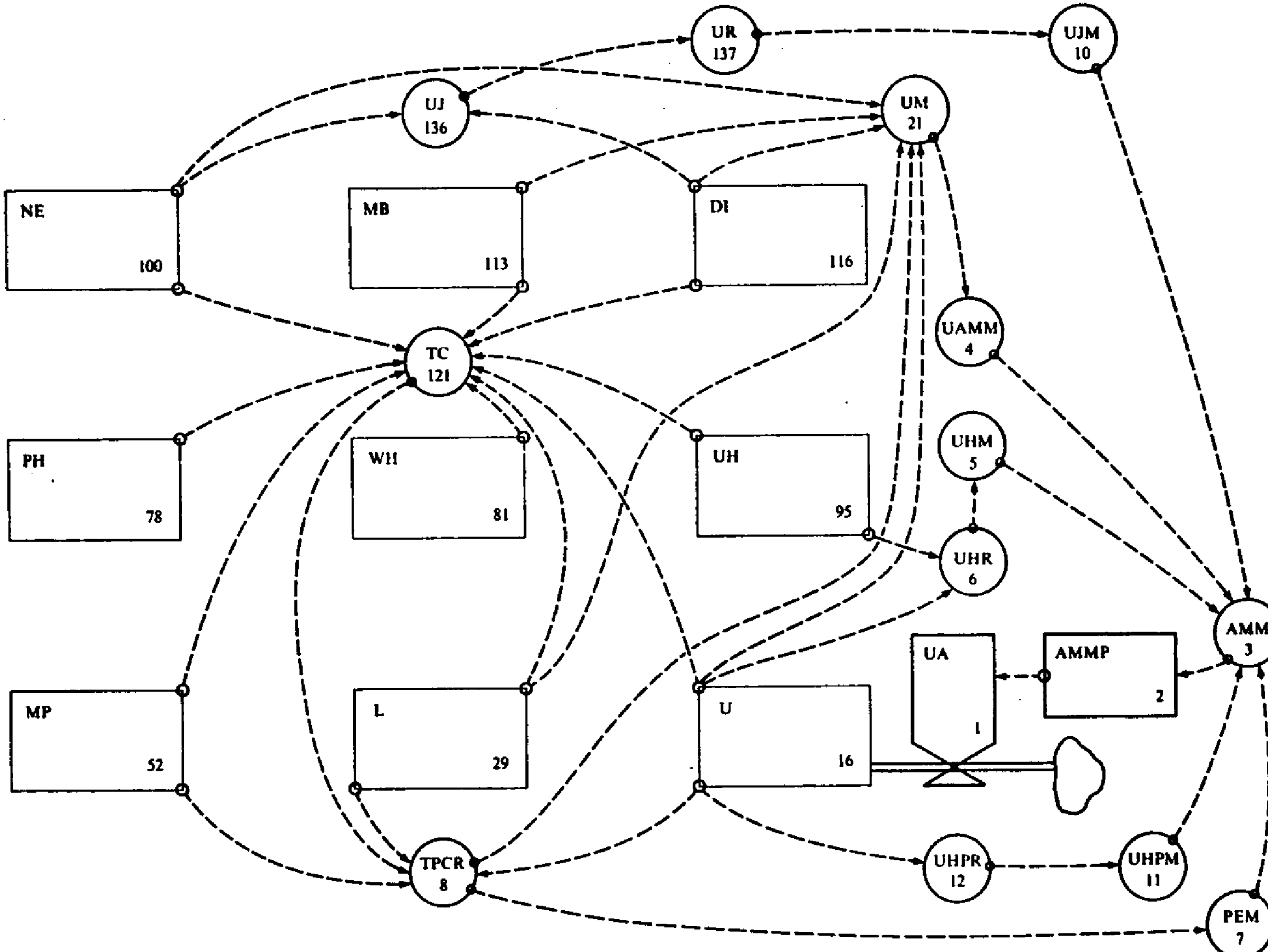

Figure 2.2 Factors Affecting a Flow Rate (Forrester,1969,p21)

relationships affect the attractiveness for migration multiplier (AMM) which then, after being delayed by perception time in the attractiveness for migration multiplier as perceived (AMMP), affects the normal rate of underemployed arrivals either positively or negatively.

Obviously, the Urban Dynamics simulation is very complex. Forrester spends most of his book explaining the relationships involved in the simulation. These include many graphs relating one variable to another which, although logical in their general shape and form, have no basis in factual data. The lack of real world substantiation for the relationships expressed has resulted in much of the criticism of Forrester's work.

Results of Urban Dynamics

Forrester uses the Urban Dynamics model in two ways. The first is shown in Figure 2.3. Starting from year zero the simulation proceeds through 250 years of what Forrester calls internal development, maturity, and stagnation. This use of the model establishes a steady state condition representing present day conditions of the city.

The second use of the model is in analyzing the future impact of two types of urban programs. The first type includes those programs which have traditionally been used to try to alleviate conditions of the city, such as tax subsidies, job training, and low cost housing

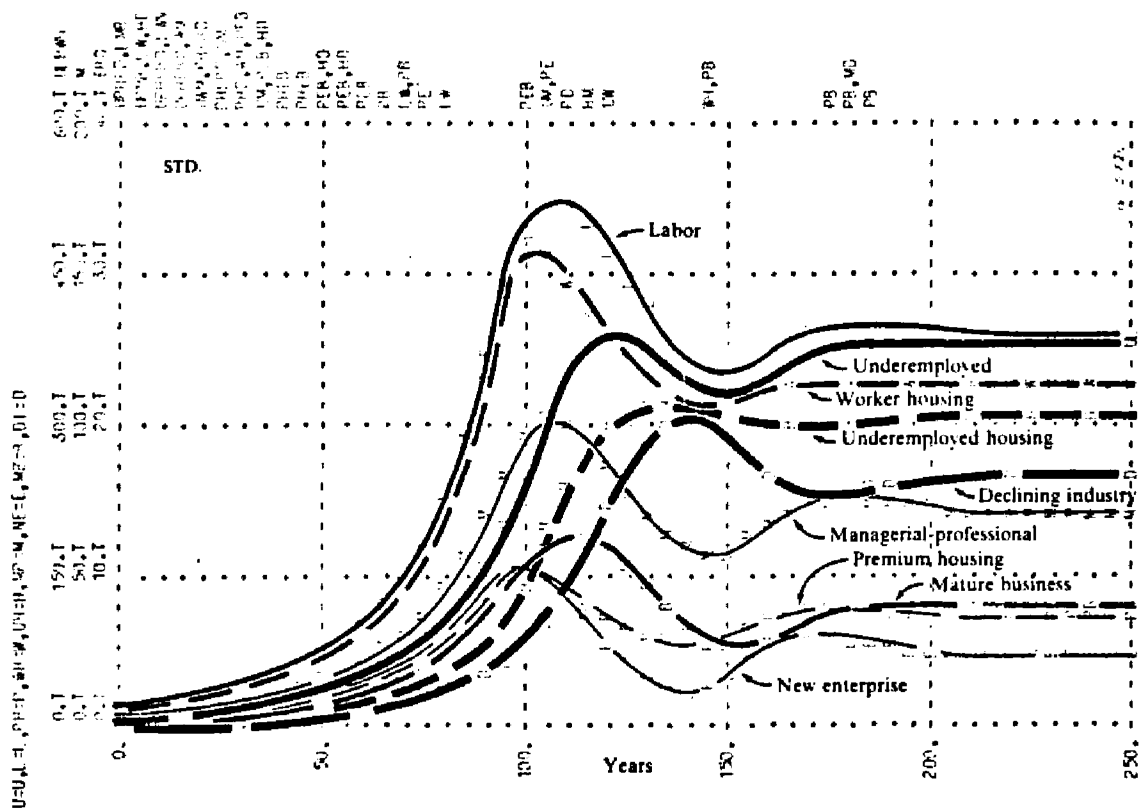

Figure 2.3 Use of the Model to Predict the 250 Year History of an Urban Area (Forrester,1969,p4)

construction. He calls these programs failures. For example, he says of the job training program:

> The training program has created a flow through the area with a much increased underemployed-arrival rate and a much increased labor-depature rate. People come to the area because of the training program and leave when they find there is no use for the skills they have acquired. As a service to society the program might be considered successful. But as a service to the city, its value is far less clear. The area is more crowded, the land fraction occupied has risen slightly, housing conditions are more crowded, the total of underemployed has risen very slightly, and the ratio of labor to jobs is higher, indicating a higher degree of unemployment (Forrester, 1969, p. 59).

The second type of program which Forrester considers includes actions which he says will lead to urban revival, such as new enterprise construction, declining industry demolition, and slum clearance. The "best" combination of these programs has results shown in Figure 2.4. This program combines the demolition of 5% of slum housing each year with business incentives which increase new enterprise construction by 40%. The results are not unexpected. All segments of the industrial sector show an increase and labor increases to keep pace, as does worker housing. The number of underemployed declines but not nearly so much as the number of underemployed housing units. This results in a vast increase in crowding in the ghetto. Obviously these results are good for labor and business but the value of this program to underemployed persons is doubtful.

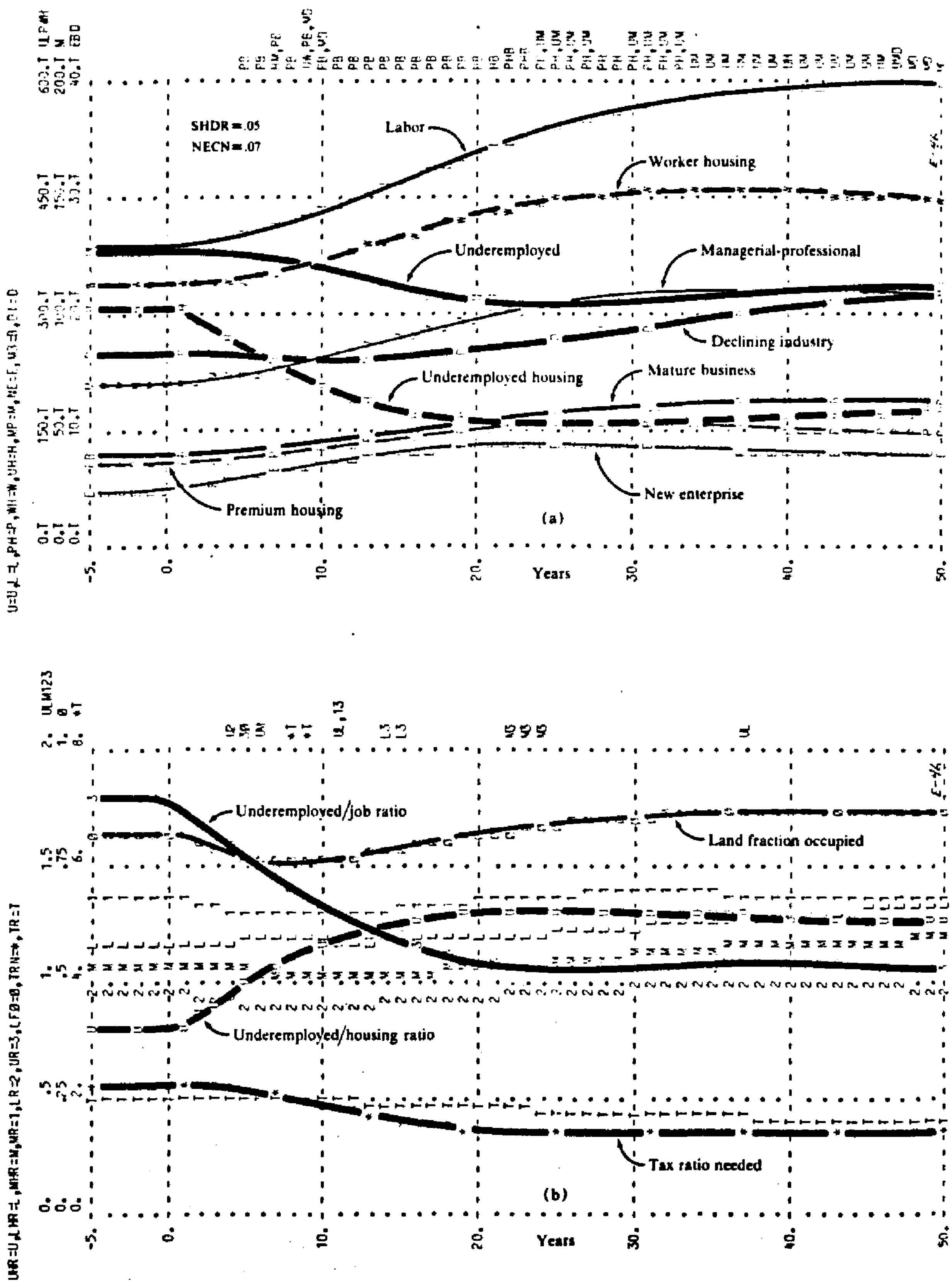

Figure 2.4 Effects of "Urban Revival" (Forrester,1969,p98)

This concludes the brief review of Forrester's method and results. The underlying assumptions and shortcomings of this work will now be examined in the light of the large number of criticisms and comments which have appeared in the literature in the three years since the publication of Urban Dynamics.

Critiques of Urban Dynamics

Perhaps the best statement which sums up all of the criticisms of Urban Dynamics is that of Kadanoff (1971, p. 262):

> Despite these criticisms of Forrester's conclusions, I would argue that his model making is so brilliant and beautiful that his ideas are certainly worthy of examination and further development. I would reject the conclusions, but accept the model as an appropriate basis for further work.

What specifics have led critics of Forrester to reject his conclusions? Generally the criticisms fall into five categories:

1. Implicit model goals.
2. Results not counterintuitive.
3. Structural errors.
4. Parametric errors.
5. Lack of real data.

The arguments of various authors concerning these points are given below.

Implicit Model Goals. There are two types of goals which have been found to be implicit in the Forrester model. The first type concerns goals of the city as a system. Forrester's implied goals for the city will be mentioned in the next section. The second type of goal concerns the motivations for individual behavior, or in effect, a person's value structure. Of this Gibson says,

> The implicit value framework is completely hidden in Forrester's text. Forrester as a technical person may even be unaware on a conscious level that there is such a thing as a value judgment or that he has made any (Gibson, 1972, p. 135).

Gibson contends that Forrester's value structure includes the following: (1) People are attracted to a city or leave it based on their perception of how well they can do economically in that city. (2) People make decisions based on the prospect of future rewards. (3) The possibility that an urban community can live in harmony with itself is rejected. (4) "Good" means that which is good for the economic life of the city. (5) The city has a constant land area. (6) The values and relationships stated in the model are unchanging even over a simulation of 250 years.

It is impossible to build a simulation model at least partially concerned with human decision making without having some statement of the value system with which decisions are made. The point is, however, that these values should be explicitly stated and not merely implied.

When it comes to the goals of the entire urban system there is some disagreement. Kadanoff is concerned with the lack of a "people oriented" evaluation procedure for any urban programs. He says:

> Forrester's assumption that there is an object called 'the city' to which we can assign benefits or debits is, I think, incorrect. We should only assign benefits and hurts to people, since the goals of our policies should be to enable people to live more satisfactory lives (Kadanoff, 1971, p. 266).

Sagner stresses the need to state explicitly the set of goals which a healthy city should fulfill. He says, "This failure to state quantitative goals for cities would appear to render any urban simulation such as Forrester's to be an academic exercise at the present time." (Sagner, 1972, p. 197).

Although there certainly is a need to better quantify the purposes, or goals, of an urban system, the question of goals, or program evaluation, could be omitted from an urban simulation model. This premise is discussed at greater length in the next chapter.

<u>Results not Counterintuitive</u>. One of Forrester's contentions has been that:

> With a high degree of confidence we can say that the intuitive solutions to the problems of complex social systems will be wrong most of the time. Here lies much of the explanation for... troubles of urban area. (Forrester, 1969, p. 110).

Yet Babcock contends that "Neither the equilibrium condition predicted by the Urban Dynamics model nor the programs recommended to improve it are counterintuitive; they follow directly from the model's assumptions and structure." (Babcock, 1972, p. 149).

Kadanoff also contends that Forrester's results are not counterintuitive but follow from his implied though not explicitly stated goals which seem to include (Kadanoff says) "minimization of the average per capita tax rate", and "to diminish population share of the underemployed." Thus he concludes that any policies which make the city more attractive to underemployed people (who according to Forrester's model demand a higher per capita share of the tax revenue than the laborer or manager class) will be classified as failures. Any programs which attract new enterprise which provides tax revenue or that provide for eliminating underemployed housing resulting in underemployed out-migration will be successful programs. Thus Kadanoff concludes that "Forrester's conclusions follow from his goals without any counterintuitive steps." (Kadanoff, 1971, p. 262).

In a paper comparing Forrester's advocated policies to those which have been followed in the past, Pack says that:

> a) urban renewal is not by any means synonymous with low-income housing construction; (b) urban

> renewal programs, in fact, reflect a view of appropriate urban revival policy which is virtually identical to Forrester's, i.e., an overriding concern with attracting new industry (often to land made available by slum-housing demolition) and keeping vigorous firms from leaving the area and with improving the tax base. (Pack, 1972, p. 192).

The implication is that Forrester's program for urban revival, far from being counterintuitive, is precisely the program followed by some urban renewal processes without the benefit of Forrester's model.

Structural Errors. Errors in a simulation's results can be traced to errors in the model's structure. For example, the omission of a necessary feedback loop or the inclusion of an imaginary loop are structural errors. Babcock raises several points in this area:

> The "natural condition of....too much housing and too few jobs for the underemployed population" represents an a priori assumption and is created in the model by biasing model constants and structure. When the model is modified to fit urban data these excesses largely disappear. ...
>
> Lack of provisions in the model to represent the close interaction between an urban core and the surrounding urban fringe severely weakens the model's predictive power. (Babcock, 1972, p. 149).

Garn and Wilson raise a similar point concerning the lack of urban-suburban interaction:

> Forrester seems to accept, during the course of his book, that the boundary assumption which he made to close the model does accurately reflect the real situation. (Garn and Wilson, 1972, p. 151).

These authors feel that Forrester has made a significant structural error.

Another structural problem frequently mentioned is that Forrester uses his unchanging model structure to simulate the entire 250 year life history of a city. As Gibson asks "Do these values adequately represent the set of values operative in the United States for 250 years...?" (Gibson, 1972, p. 136). Obviously a fixed model structure is inappropriate for simulating such a long time span.

Parametric Errors. Parametric errors in a simulation result from errors in the modeled relationships among variables. For instance, if one variable is modeled as influencing the value of another variable and the amount of that influence is incorrectly quantified, the result is a parametric error. Because of Forrester's complete absence of calibrating data for the interactions among variables, many of Forrester's critics have taken him to task. Ingram, for example, points out:

> Perhaps the main reason for carrying out sensitivity analysis on the parameters of a model is to identify those parameters whose values are crucial to the model results. One must ascertain their true values through empirical estimation. The specification of "reasonable" values for other parameters is only justified when their values are found to have relatively little impact on model results. (Ingram, 1970, p. 207).

Ingram goes on to point out that Forrester has neither performed a sensitivity analysis nor calibrated the important parameters.

Babcock points out a specific instance of a parametric error:

> The power Forrester ascribes to the influence of housing availability on unskilled migration is far greater than can be justified by urban literature. (Babcock, 1972, p. 149).

The graphically defined multiplier functions used by Forrester to relate the influence of one variable on another are critical, according to Garn and Wilson, who call these multipliers the "driving forces in the model." They continue:

> It would take much more empirical work to determine if the multipliers selected are the appropriate ones and even more to determine the shape and ranges of the functions. (Garn and Wilson, 1972, p. 152).

Pack, after noting the differences between Forrester's migration coefficients and those which she has determined on the basis of empirical research, states:

> It is unlikely that equally important differences would not be discovered in any of the submodels .... They should make us rethink the value of large urban simulation models which are based on assumed rather than estimated parameters. (Pack, 1972, p. 195).

<u>Lack of Real Data</u>. Much of the case for using real data in a large scale urban simulation has already been made in the discussion on parametric errors. In that case, the data is needed to calibrate the postulated

relationships among variables. In order to demonstrate the usefulness of the simulation model it is necessary to simulate a real world city, as pointed out by Gray, Pessel, and Varaiya:

> There is no attempt to match the initial state, parameters, or behavior of the model to a real city. Thus there is no way to correlate the behavior of (Forrester's) model with the behavior of a real city. A more rational approach is to pick key variables, empirically establish their relationships, and then tune the model to predict the past performance of the system. (Gray, et.al., 1972, p. 144).

<u>Other Critics</u>. There have, of course, been many other critics of Forrester's work. Additional authors are listed in the list of references at the end of this dissertation. In addition to these criticisms of <u>Urban Dynamics</u>, there have also been extensions to Forrester's work. Several of these are reported below.

<u>Extensions of Urban Dynamics</u>

The most extensive work on the Urban Dynamics model appears in the Doctoral dissertation of Babcock (1970). In this work the author examines, equation by equation, the Urban Dynamics model and attempts to relate it to previous urban literature. He points out many discrepancies between Forrester's work and that of other researchers, and also demonstrates several modifications of the original model. Babcock's work will be quoted several times in this dissertation.

Other authors have also extended Forrester's work. Kadanoff and Weinblatt have tried to examine the national implications of urban policies by constructing a model containing three aggregated areas: all central cities, all suburbs, and the remaining rural areas. However, even this extended model retains the problems associated with unsupported assumptions characteristic of Forrester's original work. The authors themselves recognized this:

> In fact, we do not believe that incomplete and uncalibrated models like the national metropolitan model can provide any definitive answers whatsoever. Rather these models provide novel ways of phrasing qualitative arguments. What we have done here is essentially to put our subjective beliefs into numerical form. (Kadanoff and Weinblatt, 1972, p. 165).

Graham has extended the original model to include the effects of commuting, but the addition containing the commuting model has merely been tacked on to the original uncalibrated model. It is not surprising therefore that he concludes that Forrester's revival policies are correct.

Some researchers such as Porter and Henley (1972) have taken the Forrester model and applied it to a specific urban area, in their case Houston, Texas. They used 1950 census data to determine variable values and then checked the simulation results against data from 1960 and 1970. The usefulness of their work lies not in the results, which agree fairly well with the census data as would be expected for slowly varying variables taken over only a twenty year period, but rather with their attempt at translating real world data (mostly Census) into variables useful in a computer simulation. They would like to see further research such that "the model be rewritten using variables which could be extracted from census tapes for population and housing and some standard publications such as Dunn and Bradstreet for business." (Porter and Henley, 1972, p. 183).

With regard to getting real world data to replace the educated guesses used in some of Forrester's equations, the most useful work has been done by Pack (1972), who has performed a regression analysis on certain economic and sociometric variables in an effort to estimate migration rates of white and non-white migrants. She concludes that Forrester's migration rates are too heavily influenced by the availability of housing, and too little influenced, especially for non-whites, by the percentage of their peers who make up the city's population.

Conclusions

A statement by Ingram seems to express the consensus of many authors concerning Forrester's work.

> The approach embodied in [Urban Dynamics], that of using behavioral relations in the simulation context, represents the most promising means available today for analyzing the workings of urban areas. One only hopes that critics will not

> identify the shortcomings of the model outlines in Urban Dynamics with its underlying methodology. (Ingram, 1970, p. 208).

The premise of this dissertation is that the Forrester model is so flawed that a new model is required; a model built along the same simulation concepts but built in such a way as to incorporate a wider range of previous work in a more realistic context.

Many of the problems of the Forrester model which need to be corrected have been mentioned by other authors. But there are others. For example, have all of the important variables which have contributed to the "stagnation" of the cities been taken into account in Forrester's model? What about variables traditionally associated with the white flight to the suburbs, such as deterioration of schools and an increasing crime rate? Is an urban model supposed to be insensitive to race and ignore traditional American bigotry? If these quantities are significant they must be included in a model. The Forrester model as stated seems to attribute much of the urban stagnation to a lack of available land for building of new enterprise and premium and worker housing. One need go no further than Newark to see that such is not the case. Vast areas of urban renewal land lie idle waiting only for some enterprising developer to build. The concept which is lacking in the Forrester model is profitability. Private enterprise will not build industries in an area of high tax rate if more desirable land is available. Developers will not build housing which could only be rented to low income people because of the desirability of an area if those low income people can not afford to make that construction profitable. Other forces may be significant. Suburbanites who have fled the city to escape a rising crime rate will be loath to return to the city during business hours and thus may encourage their employers to relocate in the suburbs. Any meaningful modeling effort must include these interrelationships among variables.

Based, then, on the three years of criticism since the publication of Urban Dynamics, and on the work of other model building efforts before and since, it is evident that the following characteristics should be incorporated into future urban modeling efforts on the scale of Urban Dynamics.

1. A model per se should not contain any goals. The function of the model should be descriptive and predictive. That is, the simulation should describe history and accurately predict future variable values. Any interpretation of the impact of proposed programs which are simulated by the model should be left to the decision makers.

2. The model should make no pretense of being

counterintuitive. This can be accomplished through a careful documentation of all logic, assumptions, mathematics, and calibration procedures.

3. Structural errors must be, as far as possible, eliminated. Such factors as urban-suburban interactions, race, crime, etc. not included in the Forrester model must be taken into account. A systematic way of reducing structural errors is the logical selection of pertinent variables, and then the construction of influences among these variables on the basis of urban literature and empirical data.

4. Parametric errors must similarly be reduced by calibration using existing sources or empirical data. At this stage in the state of the art data deficiencies are likely. These deficiencies should be pointed out so that they can be eliminated by further research.

5. The model should be calibrated to a real city. No theoretical tests of a model can prove the model's value as well as an attempt at calibration to a real city with a real data base.

6. For ease of comprehension, a model of this complexity should consist of a number of modules, or sectors, each of whose inputs, outputs, and functions is clearly defined. This form of definition should extend down to

the smallest computational algorithm.

7. To be realistic, a simulation model should not be expected to replicate the 250 year life history of a city. A model built to solve today's problems must reflect today's institutions. A practical simulation should have a time span of no more than forty or fifty years.

8. Care must be taken not to use the output of a simulation of one urban area, no matter how valid, as a basis for national policy decisions without post-analysis of that output to determine the national impact of such policy decisions.

III. A SECOND GENERATION URBAN MODEL

Thus far this paper has discussed the Forrester Urban Dynamics model. The shortcomings of this model, as pointed out by a wide range of authors, have been documented. This chapter is concerned with the present modeling effort. First the purposes and objectives of the model are discussed, and then the general description and specifications of the various sectors of the model are presented.

Purposes and Objectives

The traditional use of systems analysis and modeling techniques in the urban context has been by agencies who had in mind specific goals and objectives. For example, the principal objective of a transportation planning model implemented by a transportation planning agency is to determine which transportation improvements should be initiated. Information produced by the model which could be used by other agencies, such as the future demand for sewer systems, is secondary. Indeed, many sectors of urban life are completely left out of such a goal directed model.

The present model has no goals in the traditional sense. There is no transit system to be built, or policy to be decided, or money to be spent. Rather this model seeks to gain insight into the interactions among people, objects, and institutions in the complex system known as a city. The output of the model may suggest policies to alleviate urban problems, but these will not be pursued here with the vigor shown by Forrester, since the present state of the art of urban modeling is such that specific results must be treated with care.

It is the purpose of the present work to produce an expanded dynamic model of the urban environment which answers the criticisms of Forrester's original effort. Such a model should be able to predict the effects of hypothetical programs and policies on an urban area and its inhabitants, and should provide insight into the interactions involved in obtaining those effects. A fully calibrated model of this kind should be able to predict, in the future, the results of government programs, and should be able to be used as a means of selecting among program options.

It is the purpose of the present work to provide a structure which can serve as a basis for more extensive modeling efforts, to generate models of subsystems within that structure (some of which will be first attempts at the modeling of certain subsystems), and to indicate areas where further extensive work is needed, both in model structure and in data collection.

Answering the Objections to Urban Dynamics

The list at the end of Chapter II indicated the problems that must be solved in any successor to Urban Dynamics. These problems will be dealt with individually to show how the current model building effort has addressed them.

1. Built in goals. Although several authors stated that a more humanistic goal formulation in the Urban Dynamics model was necessary, it is probably more useful to leave goals out of a model, for two reasons. First, it is impossible to agree on a common set of goals which the urban system is trying to meet. For example, the slum dweller and the banker may evaluate certain programs in the light of highly different sets of values. But second, and more significant, is the fact that the professional planner is not the decision maker. It is the responsibility of the model builder as a professional to produce a model which describes the history of the city and predicts the impacts of alternative future programs. It is then the responsibility of the elected decision makers to decide which programs to implement, based on their values. Thus the model builder must provide the prediction of program impacts; the decision makers must evaluate these predicted impacts and make the best decision based on their set of goals and objectives.

2. Counterintuitive. Forrester used the term "counterintuitive" to describe the results of his model

when those results went against current trends in urban philosophy. But several critics showed that Forrester's results were a product of built in (though not explicitly stated) model biases and imperfections. Thus the results were to be expected and were to be expected and were not generated by some mysterious "counterintuitive" phenomenon.

The concept of a counterintuitive system is valid. It is possible for a system to be so large and complex that it does not respond to perturbations as would be expected because of multiple feedback loops. Yet it is probably best to do away with the counterintuitive notion altogether. A real world model is tested on the basis of its descriptive and predictive performance, not on the basis of whether or not the results seem "intuitive". Such a criterion may have seemed necessary for an abstract model with no empirical basis, but it is certainly not necessary or desirable in the real world.

3. Structural errors. The structural errors in the Urban Dynamics model were based on an inadequate formulation of the urban system. For example, it is obviously necessary to take into account city-suburb interactions, especially in terms of the day to day interactions between workers and jobs. Forrester's model assumed an urban area where the number of available jobs matched the number of available workers, with an allowance for some unemployment.

The condition of most of our central cities, however, is one with many jobs held by suburban commuters with certain skills while many potential workers living within the city are unemployed. A realistic simulation must try not only to describe this situation, but also to model the dynamic interactions which cause it.

Moreover, it is most important that a city model contain all of the sectors of urban life which can influence its results. Forrester claimed in Urban Dynamics that submodels of housing, population, and industry were all that were required to model the growth, stagnation, and decay of urban areas. Such a simplistic viewpoint overlooks the obvious importance of such factors as crime, decaying transportation facilities, racial discrimination, drug abuse, ineffective educational systems, and governmental corruption. These factors are far more difficult to quantify than the economic and socio-economic variables claimed by Forrester to be of significance, but unless an attempt is made to include the influence of these abstract factors, the model will not be realistic.

4. Parametric errors. Parameters in the model must be tested for sensitivity. If the model is insensitive to parameter changes, as claimed by Forrester, so much the better. But if the model is sensitive to changes in certain parameters, as discussed in Chapter II, then these

parameters must be very carefully determined, especially if they change the desirability of tested policies. The use of real world data in this process is essential. If data deficiencies exist in sensitive parameters, then those parameters should be tested within a reasonable range to determine their probable impact on the results of the simulation. This approach has been followed when necessary in the model to be described.

5. Real city. The real city used in this model is Newark, New Jersey. The city of Newark is typical of many decaying northern industrial cities; it is well along in the process of decay. Thus a wide spectrum of data is available. Most of these data were obtained from census publications, but some had to be culled from state and city sources. However, the data used in the simulation are of the type that would be available in any city. There are, unfortunately, parametric relationships for which no data exist. These have been subjected to sensitivity testing as described in point (4) above.

6. Modular. The model as constructed consists of four sectors, or modules, each with a specified set of inputs and outputs. These inputs and outputs define the function of the sector, which is to obtain the outputs from the inputs. This modular operation will be discussed at greater length in the next section.

7. Time span. The time span of this model is forty years. The time span runs from 1950 to 1990, encompassing 20 years of description (calibration) and 20 years of prediction. This time span appears to be realistic for a model of this nature.

8. National implications. The problem of the national implications of proposed policies is not appropriate here, since the model is not being used to propose definite policies but to determine the order of magnitude of change needed to stop urban decay in Newark. If, however, a more fully calibrated model is used in the future to test definite alternative policies, the implications of the national imposition of such policies will certainly have to be considered.

This concludes the answers to criticisms made of the Urban Dynamics model. Before going on to a presentation of the logical basis for the model sectors and variables, some of the mechanical "ground rules" will be covered.

Mechanics of the Model

The formulation of any model is dependent to some extent on the programming language used and the type of structure employed. Therefore it is necessary at this point to cover some of the mechanical aspects of the model before going on to the theory.

In accordance with the philosophy previously expressed, the model is modular in structure. This means that each sub-model or module is separate from all other modules and communicates with them only by means of state variables. State variables, following the electrical engineering parlance, are those variables which completely describe the state of a system as a function of time. Since the model is iterative, with each iteration representing one year, a complete set of state variables is computed for each year of the model operation. The communication among sectors of the model is carried out through a state variable matrix. Each sector of the model is responsible for computing certain values in the state variable matrix, and selects other values of the state variable matrix in order to perform those computations. In addition, each sector requires certain exogenous variables. Thus the job of a given sector is defined by the state variables required for computation, the exogenous inputs, and those state variables which the sector is required to compute. An over-simplified example of such a sub model would be one which computes a household food bill based on the unit prices of certain food items as a function of time (the state variables), and the desired food items (the exogenous inputs). Such a model would then compute the family's weekly food bill and return it to the state variable matrix of the total system. The food bill would fluctuate with time in accordance with the changes in the prices of individual items. This sub-model could be combined with others describing the family's needs in housing, clothing, etc., and could therefore be used to give an overall picture of a family's expenditures based on varying prices.

The importance of the modular model building technique is simply that the various modules are independent of each other. Thus they can be tested and corrected one at a time, and if a better module is developed, it can be directly substituted for the old one.

This is not to say that the computations of one sector do not depend on the results of another sector; indeed they do. But for the purposes of calibration the correct values of a given sector's inputs could be supplied exogenously instead of being computed by another sector. Of course if one sector's input requirements change the other sectors would have to be adjusted to supply the additional inputs. In that sense no model consists of independent sectors.

Another important computational feature of the model is the use of vector and matrix equations instead of scalar ones. The state variable matrix has already been discussed, and it is possible to express many intermediate variables as vectors or matrices. This method of computation has two advantages. First, it enables many computations to be done through the use of only one equation, instead of writing many similar equations. Second, it permits increasing the number of objects within a given category without writing additional equations. This computational ease is greatly facilitated by the use of the APL language[1], a language which handles scalars, vectors, and matrices with equal ease. APL is also interactive, being used by means of a terminal connected to the central computer by telephone line. Thus the computer is readily available and its responses immediate; two factors which are almost essential in model building of this complexity. The model is also portable; its possibility of use being no further away than the nearest telephone.

Another computational feature is the use of constant value dollars to eliminate the effects of inflation on the simulation. That is, all dollar values used in the model are expressed in constant 1967 dollars. Any changes in rents, municipal budgets, incomes, etc. are therefore real, not inflated changes.

Logical Basis of Sectors and Variables

Any logical basis for the choices of variables and sectors to be included in an urban simulation model must

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[1]See Falkoff and Iverson (1968) for a discussion of the APL language.

rest on an examination and enumeration of the resources of the city to be modeled. These resources include the people, physical elements, and institutions which interact to provide dynamic urban change.

People. The people who must be included in a city model obviously include the people who live in the city. In Forrester's case these were all the people who were considered. But Forrester's critics pointed out the need to include commuters. Thus the people considered in the model must include residents and commuters.

Physical Elements. The physical elements which make up a city are the physical facilities of that city, or, the uses for the city's land. These include housing, buildings for industrial and commercial use, buildings for public use, such as churches, schools, libraries and other government buildings, parks and playgrounds, a circulation system of streets and transportation facilities, and utility systems for gas, water, electricity, and sewerage.

From this array of physical facilities it is necessary to determine not which are important, but which can reasonably be expected to affect the processes of urban change.

In a developed city like Newark, such things as utility systems, streets, parks and playgrounds are well established. Considering the time span of the model little change in these facilities is likely. In a developing city, on the other hand, expansion would be contingent on the provision of utilities.

There remain housing, industrial and commercial space, transportation facilities, and the physical facilities needed for government functions. Government facilities are mainly surrogates for the services they provide. For example, the police station is not an end in itself; it is only part of a system of police protection. Similarly the physical plant of the school system is only one part of the educational service. Thus the government physical facilities will not be considered, but government services will, under the institutional category.

Transportation facilities are also a means to an end, the end being the accessability of the sections of the city to each other and to the rest of the region. Thus the impact of transportation shows up as an effect on ease of commuting.

Commercial and industrial space is important because it represents the physical facilities necessary to provide jobs, both for city residents and commuters. The space also represents a significant portion of the city's property tax base.

Housing occupies the largest fraction of the city's land area, and is an essential component in urban development and decay. Without housing there would be no residents and thus no city. The loss of housing stock through abandonment is perceived as a critical problem in Newark. Obviously the forces which determine the construction, occupancy, and abandonment of housing are of paramount significance in any city.

Institutions. The institutions involved in city life come in many forms. Corporations are institutions. So are churches, clubs, civic groups, labor unions, and the city government itself. By far the most important of these institutions are the corporations and the municipal government.

Corporations in a city supply jobs, and jobs, in the context of a central city, serve as one of the basic capital inputs which keep the city economically viable. Factors which affect corporate decisions which in turn affect the number of job opportunities are thus highly significant in the dynamic urban process.

The role of the municipal government is also critical. Local governments are, in effect, providers of services to the citizens of the city. These services include police and fire protection, education, street repair, etc. To pay for these services the government is empowered to collect taxes. In New Jersey most municipal tax revenue is in the form of a property tax. If the cost of providing services (taxes) becomes too high, or if the quality of service deteriorates, the development of the city can be adversely affected. Similarly, a city providing high quality services at low cost enjoys a more attractive position.

Sectors. On the basis of the foregoing discussion, the logic of the choice of sectors can be seen.

The Housing sector deals with the construction, occupancy, and demolition of housing units.

The Household sector deals with the resident population of the city.

The Job sector deals with the number of jobs which are available both for residents and commuters.

The Government sector deals with municipal services and taxation.

This four sector model is illustrated in Figure 3.1. The individual sectors are described in detail in the four following chapters. For each sector, the logic, mathematics, and calibration are presented. But before that, the required state variables and their level of aggregation must be discussed.

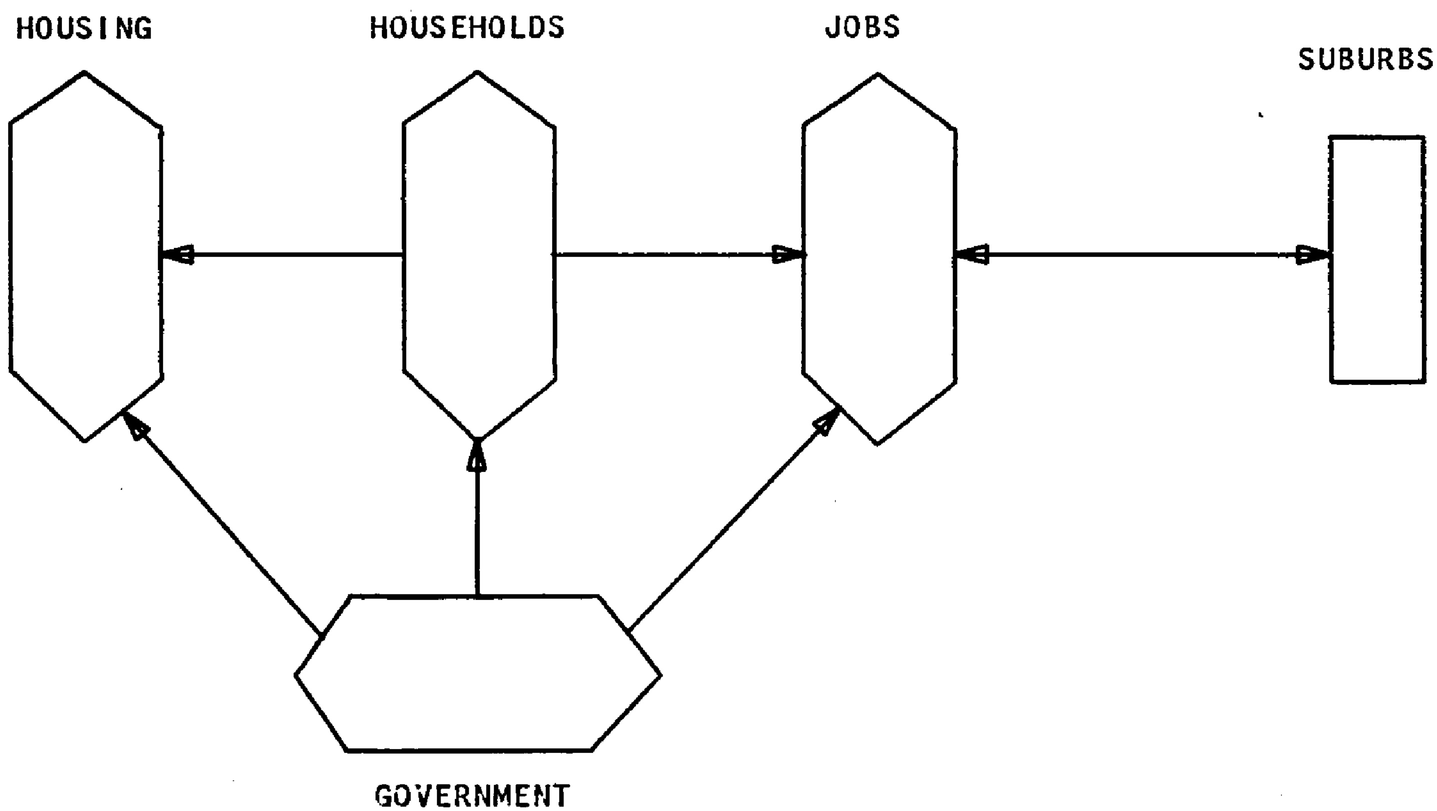

Figure 3.1 Model Sectors

State Variables

There are two types of state variables. Primary state variables are the results of a sector's computations which are used in the output of the model. These values can also be used as input to other sectors. Secondary, or communicative state variables, represent a specific influence of one sector on another. Although they can be reported for diagnostic purposes, communicative state variables have little meaning outside the context of the model. The choice of primary state variables follows from the discussion of the resources of the city: people, physical elements, and institutions.

The people of the city, with the exception of commuters, are the people who live there. For computational ease, the basic unit for people is the household, where a household is defined as a group of people who occupy a housing unit. Households are the primary state variable output of the household sector of the model.

Although the set of physical elements in the city includes industrial and commercial buildings, these are viewed as simply the locations necessary for the provision of jobs. The housing stock, however, is determined by a complex interaction of many factors, and thus forms the primary state variable output of the housing sector.

The dominant institutions of the city are corporations and government. Corporations are described by the number of jobs they provide to residents and commuters. This primary state variable is naturally supplied by the job sector.

The municipal government is viewed as a provider of services and as a collector of taxes to pay for those services. Since most municipal revenues come from the property tax, the logical choice for a state variable relating to municipal expenditure is the property tax rate.

The question of a measure of the level of municipal services is more difficult. One of the few quantifiable measures of performance in a city is the crime rate. Since crime is considered one of the principal reasons for the plight of central cities, it was taken as a measure of governmental effectiveness. One could easily argue for including other performance measures as well, such as the quality of the school system. But how is such performance measured? It would appear that many white parents equate poor educational quality with the presence of black students in the schools. Until research determines more objective performance measures in this and other areas they will have to be omitted from the model.

The primary state variables are, then, households, housing stock, jobs, tax rate, and crime rate. In addition, there are two communicative state variables which represent the effect of one sector on another. The crowding index represents the effect of overcrowding of the housing stock on migration decisions in the household sector. The variable worker changes reflects changes in household status due to a loss of job opportunities. This variable is generated by the job sector and used by the household sector. These variables will be described in detail when appropriate.

Level of Aggregation

The term "level of aggregation" refers to the number of categories into which a variable is divided. This section is concerned with the level of aggregation of the state variables.

It would be easy to build an urban model using the state variables already described without disaggregating them at all. Thus, the total number of housing units or the total number of households would be considered. Although such a model might yield some useful information, nothing would be learned about the types of housing units or the different kinds of people involved. It is also theoretically possible to build a completely disaggregated, or "microscopic" model, in which each household or housing unit is represented individually. Such models, except for very small systems with a severely limited number of objects, are a practical impossibility.

There is, then, no "correct" level of aggregation to use in the model under consideration. The disaggregation must be fine enough to reveal the dynamic interrelationships among the categories of variables, but not so fine as to present impossible obstacles in the areas of computational ease or data availability. The variables which must be disaggregated are the households, housing units, and jobs. The tax rate and crime rate are defined for the city as a whole, and the secondary state variable disaggregation is dependent on that of the primary state variables.

Housing units. There are two basic ways in which housing units can be disaggregated: location and type. Locational disaggregation involves breaking the city up into geographical subdivisions, by neighborhood, census tract, or block. Disaggregation by type involves distinguishing units by their age, number of rooms, cost, or condition.

Following the Urban Dynamics model, the city is regarded as one geographical unit. There is no breakdown of the housing stock into smaller geographical sections. However, since a market model of housing is used (Chapter IV), the housing stock is broken down into categories differentiated by monthly housing cost. A further division is made between owner occupied and rental units, and between occupied and abandoned units.

Households. In order to account for the changing racial patterns of cities like Newark, it is essential to break the household variable down into racial classifications: white and black. (The rising number of Puerto Ricans may necessitate a further breakdown of households in the future. At the present time, however, insufficient data is available to make this change possible.)

A further breakdown of households into the socioeconomic categories of white collar, blue collar, unskilled, and unemployed has been used. (The category of a household is the category of the household head.) It is felt that these categories are more relevant than Forrester's categories of managerial-professional, worker, and underemployed for two reasons. First, very few people who could be characterized as managers or professionals live in a city like Newark. These people may work there, but they generally live in the suburbs. Second, the division of workers by type of skill (or no skill) reflects the changing complexion of employment in Newark. As will be shown, there is a continuing shift from manufacturing jobs to office jobs, with a corresponding change in the type of skills required.

This emphasis on skills is demonstrated by the way in which the standard employment categories have been grouped:

White Collar	Blue Collar	Unskilled
Manager	Craftsman	Sales
Professional	Foreman	Operatives
Technical	Service Workers	Laborers
Clerical		Private Household Workers

No doubt better names for these categories could be found, since they go against the grain of traditional white collar-blue collar classification. In effect, the white collar category contains those with college or clerical skills, the blue collar category those with manual skills, and the unskilled category those with no skills, or at least, no special qualifications. In the context of the model, this breakdown results in a "worker oriented" classification by skill requirement rather than an "industry oriented" classification which groups people of various skills into one unit.

Thus the breakdown of households by race and by employment skill results in eight household categories.

Jobs. The classification of jobs must of necessity follow the classification of households. Therefore there are three job categories; white collar, blue collar and unskilled, with the same skill connotation as used for households.

Formal State Variable Definition

The discussion of the state variables has focused on their logical basis and on their degree of disaggregation.

This section deals with the exact definition of each state variable and, where appropriate, the definitions of the various categories of the state variables.

The state variables were defined as representing the state of the system as a function of time. In the operation of the model, a complete set of state variables is computed at one year intervals with a total time span of forty years. Thus, at the end of the model run there will be forty values of, for example, the tax rate, one for each year. These values are stored as a forty element vector.

In the case of a disaggregated variable such as households, with eight values per year, the result at the end of the simulation is a forty by eight matrix (40 x 8).

The seven state variables of the simulation are listed and defined below. The computer name is given in capital letters, and the size of the variable vector or matrix is given in brackets, e.g. [40;8].

I. Housing (HSG) [40;10]

The number of dwelling units in each of ten categories existing in the city in the given year. The categories are:

1. Owner occupied housing units.

2 through 7. Rented private sector housing units

with the following rent levels.

(All dollar figures are in terms of constant 1967 dollars.)

2. Rent greater than $120 per month
3. Rent between $100 and $120 per month
4. Rent between $80 and $100 per month
5. Rent between $60 and $80 per month
6. Rent between $40 and $60 per month
7. Rent less than $40 per month

8. Public housing units renting for $40 per month
9. Not used in present simulation
10. Standing abandoned dwelling units.

II. Households (HSD)[40;8]

The number of households residing in the city in each of the following categories in the given year.

1. White households with white collar employment.
2. Black households with white collar employment.
3. White households with blue collar employment.
4. Black households with blue collar employment.
5. White households with unskilled employment.
6. Black households with unskilled employment.
7. White unemployed households.
8. Black unemployed households.

III. Jobs (JOB) [40;3]

The total number of jobs available in the city in the given year in each of three categories.

1. White collar
2. Blue collar
3. Unskilled

IV. Tax rate (TR) [40]

The municipal property tax rate for each year, in dollars per hundred dollars of assessed value.

V. Crime Rate (CR) [40]

The crime rate in the city each year, given in terms of the standard FBI statistic of major crimes per year per 100,000 population.

VI. Crowding index (CRI) [40;8]

An index expressing the ratio of households not adequately housed to total households in each of the eight household categories. Normalized to a scale of 0-100.

VII. Worker changes (WCH) [40;8]

Changes in household classification caused by changes in employment. (For example, an unskilled household becoming unemployed.) Computed each year as a change (either positive or negative) added to the household computation.

<u>Sector Inputs and Outputs</u>

As previously stated, the logic of the model is such that a sector is defined by its state variable inputs, state variable outputs, and exogenous inputs. For reference, these quantities are given below for the four sectors. The need for certain inputs will be apparent when the sector algorithms are described.

<u>Housing Sector</u>

State Variable Outputs:	Housing (HSG)
	Crowding Index (CRI)
State Variable Inputs:	Housing (HSG)
	Households (HSD)
	Tax Rate (TR)

Exogenous Inputs:

Income (INC) [8]	Household income for each category ($)
Price (PR) [10]	Cost per month of each housing type (rent)
Building cost (BC) [10]	Construction cost for building each housing type
Assessed value (AV) [10]	Assessed value of each housing type
Maintenance cost (MAM) [10]	Maintenance cost per month of each housing type

<u>Household Sector</u>

State Variable Output:	Households (HSD)
State Variable Inputs:	Worker Changes (WCH)
	Households (HSD)
	Jobs (JOB)
	Crowding Index (CRI)
	Crime Rate (CR)
	Tax Rate (TR)

Exogenous Inputs:

Income (INC) [8]	Household income for each category ($)
Average Crime Rate (CRN)	National average crime rate (crimes/100,000 people)
Normal In Migration (NIM) [8]	Normal in-migration rate to metropolitan area (fraction)
Normal Out Migration (NOM) [8]	Normal out-migration rate from metropolitan area (fraction)

Job Sector

State Variable Outputs:	Jobs (JOB)
	Worker changes (WCH)
State Variable Inputs:	Jobs (JOB)
	Households (HSD)
	Tax Rate (TR)
	Crime Rate (CR)

Exogenous Inputs:

Normal Job Increase (NI) [3]	Normal job increase in metropolitan area (fraction)
Normal Job Decrease (NO) [3]	Normal job decrease in metropolitan area (fraction)

Government Sector

State Variable Outputs:	Tax Rate (TR)
	Crime Rate (CR)
State Variable Inputs:	Housing (HSG)
	Households (HSD)
	Jobs (JOB)

Exogenous Inputs:

Total Municipal Expenditure (TEX)	Total yearly city government expenditures
Assessed value (AV) [10]	Assessed value of each type housing unit
Property tax factor (PTF)	Fraction of city budget derived from property taxes
County tax factor (CTF)	Multiplier on city revenues to include those paid to county

Calibration

It may seem unusual at this point to discuss calibration when the detailed structure of the model has not yet been presented. It is next to impossible, however, to separate the model structure from the calibration process, since the initial model form was significantly modified as data were collected. Several algorithms found to have no or minimal impact on the simulation results were deleted, as their inclusion would have added no information and would have only complicated the model structure. Other algorithms were added to explain certain events. The interplay involved in structuring a simulation and comparing it with the real world it represents (as embodied in the data) is a most educational experience for the model builder. As the simulation and the real world converge the underlying processes and sensitivities become increasingly clear.

Unfortunately this interaction is never reported in the writeup of a model, which generally presents the model structure as a finished product; fully defined and unalterable. But it must be remembered that any model structure represents only one point in a continuing evolutionary process. The model can always be made more accurate or more realistic; the question is if the increase in accuracy is worth the additional time and effort. At some point the decision must be made to stop refining the model and to report on what has been accomplished. In the present case the model was declared "finished" when the simulation state variables agreed fairly well with the data and the model structure made logical sense.

The result is a simulation model of the city of Newark, New Jersey. It has been calibrated using data from 1950, 1960, and 1970, and has been used to simulate the condition of the city from 1970 until 1990.

The following four chapters deal with the structure, data, and calibration of the four sectors of the model. In each chapter, the logical basis for the sector algorithms is described, and appropriate references to the literature are included. The individual algorithms which make up each sector are, in effect, miniature sectors in themselves. Each algorithm has a clearly defined output, which may be a state variable or an intermediate variable for use by another algorithm within the sector. Each algorithm also has a set of clearly defined inputs, which may be state variables, intermediate variables produced by other algorithms, or exogenous inputs.

This breakdown of computational responsibility is illustrated by the block diagrams given for each sector, in which state variables are represented by ovals, algorithms by hexagons, and intermediate variables by rectangles.

The discussion of each algorithm is divided into three parts: logic, mathematics, and calibration. The logic section deals with the theory behind the algorithm and the definition of its inputs and outputs. The mathematical section discusses the computational procedure. The section on calibration deals with the results of the algorithm and the means used for calibration or, in some cases, the assumptions used if the algorithm is not calibrated.

Finally, for each chapter describing a sector, the overall data used to calibrate the principal state variables of that sector is presented and discussed.

IV. HOUSING SECTOR

Logic

The housing sector of the model is concerned with the construction, occupancy, abandonment, and demolition of the city's housing stock. In reality the sector is composed of two sub-models. One, dealing with occupancy, is concerned with the housing market. The other deals with the construction of new housing, the abandonment and demolition of old housing, and price changes occurring within the existing housing stock.

The housing market model used in the simulation is a highly simplified form of the San Francisco Community Renewal Plan housing model reported by Robinson, Wolfe, and Barringer (1965). In that model, housing units were categorized by location, type, number of rooms, condition, tenure, and rent or value. By means of a matching algorithm, these housing units were assigned to households which were described by type, number of members, race, income, occupation, and rent paying ability.

The present model applies the same theoretical concept to a greatly simplified computational scheme. Housing units are described by only one variable: their monthly cost. There is no attempt at geographical disaggregation. Households are described by race, occupation, and income. The desired housing cost to a household is considered a fixed percentage of that household's income.

In a market algorithm, the numbers of households seeking housing at desired expenditure levels and the numbers of housing units and their monthly costs are combined, or matched. Market imperfections of two types are noted. One type is called unmet demand, and is represented by those households who could not find housing within their means. The second type is called unused supply, and represents the possible surplus of certain types of housing.

One further algorithm in the market section of the sector deals with the housing plight of low income (unemployed) households. If these households are unable to find housing within their means, and if more expensive housing is available, they will be given welfare rent supplements to enable them to live in the more expensive housing.

In the section of the housing sector dealing with changes in the housing stock, a cash flow profitability model similar to the "Housing Analyzer" model (O'Block and Kuehn, 1970) is used. This model used the concept of cash flow profitability to determine whether or not a particular type of housing construction represented a profitable investment.

In the present model, cash flow profitability is used in two ways. First, it is used to analyze the feasibility of new construction. The profitability of each possible type of housing is determined, and if there is a demand for that type of housing (indicated by its unused supply being equal to zero), that type of housing will be built. The more profitable it is, the greater the number of newly constructed units.

In a similar manner, the rate of abandonment is considered to be a function of the lack of cash flow profit on existing housing types. The greater the loss on a particular type of housing, the larger the abandonment rate. As will be shown, the abandonment rate is also affected by racial considerations.

One final algorithm reflects changes in the rent levels of the rental housing stock apparently caused by racial considerations. That is, blacks attempting to move into a white neighborhood are confronted with higher rent demands than would face whites. This upward push in rents stops when the neighborhood becomes largely black. (This is called up-pricing.)

In the model, the three changes in housing stock (from new construction, abandonment, and up-pricing) are combined to yield the net change in housing stock from one year to the next.

The block diagram of the housing sector is shown in Figure 4.1, and represents the logic just described. The diagram will be much clearer after a reading of the algorithm descriptions, however.

Inputs and Outputs

Before describing in detail the logic, mathematics, and calibration of the individual algorithms, a review of the state variable inputs and outputs will be helpful. The exogenous inputs will be discussed when the need arises in describing the various algorithms used within the sector.

As stated in Chapter III, the state variable outputs of the housing sector are:

Housing HSG [40;10]

Crowding Index CRI [40;8]

The housing variable is the primary output of the housing sector. It is a vector of 10 types of housing computed each year for 40 years. The 10 types of housing are as follows:

1. Owner occupied units.
2. Rent greater than $120/month.
3. Rent between $100 and $120/month.
4. Rent between $80 and $100/month.
5. Rent between $60 and $80/month.
6. Rent between $40 and $60/month.

Privately Owned Rental Units

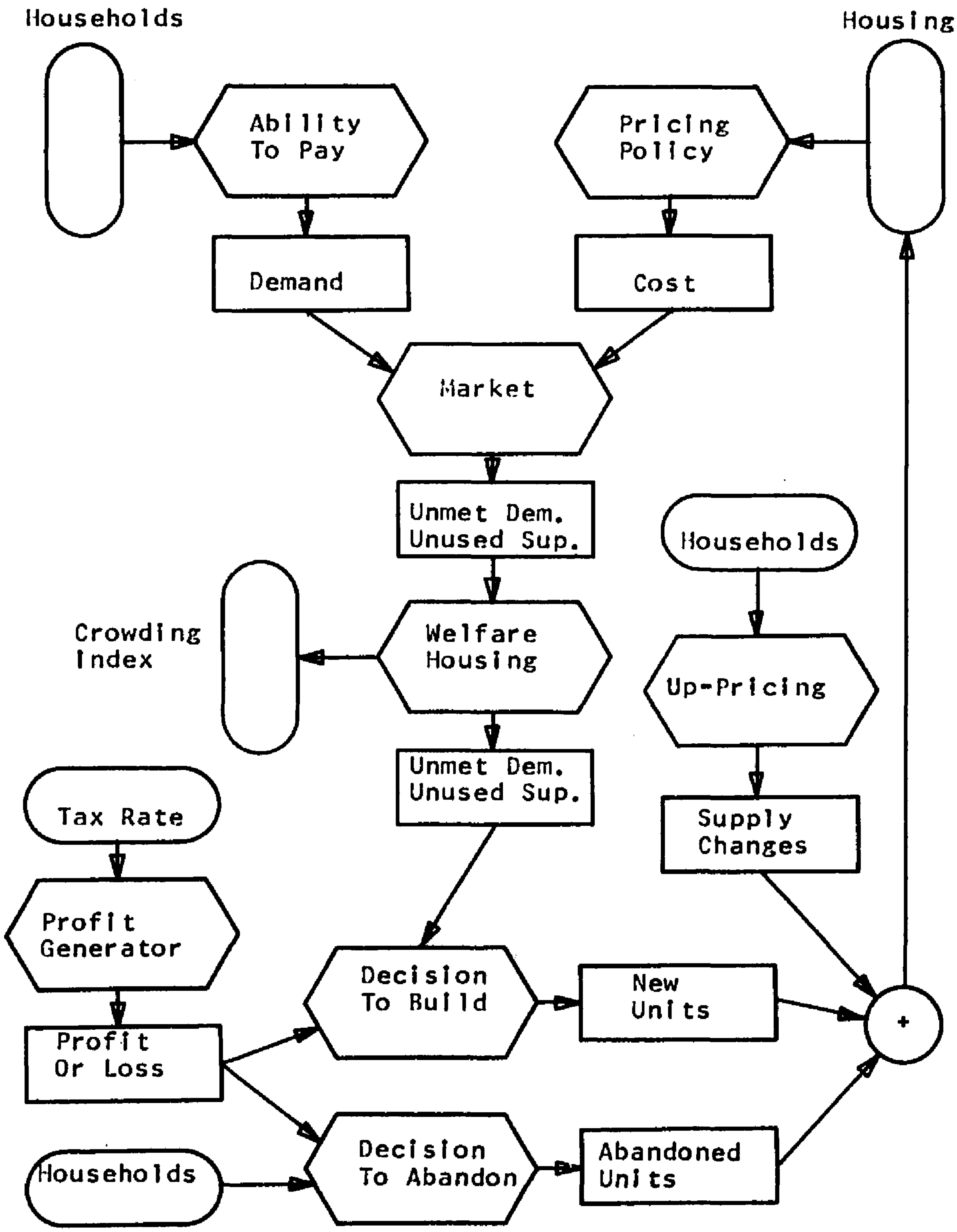

Figure 4.1 Housing Sector

7. Rent less than $40/month.
8. Public housing units renting for $40/month.
9. Category not used. (Provided for future expansion of variable.)
10. Standing abandoned units.

The simulation groups all privately owned owner occupied units into Category 1, regardless of their price or condition. This approach would not do for an affluent suburb, but in the city of Newark only 23% of the housing units are owner occupied (see Calibration), and many of these units are similar row or two family houses. Thus this level of aggregation does not seem unjustified. Categories 2 through 7 are the privately owned rental housing units. These are described by one quantity, their rent per month. It must be remembered that these rent levels, as well as all simulation values expressed in dollars, are given in constant 1967 dollars. The value of the dollar, according to the Department of Labor (New York Times, 1972, p. 497), is given in Table 4.1.

TABLE 4.1 DECLINING DOLLAR VALUE

Year	Dollar Value	Consumer Price Index
1950	$1.39	72.0
1960	$1.13	88.5
1967	$1.00	100
1970	$ .86	116

An apartment renting for $72 in 1950, $88.50 in 1960 and $116 in 1970 would be indicated as an apartment renting for $100 at all times, in terms of the constant dollar. It would always be counted in Category 4. If, however, an apartment increased its rent faster than the rate of inflation it would move from one category to another, as from Category 4 to 3. Category 8 represents public housing units for low income residents at an arbitrary at $40 per month. The decision to build these units is a political one, so they are unaffected by the algorithms in the simulation which affect private housing construction, and are simply added on. For example, one could define 2,000 units built in 1955, 3,000 more in 1960, etc.

The Crowding Index state variable is computed by the housing sector but used by the household sector. It describes the housing condition of the eight classes of households in terms of the ratio of the number of households not adequately housed to the total number of households in each of the eight categories. The computation of this variable will be described later.

The state variable inputs of the housing sector are:

Housing HSG [40;10]
Households HDS [40;8]
Tax Rate TR [40]

The Housing variable is both an output and an input because the simulation is iterative. That is, the results for the current year depend on the results for the previous year. The Household variable is needed as an input since these are the people who are going to be housed. The eight categories have already been described. The Tax Rate variable affects the profitability of housing and therefore affects decisions to build or abandon housing.

Housing Sector Algorithms

Within the housing sector program, various algorithms written as sub-programs are called upon to perform various computations. These sub-programs have outputs and inputs, just as does the sector as a whole. The inputs to a sub-program can be state variables, variables computed by other sub-programs within the sector, or exogenous variables. The outputs can be those needed by other sub-programs within the sector or they can be state variables.

The algorithms to be described (in their order of execution) are:

Housing Cost	(HCST)
Pricing Policy	(PPOL)
Market	(MARK)
Welfare Housing	(WELH)
Up-Pricing	(UPPR)
Profit Generator	(PGEN)
Decision to Build	(DBLD)
Decision to Abandon	(DABD)
Housing (calling program)	(HSNG)

Housing Cost

Logic. The housing cost algorithm (HCST) determines the monthly housing cost which the eight household categories can afford. The in-puts are two eight-element vectors: the number of households for the year in question (HSD) and the average yearly income for each household type (INC), supplied exogenously. The output is a two by eight matrix called demand (DEM). The first row is the number of households in the eight categories, and the second row is the desired monthly housing cost. The algorithm computes the desired monthly housing cost as a fixed percentage of income.

Mathematics. In the APL language, vector operations are performed if the elements of the computation are vectors. Thus an eight element vector of monthly housing costs is obtained from an eight element vector of incomes simply by multiplying that vector by a constant. Thus:

$$\underline{DEM}_2 = K \times \underline{INC}$$

The notation $\underline{DEM}_2$ indicates that all eight elements of the second row of DEM are generated by the computation.

Calibration. The census data from Newark given below reveals that Newark residents, over a twenty year period, paid roughly 20-25% of their income for rent. (U.S. Census of Housing, 1960, 1970).

TABLE 4.2 NEWARK RENTS AS A PERCENTAGE OF INCOME

1960	Rent ($/month)	30-40	50-60	70-80	100-120
	Median income	2300	3700	4800	5700
	Rent % of income	18%	18%	19%	23%
1970	Rent ($/month)	50-60	70-80	100-120	150-200
	Median income	2300	4400	6100	8200
	Rent % of income	28%	20%	22%	25%

In the case of owner occupied housing, a rule of thumb developed by Shelton (1968, p. 70) is used.

> Combining the fact that housing costs should not run more than 25% of a family's income and housing costs are 10% of the residence's market value leads to an explanation of the rule-of-thumb linking the value of a home to family's annual income. A home that costs two and one-half times the income will incur annual carrying costs of approximately 25% of annual income.

An average figure of 23% is taken as the desired housing cost as a function of income. This figure becomes the K in the HCST equation.

Pricing Policy

Logic. The pricing policy algorithm (PPOL) determines the monthly housing cost of the eight types of occupied housing units (HSG). (Note that housing type 9 is not used and housing type 10 represents abandoned units.) The algorithm combines the numbers of units (HSG) with the price per month (PR), supplied exogenously, into a two by ten matrix called cost (CST), similar to the demand (DEM) matrix. There are no mathematical relationships involved.

Calibration. The only quantity to be calibrated in this algorithm is the exogenous price vector (PR). Since rental units are defined by their monthly rent, the price vector is simply a statement of what price housing units are being considered. The monthly cost of owner occupied housing is taken at roughly one-tenth its value, following

Shelton (above). The resulting price vector is:

PR = 150 130 110 90 70 50 40 40 0 0

Market

<u>Logic</u>. The market algorithm (MARK) is used to match up the households (DEM) with the housing units (CST). Beginning with owner occupied housing units and white-white collar households, it compares the desired housing cost with the actual cost of the housing unit. If the actual cost is between .6 and 1.3 times the desired cost for any household-housing unit combination, those households are allocated to those housing units. Of course the number of households may not agree with the number of dwelling units, so provision is made for carrying over either unused units or unhoused people. The algorithm proceeds for the 10 types of units and the 8 types of households, and produces 2 vectors: Unused supply (US), and unmet demand (UD). Unused supply is a ten element vector of unoccupied units, and unmet demand is an eight element vector of unhoused people.

These outputs cannot be interpreted to mean that there are really families standing in the street. Census data reveals that, somehow, the households have found housing. But what can be inferred from the results of this algorithm is that the so-called unhoused households have had to settle for housing which they would not normally occupy. This indicates a housing "pressure" which is reflected in the crowding index state variable (CRI), which will be described below.

Mathematics. A simple example should clarify the logic of this algorithm. Assume demand and supply as follows:

Demand

Number households	2000	4000	3000
Desired Housing Cost	$120	$90	$65
Designation	A	B	C

Supply

Number units	1500	4000	3500
Monthly cost	$130	$80	$50
Designation	D	E	F

The algorithm first determines what units could be occupied by households A. Since the desired cost is $120, the range is from $156 to $72, (.6 to 1.3 of desired cost) which includes housing types D and E. Households A would be placed in units D, but there would be 500 households left over (2,000 - 1,500). The remainder would be placed in type E leaving 3500 vacant (4000 - 500). All type A households would be accommodated.

Households B have a desired rent of $90 which gives a range of $117 to $54. Thus only housing type E is suitable. But now there are only 3500 units vacant for 4000 households, so 500 will be unhoused. Finally, the type C households have a range of $84 to $39 which includes units

E and F. No type E units are vacant, so the 3000 C households are housing in type F units, leaving 500 units vacant (3500 - 3000).

The outputs of this process are the unmet demand vector UD=0 500 0 and the unused supply vector US=0 0 500. Even though the total number of units was equal to the total number of households, because of the unsuitability of certain units for certain households there are vacant units and unhoused people remaining, just as there would be in a real market situation.

The operation of the MARK algorithm in the simulation is identical to this but operates on the 8 household types and the 8 kinds of occupied dwelling units. (Note that type 9 is "not used" and type 10 is "vacant abandoned units.") From the order in which the households are arranged, an obvious racial and socioeconomic bias is generated. Whites get first choice over blacks of supposedly similar status, and white collar workers get first choice over blue collar workers, even if the desired housing cost is the same. This could be eliminated by a different type of algorithm, but the type of bias exhibited by the present technique is probably a better reflection of the real world than that which could be achieved by a non-biased method.

Calibration. There is no calibration associated with this algorithm, other than setting the acceptable price limits at .6 and 1.3 times the desired rent. This was done by examining census data and noting the variance of rents paid by people with the same average income. The limits were chosen to encompass most of this variability.

Welfare Housing

Logic. The welfare housing algorithm (WELH) is included to account for housing subsidy payments to welfare clients, here regarded as unemployed households (HSD categories 7 and 8). If these households do not find housing as a result of the market algorithm (they are the last in line to seek housing) and if there are vacant units up to $100 per month rent (HSG types 4, 5, 6, and 7), then the households are assigned to the housing units. Depending on which is greater, the number of units or the number of households, the appropriate values in the unused supply (US) or unmet demand (UD) vectors are reduced to zero, and the values of the other vector are adjusted.

Mathematics. For example, take the following values of the US and UD vectors.

US = 200	500	0	0	1000	500	0	0	2000
UD = 0	0	0	500	0	500	200	500	

The total demand which qualifies for housing assistance is 700 households, and the total number of vacancies applicable is 1500. Thus the total number of households is accommodated and the UD vector becomes:

UD = 0 0 0 500 0 500 0 0

Terms 4, 5, 6, and 7 of the supply vector are decreased by 700 units according to:

$$\frac{1500 - 700}{1500} \times 0 \quad 1000 \quad 500 \quad 0 = 0 \quad 534 \quad 266 \quad 0$$

The new supply vector is:

US = 200 500 0 0 534 266 0 0 0 2000

A similar computation would have been made if demand had exceeded supply.

The computation of the Crowding Index state variable used by the household sector is also performed by the WELH algorithm. This variable is the ratio of unhoused households in each group (the remaining UD) to the total number of households in each group. (HSD [I;]). The resulting 8 element vector for year I is normalized on a scale of 0 to 100 and stored as CRI[II;]where II=I+1.

As previously stated, this crowding index does not indicate that the supposedly unhoused people are really out in the street. They will have found housing, either by finding lodging with friends or relatives, or by paying more than they can afford, or by moving elsewhere. What the crowding index does indicate is that there is a housing "pressure" generated, a pressure which will affect the in and out migration of the class for which this pressure exists. This effect is computed in the household sector.

Calibration. This algorithm represents a policy decision to pay rent supplements to welfare families. As such there is no calibration involved. An alternative policy would eliminate or modify the algorithm.

It is not possible to directly calibrate the state variable output of the welfare housing algorithm, the crowding index (CRI), since this index is a dummy variable having no counterpart in real life. The use of this index is to affect the rate of in-migration in the household sector as will be discussed in the next chapter. Since this index is that fraction of every group not properly housed, and since a normal real world situation would have few people in this category, the crowding index should always be zero or a low number (on a scale from 0 to 100). These numbers do not indicate that the housing is not inadequate or run down, but only that there are not three families for every two dwelling units, or some such unrealistic condition.

This concludes the section of the housing sector dealing with the housing market. The following algorithms deal with the changes in the housing stock from racially induced price rises, new construction, abandonment, and demolition.

Up-Pricing

Logic. The up-pricing (UPPR) algorithm is an attempt to quantify a phenomenon suggested to this author by housing authority Dr. George Sternlieb of Rutgers University. He points out that it is common practice for white landlords in a given area to raise quoted rents in an effort to keep blacks out of that area. Once the landlords fail to "save" an area, however, and the area becomes largely black, the rent increases stop. Since in the simulation the entire city is treated as one unit, the rent increases cannot be applied on an area by area basis. But an examination of the data revealed that an algorithm could be developed city wide. This UPPR sub-program begins by finding the overall fraction of black households for the year being computed. This black fraction (BF) is used to determine the fraction of housing in each rent category which moves into the next higher category. This fraction (FS) is given by a relationship described graphically in Figure 4.2. (Many relationships which will be discussed will be given as graphs.)

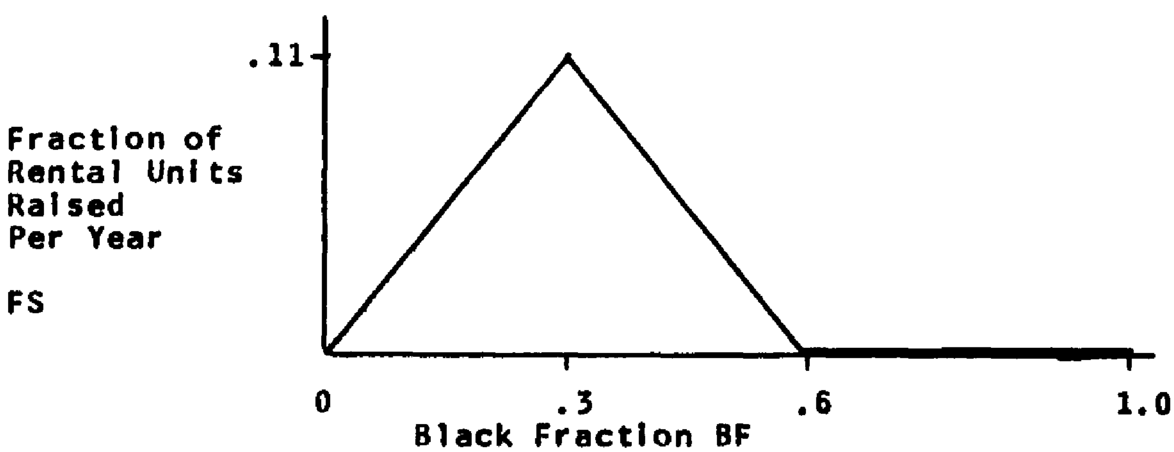

Figure 4.2 Graphical Relationship of UPPR Algorithm

Figure 4.2 indicates that, as the size of the black area of the city is growing, landlords are raising their rents to try to keep blacks out of previously white neighborhoods. (For an example of the growth of a black area see Morril, 1965.) Once the black fraction has increased, however, landlords perceive the area as "lost", and the pattern of rent increases stops. Although this phenomenon does not change the absolute numbers of housing units, it does change their rental category and thus is considered a change in the housing stock.

Mathematics. Again, a brief example will clarify the logic. Suppose there are three classes of housing, as shown.

Class	A	B	C
Rent	\$100	\$100-\$80	\$80-\$60
Number Units	1000	2000	1500

Black Fraction .3

These figures are for year I, and the figures for year I+1 are desired using the UPPR algorithm. The BF of .3 gives an FS of .11, which means that .11 of the B and C class units will move up to the next higher class. (In the simulation the graphical relationship between two variables is performed by a linear interpolation routine called TABL.)

The calculations yield:

Class	A	B	C
Year I	1000	2000	1500
added	220	165	
subtracted		-220	-165
Year I+1	1220	1945	1335

The numbers used in the relationship between BF and FS were determined experimentally from the data, as follows.

Calibration. The calibration of the up-pricing algorithm was accomplished by purely empirical means. Once the abandoned and newly constructed units were accounted for, the remaining changes in price categories must be explained, in this model, by up-pricing. It must be assumed that, except for public housing, new construction is associated with the high end of the rent scale while abandonment occurs to those buildings at the low end of the scale. Since most new construction in Newark in the past twenty years has been either public housing or luxury high rises, and since the condition of most abandoned buildings has been such that even low rents were hard to justify, this assumption seems valid.

The shift in real rents from the low to the high end of the rent scale, after new construction and abandonment are considered, is then modeled as up-pricing. The height and width of the triangular function relating the black fraction to units upgraded per year were determined so that the resulting housing variable reasonably matched the data. Of course the use of a triangular function to model this relationship is open to question, but it seems as though the phenomenon would start slowly as blacks moved into a few areas, increase in intensity as more neighborhoods shifted from white to black, and finally diminish as landlords gave up trying to "save" their neighborhoods.

The UPPR function affects the rate of upward shifts in rent levels. The calibration is achieved on the rent levels themselves, or the integral of the UPPR function. In addition, only three data points in time are available. Clearly, this phenomena needs a great deal of further investigation.

Profit Generator

Logic. The profit generator (PGEN) algorithm relates to the construction of new housing and the abandonment of existing housing by computing the cash flow profitability of the various classes of housing. This profitability is computed for two types of housing: existing and proposed. The cost of proposed housing includes a mortgage; the cost of existing housing does not. Following the logic of the housing analyzer model (O'Block, et.al., 1970), the total cost per month includes three terms: amortized building cost per month, or mortgage, taxes per month, and maintenance per month. The cost of existing housing includes only the last two terms, since no mortgage is assumed.

The cash flow profitability is determined by subtracting the cost of each unit per month from the income per month, i.e., the unit price per month. (See the pricing policy algorithm, above.) The resulting quantity is positive for profits and negative for losses. To make the result a fraction, the profit or loss in dollars is divided by the monthly cost in dollars. This results in two fractional profit-loss vectors, PLE for existing housing, and PLN for new (contemplated) housing.

Considering the great variety of programs to increase the profitability for landlords of certain types of housing this simple cash flow algorithm is somewhat unrealistic. There is no provision for doubly declining depreciation, tax abatements, capital gains writeoff, etc., since it was desired to keep the model as simple as possible. However, it is relatively easy to include programs such as tax abatements for new construction or special long term low interest mortgages for certain kinds of housing. There are relatively few large private sector real estate holdings in a city like Newark, and to include the special tax provisions enjoyed by these landlords would only tremendously complicate the model.

The question may arise as to the relevance of a cash flow model for the resident owner of a housing unit. In this case a loss would indicate that the resident was spending a higher than normal proportion of his income on housing. This would logically tend to discourage new construction and encourage abandonment, just as it would in the case of a landlord.

Mathematics. In this algorithm several steps are involved. The building cost per month is determined by the total cost of building a housing unit ($\underline{BC}$), which includes construction and land costs and is supplied exogenously, and an exogenous mortgage and interest factor (MIF) which is based on prevailing loan terms and interest rates. Thus:

$$\underline{BCM} = \underline{BC} \div MIF$$

(This equation, like the ones that follow, is a vector equation. The computations are performed for all ten categories of housing in one equation.) A longer term of mortgage or a lower interest rate results in a larger MIF and therefore a lower building cost per month.

The taxes per month are determined by the tax rate state variable (TR) and the exogenous assessed value for each type of housing unit ($\underline{AV}$). The taxes per month are:

$$\underline{TM} = \underline{AV} \times TR \div 1200$$

The 1200 is necessary since the tax rate is expressed in dollars per one hundred dollars of assessed value.

The maintenance cost per month for each type of housing unit is given exogenously. Thus, for existing housing the total cost per month (TCM) is:

TCM = TM + MAM

For new housing the cost is:

TCM = BCM + TM + MAM

For both cases the cost represents an outflow of money spent by the resident. Therefore the profit or loss (in dollars) per month to the landlord or resident owner is:

PL = PR - TCM

The variable PR is the price per month for each type of housing unit and is the same exogenous variable used by PPOL. It is desirable to express this profit (+) or loss (-) as a fraction of expenditures, so PL is divided by TCM. The result is two 10 element vectors, one called PLN for the fractional profit or loss on new (contemplated) housing, and the other PLE for existing housing.

Calibration. This algorithm represents a logical process, and therefore requires no calibration. It is important, however, that the correct values for building cost (BC), mortgage and interest factor (MIF), maintenance (MAM) and assessed value (AV) be specified.

Decision to Build

Logic. In order for any new housing construction to proceed, according to the DBLD algorithm, the builder must be assured of two things: profitability and occupancy.

The occupany condition is assured by examining the unused supply (US) vector. If the unused supply of a particular housing type is zero, the possibility for building that type of housing exists. How much of that housing is built in any one year is determined by how profitable it is. The number of new units of a given type built in one year (expressed as a fraction of the number of standing units of that type) is modeled as being linearly related to the profitability of that housing type, once the occupancy condition is satisfied. The number of new units built (NUB) is the output of the algorithm.

Mathematics. The only computation of the DBLD algorithm is that using the graph relating the expected profit on a new housing type to the fraction of units of that type built in the year in question (Figure 4.3).

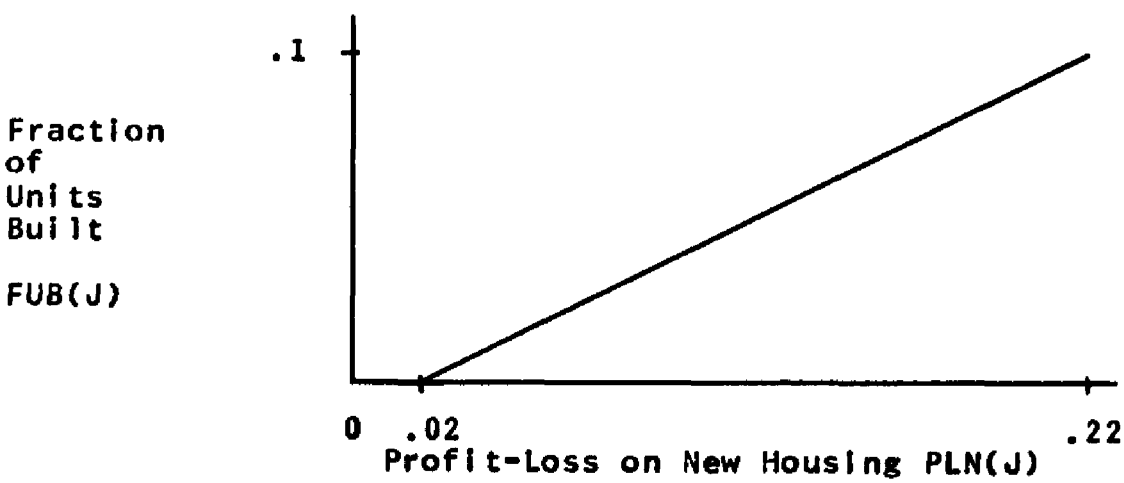

Figure 4.3 Graphical Relationship for DBLD Algorithm

(The index J in Figure 4.3 refers to the housing type. In the simulation this graphical relationship is performed in a loop with index J. At the end of the loop FUB is a ten element vector.)

The computation of new units built is:

NUB = FUB x HSG (I)

where HSG (I) represents the ten element vector formed by the Ith row of the state variable matrix of housing (HSG). I refers to the current simulation year.

Calibration. The calibration of the DBLD algorithm was accomplished using census data for Newark from 1950, 1960, and 1970. The census information on age of housing units revealed how many new units were built in each ten year period. The slope and intercept of the DBLD algorithm were adjusted to produce the correct numbers of new units in the simulation.

Decision to Abandon

Logic. The increasing importance of housing abandonment in central cities is modeled by the DABD algorithm. This algorithm makes use of the recent study by James (1972) revealing a significant influence of non-economic (racial) factors in a landlord's decision to abandon a residential structure. James (1972, p. 55) shows that in a sample of residential structures in Newark examined in 1964 and 1971 the abandonment rate for white landlords was 2.8 times that for black landlords, and attributes this to a discriminatory attitude of white landlords to black tenants. The black landlords seemed to abandon buildings for purely economic reasons.

It is very difficult to model this kind of behavior in the present simulation since the model does not indicate the race of the landlords of rental housing. It is reasonable, however, to assume that black ownership of buildings in an area follows black tenancy in that area. As a city changes from white to black (data from Newark strongly indicate that there is no stable integration), the ownership of rental properties within the city should also change from white to black, but at a slower pace, as indicated in Figure 4.4.

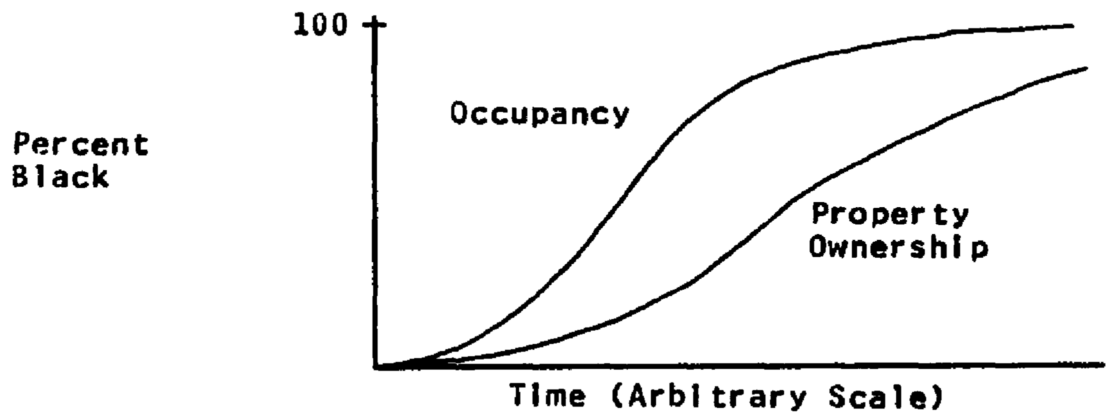

Figure 4.4 Black Occupancy and Property Ownership

The racial factor which would accelerate abandonment is then dependent on two things: the interaction of black tenants and white landlords and the fraction of black landlords. In other words, the economic factors which produce abandonment are accelerated, as blacks move into an area, by the white landlord-black tenant relationship. But as black ownership catches up with black tenancy the abandonment decision again becomes a purely economic one.

The economic side of the abandonment decision is based on the profit-loss for existing housing (PLE). The greater the loss on a particular type of unit, the larger the fraction of those units which will be abandoned each year. The results of the economic decision to abandon, modified by the racial factor, is a ten element vector called Change in Housing from Abandonment (CHA). Since the tenth element of the housing state variable represents standing abandoned units, those private market units which are abandoned are indicated in CHA as negative in elements 1 to 9, but become additions to element 10.

One further function performed in the DABD algorithm is the demolition of abandoned units. The fraction of those units demolished per year is graphically related to the fraction of total housing stock which the abandoned units represent.

Mathematics. The basic equation which determines change in housing stock from abandonment is:

CHA = HSG (I) x FUA x RFA

where RFA is the racial factor, FUA is the expected abandonment fraction from economic causes, and HSG (I) is the current year's housing stock.

The racial factor is determined by examining the fraction of city households who are black. Since the racial factor acts as a multiplier on economic abandonment decisions, it has a value of one if all landlords and tenants are white, or if all landlords and tenants are black.

Using the fact that white landlords with black tenants are 2.8 times as likely to abandon their structures compared with landlord-tenant pairs of the same race, the composite city wide relationship of Figure 4.5 can be postulated.

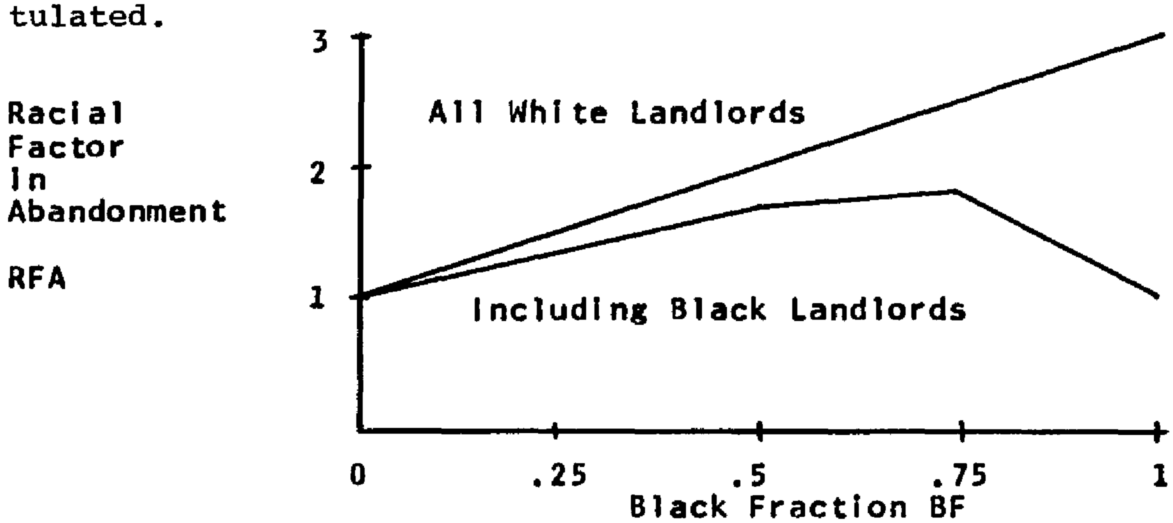

Figure 4.5 Racial Factor in Abandonment

When BF is zero the RFA is 1, since there are no black tenants. When BF = .5, assumedly half of the white landlords have black tenants, which would result in an RFA of 1.9 if all landlords were white (1 + .5 x (2.8-1)).

However, some of the landlords are black, so this factor is reduced. If one-fourth of the landlords were black, the factor would be reduced to 1.7 (1.9 - 1/4 x (1.9-1)). This number is quite approximate but seems reasonable. The rest of the curve reflects increasing black ownership until 100% of the landlords are black when 100% of the tenants are black. Thus the abandonment of housing for racial reasons is never greater than 1.8 times what it would be for purely economic reasons.

The fraction of units abandoned for economic reasons (FUA) is determined from the profit or loss for existing housing as shown in Figure 4.6.

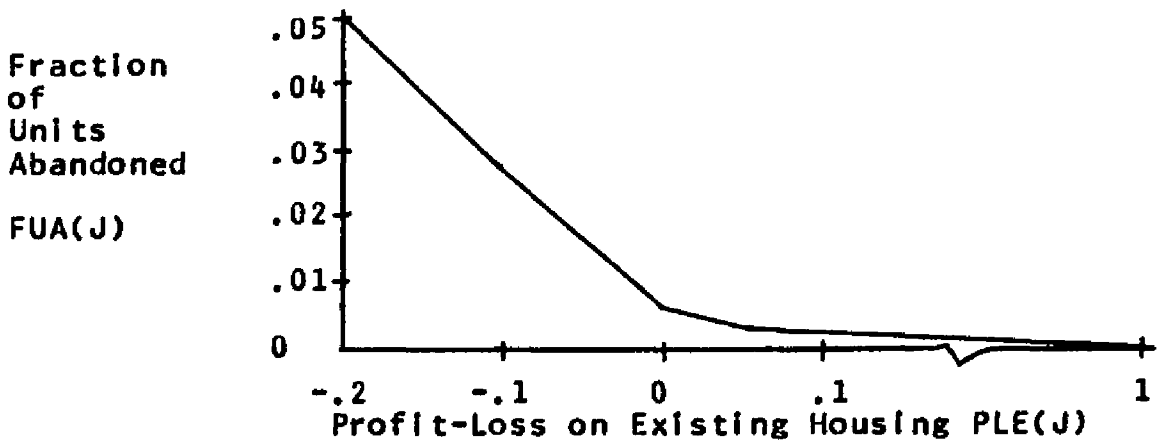

Figure 4.6 Economic Influence on Abandonment

As in the case of the DBLD algorithm, the index J refers to the type of housing unit. The result for FUA is a 10 element vector.

The change from abandonment is then found by:

CHA = HSG (I) x FUA x RFA

A typical CHA might have the form:

CHA = 0 0 0 5 67 208 173 0 0 0

This form must be modified so that the abandoned dwellings are subtracted from the occupied housing stock and added to the abandoned units (element ten). Thus CHA would be modified:

CHA = 0 0 0 -5 -67 -208 -173 0 0 453

However, the modification of CHA is still not complete. Some of the abandoned units which remain standing are demolished each year. In the simulation, this demolition process is modeled as a function of the fraction of the total housing stock which the standing abandoned units represent. As this fraction grows, so does the response. Figure 4.7 relates the fraction of abandoned units in the housing stock to the fraction of those units demolished each year.

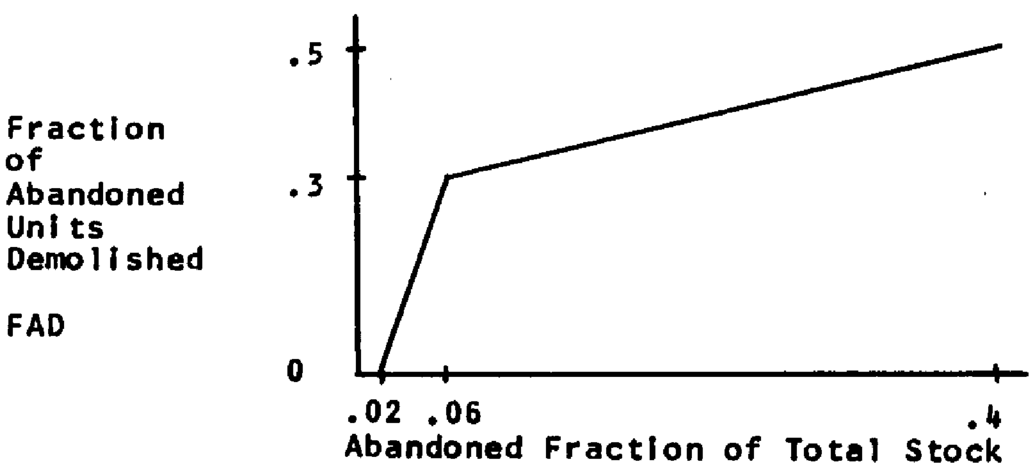

Figure 4.7 Demolition Rate Determination

The number of units demolished is FAD x HSG (I,10). This quantity is subtracted from CHA (10). The resulting CHA represents the total change from abandonment and demolition for the year.

Calibration. There are two graphical relationships to calibrate in the DABD algorithm: the economic influence on abandonment and the demolition rate. (The racial effect on abandonment has already been discussed.) An analysis of census data yields figures which can be used to partially calibrate these relationships. The word partially is used since the relationships are only calibrated within the limits for which data exist. Outside that region extrapolations are necessary. Moreover, the data provided by the census are very rough, coming ten years apart. For these reasons, much more work needs to be done to achieve a finer calibration of relationships of this type.

The preliminary calibration is easy, however. Knowing total numbers of dwelling units, new units built, and vacant units, it is possible to determine, for each ten year period, the number of units abandoned and the number of units demolished. An additional input comes from the James (1972) study which revealed a 2% abandonment rate of the Newark housing stock in 1970. Adjustment of the two graphical relationships to produce these figures in the simulation output achieves a preliminary calibration of these relationships.

Housing

The housing (HSNG) sub-program is a master program which calls all of the other sub-programs in the housing sector in the order in which they have been described. The housing state variable (HSG) is also determined in this sub-program by the equation:

$$HSG\ (II) = HSG\ (I) + CHS + NUB + CHA$$

where II refers to the following year, I the current year, and the three terms CHS, NUB, and CHA are the changes in housing stock from price changes, new construction, and abandonment. Another equation introduces the number of public housing units available during the year.

What Has Not Been Modeled

Before discussing the overall calibration of the housing sector, it would be useful to discuss the two housing phenomena which have not been included in the algorithms described and the reason for their omission. These two processes are filtering and land shortage.

Filtering is that process where, as housing units age, they pass from occupancy by higher income groups to occupancy by lower income groups with a concomitant decrease in housing costs. This is a classic housing theory. As an explanation for the housing picture in the city of Newark over the last twenty years however, nothing could be more inaccurate. True, there has been a change in occupancy from a higher status (white) group to a lower status (black) group, but this change was accomplished with an increase in housing costs because of discriminatory housing policies on the part of largely white landlords.

Similarly, the idea that housing construction stops because there is no available land cannot be applied to Newark at this stage of evolution. True, a great deal of the land available for housing is already occupied, but much of this is taken up by old frame dwellings which could be easily demolished. Indeed, many of these structures have been abandoned over the last twenty years and could be bought very inexpensively. But the simple fact is that housing construction has become less and less profitable in Newark and has, within the last five years, almost ground to a halt. This lack of profitability, not a lack of land, has been the reason for the paralysis of private housing construction, and this phenomenon is incorporated in the model.

Overall Calibration

Just as the housing state variable (HSG) is the primary output of the housing sector, it is also the principal means for calibrating the sector and evaluating its performance. Information about the housing stock is obtained from the United States Census of Housing for the years 1950, 1960, and 1970. These data directly give the number of owner occupied units, and by manipulation to account for inflation, the number of rental units in each category as defined by the HSG state variable. The adjusted data for the city of Newark are given in Table 4.3. (These figures are derived in Appendix II.)

TABLE 4.3 CENSUS DATA FOR HOUSING STATE VARIABLE

(Number of Units in thousands)

		Rent Levels in $/month					
Year	Owner Occupied	>120	100-120	80-100	60-80	40-60	<40
1950	28.8	4.7	6.0	14.7	31.0	26.3	5.8
1960	29.1	13.7	17.8	27.7	21.8	12.3	4.0
1970	24.9	24.3	18.7	27.2	14.0	9.1	3.3

The test of the housing sector model is if, when initialized with the 1950 data, it reproduces the 1960 and 1970 data. Of course the housing results are dependent on state variable outputs from the other sectors. But if these variables are accurate, the correctly calibrated housing sector should reproduce the above data.

Nor is this all the data available. An examination of the age of structure data from the 1970 Census reveals that, of the total 96,085 rental units in 1970, 9622 were built between 1960 and 1970 and 10,802 between 1950 and 1960. The 1950 Census reveals 93,200 rental units and the

1960 Census 98,944 units. This means that about 5,000 units between 1950 and 1960 and 12,500 units between 1960 and 1970 were abandoned or otherwise removed from service. These data are required to calibrate the decision to build and decision to abandon algorithms, as has been discussed.

Results

The results of the housing sector sub-model will be discussed in Chapter VIII, when the calibration run for Newark is presented.

V. HOUSEHOLD SECTOR

Logic

The household sector is concerned with the creation, dissolution, and migration of household units in the area modeled. The sector uses a basic iterative equation to determine the number of households living in the city each year. (Gibbs, 1961, p. 564).

$$P_2 = P_1 + (B - D) + (I - O)$$

In this equation, first used for total population computations, P_2 is the population computed; P_1, the initial population; B, births; D, deaths; I, in-migration; and O, out-migration. In the model, the computation is performed on the numbers of households, and eight household groups are accounted for. Thus an additional term reflecting internal changes from one category to another is included.

The household sector breaks down into two sections: the computation of household formations and dissolutions (births and deaths), and the computation of migration.

Migration. The logic of the household migration model is the same as that used in Urban Dynamics (Forrester, 1969, p. 135). During a given year a certain fraction of a household class will move into the city, and a certain fraction will move out. The migrating fraction is equal to some normal rate modified by the attractiveness of the city for that group. That is, for each household category:

$$I = N \times NIM \times AFI$$

$$O = N \times NOM \times AFO$$

where I and O are in and out migration, N is the number of households in the particular category living in the city, NIM and NOM are the normal rates of in and out migration, expressed as fractions, and AFI and AFO are the attractiveness factors for in and out migration. These are neutral when they have a value of unity, and are computed on the basis of certain influences.

The heart of the migration model is the determination and quantification of the influences which affect the attractiveness factors. In this model, there are four influences taken into account.

1. Race
2. Job Availability
3. Housing Availability
4. Government Performance - taxes and crime

Before presenting the rationale for the inclusion of these four factors, one point should be noted. These four influences are not assumed to account for the total degree of attractiveness of a particular area, but only for a "differential" attractiveness. That is, if the normal migration rates used are those not just for the central city but for the entire metropolitan area, then the attractiveness factors should measure the differences in attractiveness between the central city and its suburbs. Thus the attractiveness factors used do not include the attractiveness of the metropolitan area relative to the rest of the country. This is included in the normal migration rates. The attractiveness factors do include those influences listed above which appear to determine the relative drawing power of the central city vis-à-vis the suburbs.

The AFI and AFO for each household category are each products of four neutral-unity factors, one for each of the four influences on attractiveness.

Race. The racial problem has been evident in American cities for many years. In 1955 the sociologist Bergel (1955, p. 217) wrote:

> The difficulties in absorbing so large a minority are enormous, but the social forces in a system where the mere suggestion of assimilation causes horror are an even more serious obstacle. There can be no doubt that under present conditions the color question poses the gravest of all problems arising from the complexity of American urban society.

The racial mix of the city will be shown to be one of the most important factors affecting migration decisions.

Job Availability. Although the importance of job location in migration decisions has diminished in importance because of increased personal mobility, a central city still owes some of its relative attractiveness to the presence of a large number of available jobs. For example, in the city of Newark there are about 210,000 employment positions, and only 125,000 households. Thus the employment opportunities in the city provide jobs not only for many Newark residents, but also for thousands of commuters. The effect of employment opportunities on residential attractiveness is taken into account in a migration algorithm.

Housing Availability. It is obvious that the availability of housing in a city will affect decisions to migrate to that city. If vacant housing in the appropriate price range does not exist, for all practical purposes in-migration is terminated. Included in the algorithm which measures the effect of housing on migration is, however, a model of overcrowded housing, that is, the sharing of one housing unit by more than one household.

Government Performance. The use of the tax rate and crime rate variables as performance measures of the government sector has already been discussed (Chapter III). All that is postulated at this time is that these variables have some effect on migration decisions. Ample evidence of that fact exists:

> One basic point here is that if the city is to attract upper-middle income families, it has

> to meet their standards. One of their standards is the demand for good and safe schools and side-walks. If the city wants them back, the city cannot afford to mix them with the very groups they were fleeing. (Bebout and Bredermeier, 1963, p. 70).

The middle class expects certain municipal services, and if these are not provided or are provided at too great a cost, these people will migrate elsewhere.

This concludes the discussion of the factors used in the migration model. The specific use of each factor will be discussed when the individual algorithms are considered.

Formation and Dissolution. The second section of the household sector is far simpler than the first. This section models the formation of households by young adults, and the dissolution of households because of deaths or the combination of households. A discussion of the logic employed in each process will be postponed until the two algorithms are discussed.

Inputs and Outputs

The state variable output of the household sector is the household variable (HSD). This variable is the number of households of eight types living in the area in each of the forty years of the simulation. The eight types are:

1. White white collar households
2. Black white collar households
3. White blue collar households

4. Black blue collar households
5. White unskilled households
6. Black unskilled households
7. White unemployed households
8. Black unemployed households

The state variable inputs to the sector include:

Households (HSD)
Worker Changes (WCH)
Jobs (JOB)
Crowding Index (CRI)
Crime Rate (CR)
Tax Rate (TR)

The Household variable is an input because, just as in the housing sector, the value for the following year is an incremental change from the value for the present year. The Worker Changes are supplied by the job sector and reflect changes in category through unemployment. The rest of the inputs are used in algorithms which compute the relative attractiveness of the city for different household groups. The need for these variables will be discussed with the various algorithms.

Sector Algorithms

The block diagram of the household sector is shown in Figure 5.1. Following the logic already presented, the sector consists of the following algorithms:

Household Migration Effects Computer	(HMEC)
Job Migration Effects Computer	(JMEC)
Crowding Migration Effects Computer	(CMEC)
Government Migration Effects Computer	(GMEC)
Net Migration Computer	(NMIC)
Household Dissolution Rate Computer	(HDRC)
Educational Process Computer	(EDUC)
Household (calling program)	(HSHD)

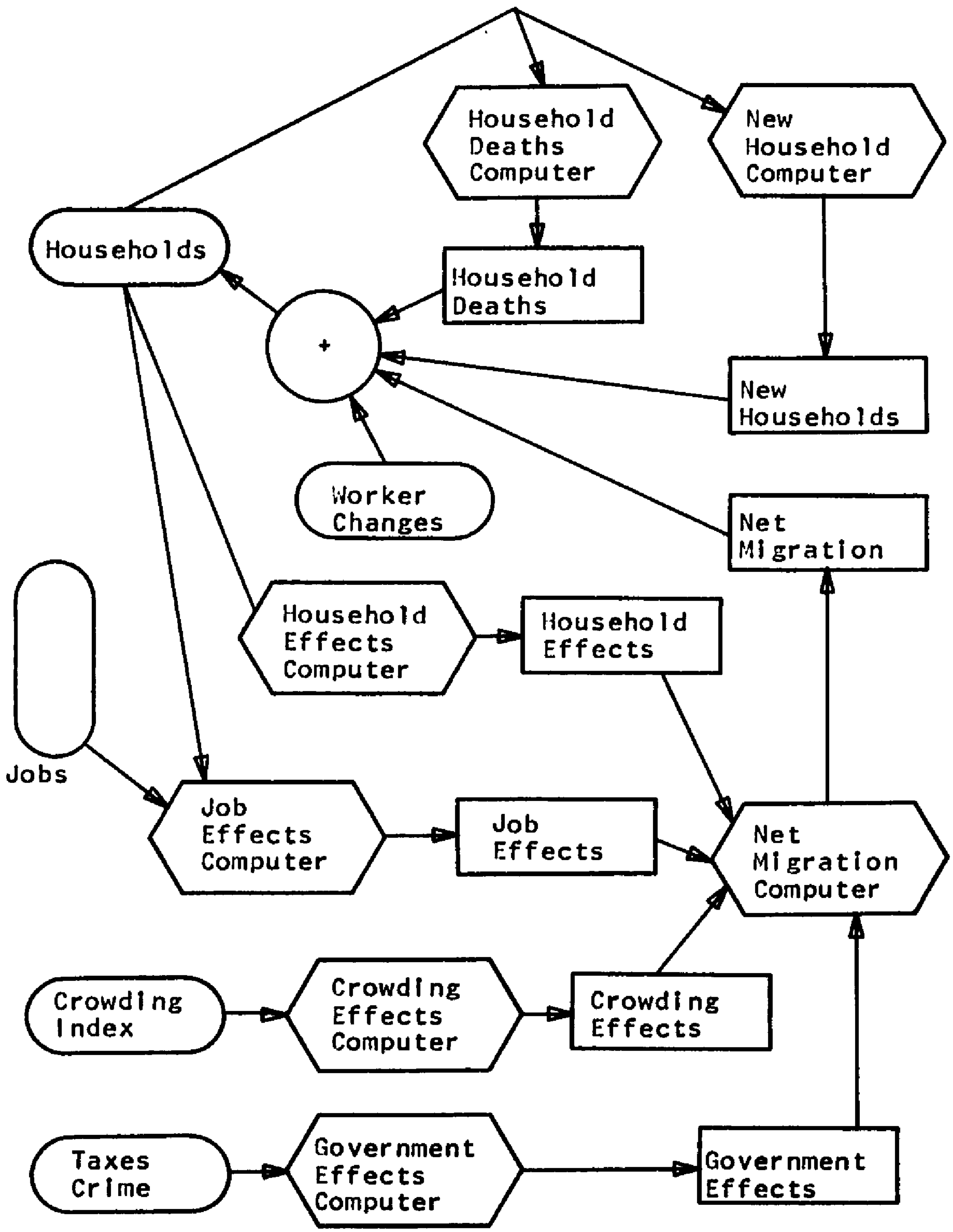

Figure 5.1 Household Sector

The first five algorithms make up the migration half of the sector; the following two (HDRC and EDUC) account for household formation and dissolution; and the household calling program computes the value of the household state variable.

Household Migration Effects Computer

Logic. The HMEC algorithm computes in and out migration factors for the eight household groups on the basis of race. The rationale for using race as a factor in migration decisions has already been discussed. There are two sets of neutral unity migration factors to be computed: one set for in-migration, the other for out-migration. In the Forrester model, the multiplier for out-migration was taken to be the inverse of the multiplier on in-migration, the rationale being that what induces people to move to a city will also induce them not to leave. This is not always the case, however. If every housing unit in the city is occupied, people will be discouraged from moving in, but if the residents are comfortably housed, this condition will not encourage them to move out. The present model has tried to make the distinction between in and out migration factors, where necessary.

In this algorithm the relative attractiveness of the city for in-migration is determined graphically with the black fraction (BF) of the city's households as the explanatory variable. The quantity BF is easily obtained from the household state variable. As BF increases, the attractiveness for white in-migration decreases. The out-migration factor is taken as the inverse. For blacks the situation is more complex. Pack (1972, p. 191) points out that the presence of other blacks in a city is the most important factor in determining black migration patterns. The logic is reasonable. Rural Southern blacks, being both poor and racially oppressed, hear of better jobs in Northern industrial cities. A few go North. Most wait to hear from friends or relatives that there is a black enclave offering protection from whites. By letter and word of mouth the message passes from the North to the South and the wave of migration ensues. Thus one would expect a low initial attractiveness for the city based on race, but as the black population builds the attractiveness increases. Once a sufficient black population is reached, however, protection is guaranteed, so the attractiveness is no longer as important. This form of attractiveness has been used in the model.

The result of the in and out migration computations is a sixteen element vector called household migration effects (<u>HME</u>). The first eight elements are the in-migration factors, and the last eight are the out-migration factors.

Mathematics. Once the black fraction (BF) is computed, the rest of the algorithm consists of table functions (TABL) with BF as the independent variable and elements of the HME vector as dependent variables. These graphical relationships, which were developed and then calibrated using Newark data, are presented in Figure 5.2.

Calibration. The graphical relationships were first postulated and then adjusted so that the simulation results coincided with the Newark data. In that sense they are calibrated, but more work needs to be done with data from other cities before they can be considered general behavioral relationships.

One may question why the first relationship in Figure 5.2 holds for both the well-paid, well-educated group and the low paid or unemployed group, while the white blue collar households show a lower tolerance for blacks. There may be two factors at work. First, the white collar workers are better educated than the blue collar workers and could have a more liberal attitude in dealing with blacks. Both groups have the financial ability to move to suburbia, but the blue collar workers are more sensitive to the black presence. The second factor applies to the unskilled and unemployed group, who are just as apprehensive about blacks as the blue collar workers, but because of their low economic status have

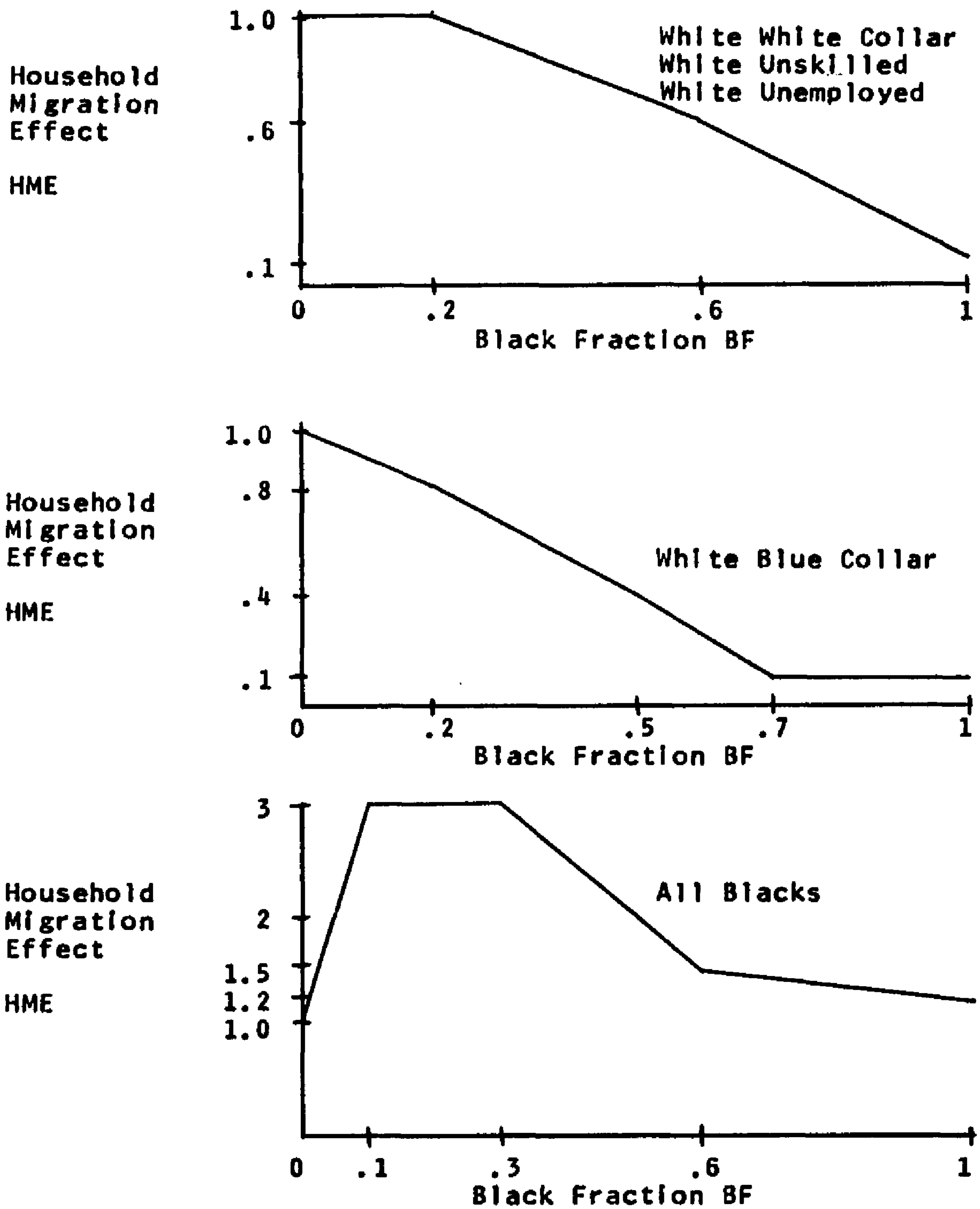

Figure 5.2 Household Migration Effects.

difficulty moving, due to a lack of suburban low income housing. This lack of suburban housing is not included in the model, so the effect shows up here instead.

The attractiveness factor for blacks of all groups may seem very high, but a factor of this magnitude was necessary to account for the extreme differential attractiveness between blacks and whites during the time when a black majority was building. The remainder of the graph, from a non-white fraction of .6 to 1, represents only a guess that the relative attractiveness for blacks will decline as the city becomes almost all black. Obviously more work needs to be done with data from other cities to see if these graphs represent general behavior patterns.

As mentioned in the discussion of logic, the out-migration factors for whites were taken to be the inverse of the in-migration factors, as were those for blacks, the rationale being that the increased security brought about by a significant black population encourages black households to stay, up to a point, when an increased black fraction brings no further increase in security.

Job Migration Effects Computer

Logic. The logic for the Job Migration Effects Computer (JMEC) has been covered in the discussion concerning the choice of factors to be included in migration decisions. The actual computation of attractiveness factors dependent on job availability uses the concept of a ratio between the number of central city jobs and central city households of the same category (i.e., total central city unskilled jobs and total unskilled households.) Since the central city has many more jobs than households, the neutral value of this ratio will be greater than one. The use of a neutral value means that, when the job to household ratio is equal to that value, the city will have normal attractiveness for households of that type. An increase in the ratio would mean more job opportunities, and would thus increase the attractiveness of the city.

This relationship is certainly oversimplified, but has been used anyway, since in the running of the simulation the job migration effects (JME) produced by this algorithm varied little from unity. Since there is little sensitivity to these effects, the graphical relationships presented below have not been calibrated, but are only logical postulations. However, the neutral values of the job to household ratios have been given their 1950 values, since that year represents a time of relative stability in Newark. Obviously these ratios would vary for other cities.

Mathematics. The output of this algorithm is the sixteen element vector called job migration effects (JME).

The first eight elements of this vector represent the attractiveness of the city for in-migration for the eight household categories. (White white collar, black white collar, white blue collar, black blue collar, white unskilled, black unskilled, white unemployed, and black unemployed.) The second eight elements represent out-migration factors. (Numbers greater than unity increase out-migration.)

If W, B, and U, are the attractiveness for white collar, blue collar, and unskilled workers respectively, then JME would be:

W W B B U U 1 1 1 1 1 1 1 1 1 1

Each quantity affects those household groups for which it applies. The out-migration factors are all unity, as will be discussed below. Obviously, unemployed households are not affected by job availability.

The relationships used to find W, B, and U are shown in Figure 5.3. The unskilled households are modeled as having greater dependence on job locations (greater slope) because of the reliance of many unskilled workers on the public transportation system. The white and blue collar workers, being more affluent, generally travel to work by car and are thus less concerned with the relative position of job and home. The neutral point for the two groups was found to be different, however.

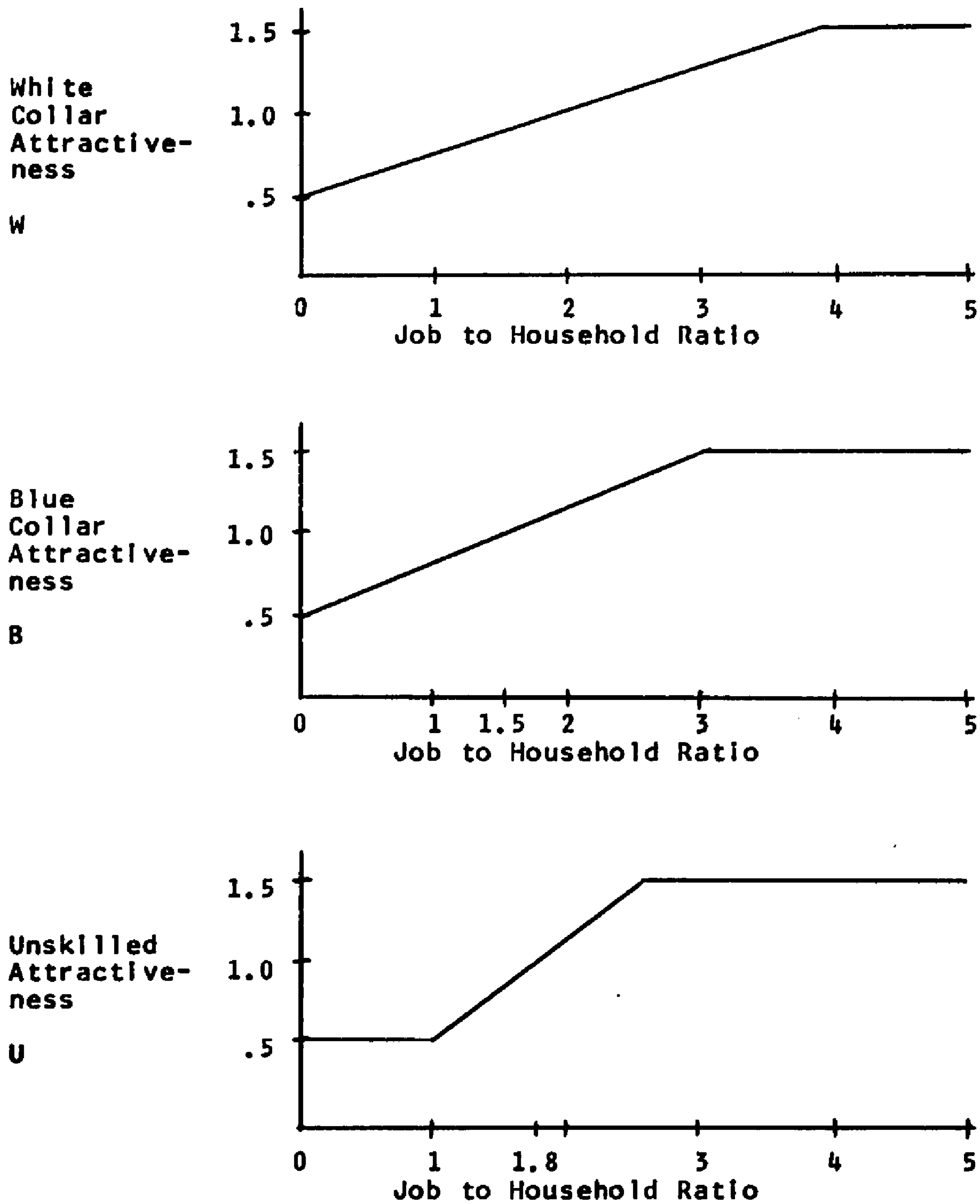

Figure 5.3 Job Migration Effects.

This algorithm affects only the in-migration decisions of potential city residents. It is assumed that the relative numbers of jobs and households will not affect a resident household unless that household's wage earner loses his job. This unemployment problem is covered by an algorithm in the JOB sector and transmitted to the household sector by the state variable WCH (worker changes).

Calibration. The only calibration performed on these graphs was the selection of the neutral point. From 1950 Newark data, this was found to be 2, 1.5, and 1.8 for white collar, blue collar, and unskilled, respectively. The range of these relationships (from .5 to 1.5) and their slopes are postulated.

Crowding Migration Effects Computer

Logic. The purpose of the Crowding Migration Effects Computer (CMEC) is to limit the inflow of new households when the supply of available housing is exhausted. To do this, the algorithm makes use of the crowding index (CRI) state variable generated by the housing sector. The crowding index for any year is an eight element vector (one for each household type) of the ratio of unhoused households to total households of that type, normalized to 100. For example, if there were 4000 unhoused households out of 20,000 total households of one class, the crowding index for that class would be 20.

These crowding index values are graphically related to values of a multiplier on in-migration. A crowding index of zero produces a multiplier of one, since housing is still available and in-migration will not be affected by overcrowding. Crowding indices greater than zero produce multipliers with values less than one. These multipliers only work on in-migration, since people adequately housed are not going to increase their out-migration rate just because all housing units are filled.

Mathematics. Just as in the two previous algorithms, the result of the CMEC algorithm is a sixteen element vector called crowding migration effects (CME). The second eight elements of this vector, representing out-migration effects, are all unity. The graphs relating CRI to CME are postulated, not calibrated. Different socio-economic groups have been treated differently, as can be seen in Figure 5.4.

The first graph in Figure 5.4 is for white and blue collar workers, and expresses the relationship that in-migration will be cut to one-tenth its normal value if there is 10% overcrowding. The second is for unskilled and unemployed white households and shows a larger tolerance for overcrowding. The third is for unskilled and unemployed black households and reveals the highest tolerance for overcrowding, with in-migration not being

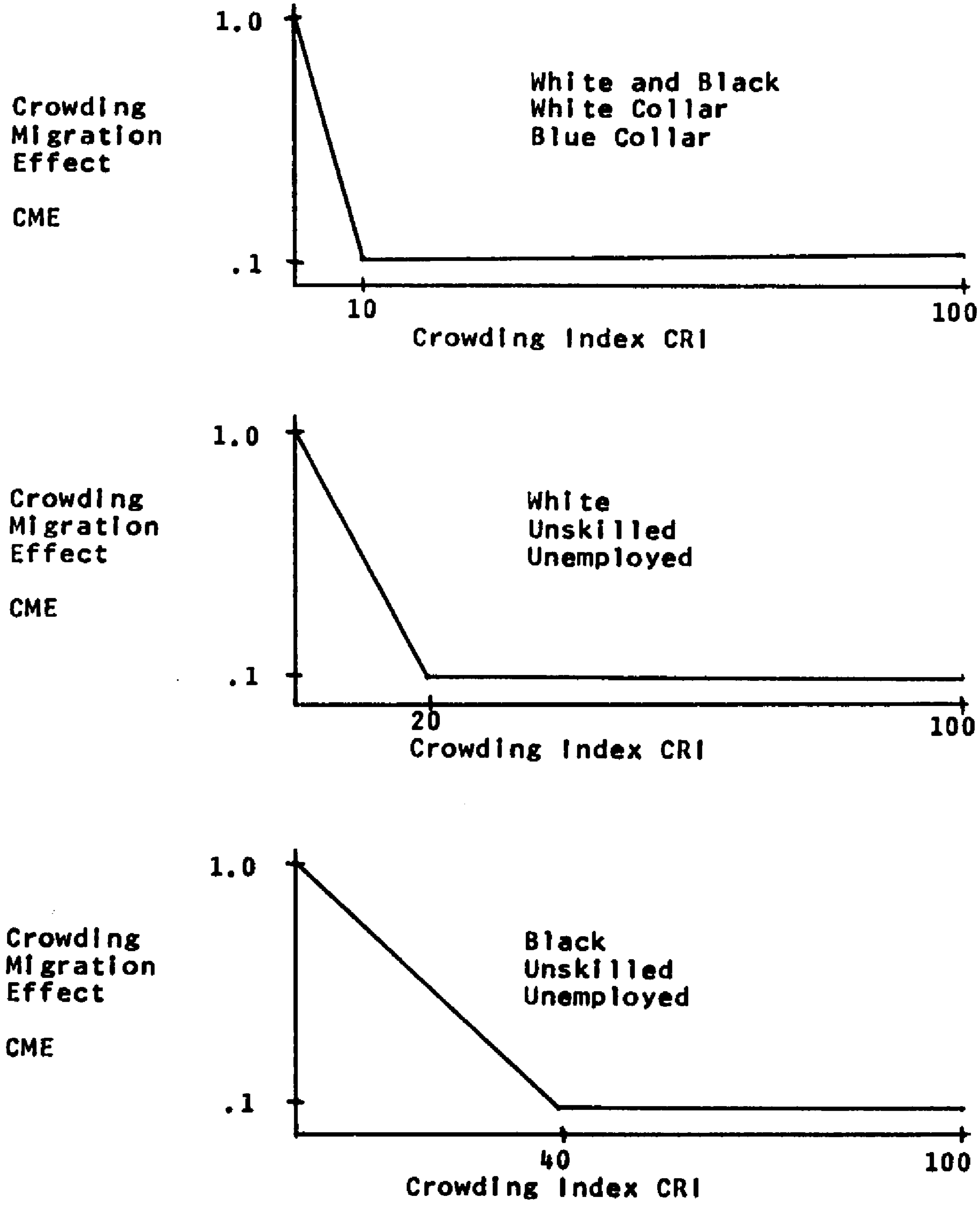

Figure 5.4 Crowding Migration Effects.

curtailed (.1) until overcrowding reaches 40%. There is no empirical justification for these relationships, just the generally accepted notion that lower socio-economic groups will double up in housing units more than higher socio-economic groups, and that blacks will do so more than whites.

Calibration. The graphical relationships above are postulated, not calibrated. In running the simulation, however, only the relationship for black unskilled and unemployed households came into play; the rest were never required. Further work should be done to determine the accuracy of this relationship.

Government Migration Effects Computer

Logic. The Government Migration Effects Computer (GMEC) generates migration multipliers based on the values of the two governmental state variables, tax rate (TR) and crime rate (CR). The use of these two variables as performance indices for the government sector has already been mentioned. This algorithm converts these objective measures into an influence on migration decisions, expressed as a sixteen element vector called government migration effects (GME).

As modeled, the influence of crime is felt equally by every household class. That is, as a factor in migration decisions, a high crime rate affects all households to the same degree. The crime rate that is used is determined by the government sector in a way which will be described, and conforms with the FBI method of reporting crime in terms of number of crimes per year per 100,000 persons (United States Federal Bureau of Investigation, 1970). This crime rate for the city is compared with the normal crime rate (CRN), which is the average crime rate for the country and is supplied exogenously. This normal rate has not been constant since 1950, but has risen more or less linearly, according to FBI statistics. This normal rate is modeled as a linear increase in the simulation.

In addition to this crime factor, the GMEC algorithm generates another factor based on the tax rate. This factor is used only for the white collar and blue collar households, both white and black, on the theory that they will be more directly affected by higher taxes since they either own their housing or pay high rents for it. This factor is determined by a comparison of the city property tax rate (TR) to the "normal" tax rate of five dollars per 100 dollars of assessed value. All computations are in constant dollars with a constant valuation scheme.

The net government migration effect (GME) on in and out migration is the product of the crime and tax rate factors, the crime factor applied to everyone and the tax factor applied to the four upper socio-economic classes.

The out-migration factors are taken as the inverse of the in-migration factors.

Mathematics. The tax and crime rate factors are given by two graphical relationships. These were initially postulated, and then adjusted to produce correct simulation results when compared with Newark household data. The graphs are given in Figure 5.5.

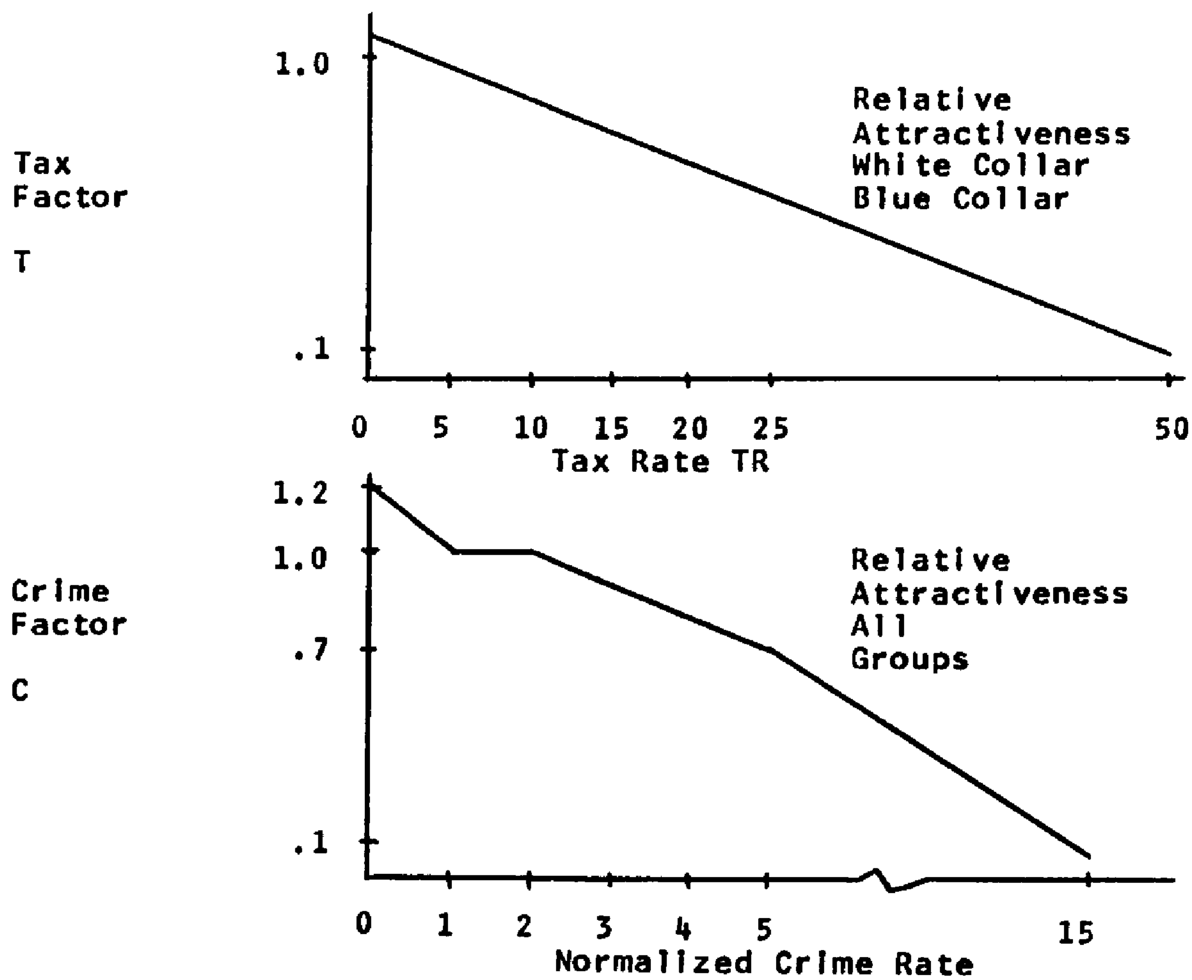

Figure 5.5 Government Factors

Calibration. The calibration of the graphical relationships in Figure 5.5 was achieved by adjusting the graphs until the simulation results matched the Newark data. Because of the range of calibration data, much of both graphs is extrapolated. The tax rates used ranged from 5 to nearly 10, and the crime rates were between 1 and 3 times normal. The linear extrapolations are logical, and even conservative in nature. There is reason to believe that, for example, an increasing tax rate would produce a greater than linear decrease in the city's attractiveness. Thus the linear extrapolation, if it is in error, at least errs on the conservative side.

Net Migration Computer

Logic. The net migration computer (NMIC) multiplies the household, job, crowding, and government migration effects described in the four previous algorithms and then computes the net migration for the year using normal migration rates. The computation begins by finding the net migration effects ($\underline{NME}$).

$$\underline{NME} = \underline{HME} \times \underline{JME} \times \underline{CME} \times \underline{GME}$$

where all variables are 16 element vectors, 8 elements for in-migration and 8 for out-migration. The NME vector is then separated into its first 8 elements (in-migration factors) and its last 8 elements (out-migration factors). Following the logic described at the beginning of this chapter, the in and out migrations are found as the product of the migration factors, the normal migration fractions, and the numbers of households already living in the city. The resulting quantities, net migration in (NMI) and net migration out (NMO) are both eight element vectors. The mathematics of this computation are obvious.

Calibration. The only quantities which must be adjusted in this algorithm are the normal in and out-migration rates. These are supplied exogenously and are derived from Babcock (1970, pp. 60-64) who used them in an improvement on the Forrester model. His rates, based on 1960 census data on in-migration and net-migration to metropolitan areas, are as follows:

	Manager-Professional	Labor	Underemployed
In-migration fraction	.040	.030	.030
Out-migration fraction	.037	.026	.023
Net rate	.003	.004	.007

These rates are based on the Forrester household categories of Managerial-Professional, Labor, and Under-employed. They show, as would be expected, a higher mobility for the higher socio-economic classes, but a lower net migration rate into the metropolitan areas.

From these rates the following rates for in and out migration for the eight household categories have been derived:

NIM	=	.037	.037	.030	.030	.030	.030	.030	.030
NOM	=	.034	.034	.026	.026	.023	.023	.023	.023

Forrester's underemployed class includes the present unskilled and underemployed classes, so these rates have been adopted, as has the labor rate for the blue collar households. The white collar households are a combination of managerial-professional and labor, so an intermediate set of rates has been chosen.

This completes the migration section of the household sector. However, the numbers of households are still modified by household formations and household dissolutions, and these are covered by the next two algorithms.

Household Dissolution Rate Computer

Logic. The purpose of the household dissolution rate computer (HDRC) is to account for the death, or dissolution, of household units. This algorithm assumes an average household lifetime, measured in years, for each household category. The household dissolution rate is then the inverse of the household lifetime. The number of households dissolved each year (household deaths) is simply this rate times the number of households. The result is the eight element vector HDR.

Calibration. The only quantity to be calibrated is the average household lifetime for each group. The normal lifetime of a household would be from the time it is formed, with its progenitors being in their late teens or early twenties, until the time it is dissolved, with the couple in their sixties. This would mean a household life of about 40 years, and this figure is used for some black households. However, 1960 Census data reveals, in the city of Newark, a mean age for blacks of 25.3 and for whites 36. This is due to the presence of many older or retired white families. To account for this, the white household lifetime has been reduced to 30 years. In addition, the lifetime for poor black households (unskilled and unemployed) has been reduced to 33 years to account for the shorter life expectancy of these groups due to poor health care and unsatisfactory living conditions. The household death rate is the inverse of its lifetime; thus the rates are .033 for white households and .025 and .03 for black households. These rates are used in the following equation which computes the number of dissolved households each year as the death rate fraction of existing households (HSD).

HDR=-1 x .033 .025 .033 .025 .033 .03 .033 .03 xHSD(I)

The resulting HDR is used in the final household computation.

Household Formation

Logic. Household formation was originally designed to be a separate sector dependent on the educational process for the categorization of new households, so the algorithm is still called EDUC. However, the data necessary to calibrate the educational model first proposed does not exist, so this much simpler algorithm was developed and is used within the household sector.

The first step in determining household formation is to compute the household generation rates for white and black households, a figure similar to birth rate but not quite the same, since two children are required to create a married household. (The problem of unmarried households will also be dealt with.) Once the household generation rates are determined, the numbers of new households formed each year (<u>NHD</u>) is obtained by multiplying the formation rate by the numbers of households (HSD). <u>NHD</u> is an eight element vector representing the new households generated by the existing households. But it would be unwise to assume that each new household fits into the same category as that of its parents. First, with the exception of unwed mothers, there will probably be few new households in the unemployed category. Some may become unemployed if market conditions are poor, but there is no reason to assume that they all will be unemployed simply because their parents are unemployed. Thus the households generated by unemployed parents are mostly distributed to the white collar, blue collar and unskilled categories, with the greatest share going to unskilled (.5) since most of the unemployed have no skills themselves.

Once the households generated by unemployed parents have rejoined the working classes, another change must be recognized. This is the upward mobility of, for example, the children of unskilled parents to enter the working world as blue or white collar workers. This upward mobility, whether due to increased education, higher aspirations, or simply an awareness of what skills are needed in the marketplace, must be considered when determining the status of new households.

The recent study of the effects of education by Jencks (1972) has cast much doubt on the effects of education on eventual income and status. Jencks' conclusion is that the variability among incomes is far greater than can be explained by educational variables, and that success is due more to individual talent and luck than to the quality of education received. There is, however, a definite trend among young people to get more education than their parents, and whether or not this education is valuable, the quantity of education is sometimes taken as qualification for certain jobs.

Thus the EDUC algorithm makes use of an exogenously supplied education factor (EDF) which represents that fraction of the new households which will enter the next higher status category because of an increase in education or a rise in aspirations. That is, the EDF fraction of new households with unskilled parents will enter the market as blue collar households, and the EDF fraction of new households with blue collar parents will enter the market as white collar households. (New households with unemployed parents have already been accounted for.) The net result is a shift from households entering the market with no skills to those entering with white collar skills, a shift which parallels the changing complexion of jobs in urban centers.

One last factor which must be considered in new household generation is, unfortunately, the large number of black unwed mothers. The unwed mother obviously does not fit the pattern of two young adults forming one household, and this leads the two adult algorithm to generate fewer households than are in fact produced. This effect is compensated for by an equation which generates an additional fraction of households (.2) from the black households produced by unskilled and unemployed parents, and adds them to the new unemployed households.

To sum up, this algorithm makes three corrections to the new households (<u>NHD</u>) before assigning them to a household category. First it removes most households generated by unemployed parents and distributes these households to other categories. Second, it uses an education factor (EDF) to shift new households from lower skill to higher skill categories. Third, it accounts for the large number of black unwed mothers forming additional households.

<u>Mathematics</u>. The computations of this algorithm are very complex, and make use of several powerful APL vector operations. Thus it will be easier to demonstrate the algorithm by means of an example. Consider that for the year in question, the household state variable has the following value:

```
HSD (I) = 13,000  12,000   8,000  15,000  19,000
          25,000   3,000  13,000
```

The household generation rates (see Calibration) have been found to be:

```
.015   .027   .019   .03   .023   .035   .023   .035
```

Multiplying these two vectors yields the new households (<u>NHD</u>).

```
NHD =  195  324  152  450  437  875  69  455
```

(Remember that the order of these numbers is always white white collar, black white collar, white blue collar, black blue collar, white unskilled, black unskilled, white unemployed, and black unemployed.)

The households formed by children of unemployed parents are distributed to the other categories. One-tenth go to white collar, one-tenth to blue collar, one-half to unskilled, and three-tenths remain unemployed. Thus:

NHD	195	324	152	450	437	875	69	455
correction	+7	+45	+7	+45	+35	+288	-49	-318
new NHD	202	369	159	495	472	1103	20	137

The second step is shifting of households from lower to higher skill categories by means of an education factor (EDF). The EDF is taken as .2. The computation is:

NHD	202	369	159	495	472	1103	20	137
+	32	99	94	221	4	27	0	0
-	0	0	32	99	94	221	4	27
new NHD	234	468	221	617	382	909	16	110

The arrows indicate the upward skill mobility of each group.

The final correction is for black unwed mothers. The algorithm takes one-fifth of the black new households in unskilled and unemployed categories (.2 x 1019) and adds them to the unemployed category. Note that this is the only process in the algorithm which generates additional new households. The other two steps only shift households from one category to another. The generation of additional households in this case is justified because the generation rates initially used were based on a two-parent household. Thus the final NHD is:

NHD = 234 468 221 617 382 909 16 330

<u>Calibration</u>. A study of Newark (Chernick, et.al., 1967) revealed 10,500 white children and 13,600 black children between the ages of 16 and 19 living in the city. Interpretation of census data indicates that these children were the products of roughly 70,000 white and 52,000 black households. These figures yield household generation rates of .019 for whites and .033 for blacks, assuming two people per household. Figures in Babcock (1970, p. 54) show that well educated and poorly educated mothers have .8 and 1.2 times, respectively, fewer and more children than the average. This leads to the following household generation rates for the eight household categories:

.015 .027 .019 .03 .023 .035 .023 .035

These figures assume that white collar households have well educated mothers, blue collar households have mothers with average education, and unskilled and unemployed households mothers with poor education.

The rest of the figures used in this algorithm have not been calibrated, but they have been adjusted to give reasonable results. These figures include the distribution of households produced by unemployed parents to the other household categories, the education factor, and the factor for unwed mothers. A great deal of data collection and analysis will be required to refine these figures.

Household (calling program)

The household program (HSHD) is the master program of the household sector. It serves as a calling program for the other algorithms of the sector, and performs the computation of the household state variable by means of the following equation:

$$\underline{HSD}\ (II) = \underline{HSD}\ (I) + \underline{WCH}\ (I) + \underline{NHD} + \underline{HDR} + \underline{NMI} + \underline{NMO}$$

In this equation II refers to the upcoming year; I to the present year. WCH is the state variable Worker Changes supplied by the Job sector, and the four variables, NHD, HDR, NMI, and NMO are the yearly changes computed in the household sector for household creation, dissolution, and in and out migration.

Overall Calibration

The household sector was calibrated using values of the household state variable for the city of Newark in the years 1950, 1960, and 1970. These values are obtained indirectly from the U.S. Census of Population for the three points in time. Some estimation is required since the Census does not give households by race and occupation of the household head, but instead gives households by race and sex of head, and male and female workers in various classes. The determination of the figures used in the simulation is discussed in Appendix II.

As stated in Chapter III, the grouping of households into white collar, blue collar, and unskilled is on the basis of the type of skills used, not on the type of industry in which employed.

The reduced data for the household state variable is given below.

TABLE 5.1 NEWARK HOUSEHOLD DATA

Newark Households (in thousands)

	WWC	BWC	WBC	BBC	WU	BU	WUN	BUN
1950	30	2	30	3	36	15	4	2
1960	25	4	22	8	36	22	5	5
1970	17	9	13	13	22	25	7	13

The algorithms of the household sector have been calibrated to the point where the simulation output for the household variable agrees with the 1960 and 1970 data to within five hundred households in almost every category.

VI. JOB SECTOR

Logic

The job sector of the central city simulation model is concerned with the number of job opportunities which exist in the city, both for residents and commuters. Two processes are modeled in this sector. First, the total numbers of employment positions within the city is determined by a differential job migration model. Second, the effects of unemployment on the household categories are determined.

Job Migration. Most of the algorithms of the job sector deal with the determination of the total numbers of jobs within the city in the three job categories: white collar, blue collar, and unskilled, as defined in Chapter III. As in the case of households (Chapter V), jobs are modeled as migrating to or from the city. The rate of job migration is determined by two types of influences: exogenous and endogenous.

If the central city is viewed as part of a larger urban region, the exogenous influences on job migration, for the purposes of this model, are those which differentiate the urban region from the rest of the country. The endogenous influences are those which differentiate the central city from the rest of the urban area. The net attractiveness of the urban region for job migration is not a concern of this model. The relative attractiveness of the region vis-à-vis the rest of the country will be taken into account by "normal" migration rates, supplied exogenously.

However, those factors which make the central city more or less attractive than its surrounding urban areas are endogenous to this type of "differential" job migration model. The term "differential" refers to the differential rates of job growth and decline between the city and its urban area, not between the urban area and the country as a whole.

What are the factors which influence job location decisions? In a study of the New York Metropolitan Region Lichtenberg (1960, p. 31) lists them as inertia, transportation costs, labor costs and supply, and the presence of external economies. He goes on to examine how the New York Metropolitan Region differs from the rest of the country in terms of these factors. But these differences are exogenous to the central city model. What is significant is how these factors influence locational decisions between the central city (Newark) and its surroundings. These factors will be discussed in this context.

Inertia is the reluctance of an employer to move because of the investment in physical plant and the disruption of work involved in the moving process. This problem is applicable anywhere and therefore is not a subject of intraregional differences.

Transportation costs used to favor central city locations because of rail connections, but the continuing increase in the importance of truck transportation in all but the heavy industries has reduced the importance of rail access. In terms of transportation costs having a bearing on locational decisions, there is little difference between a location in downtown Newark and one in the surrounding area.

The differences in labor costs throughout the area are viewed as unimportant in locational decisions. In the words of Hoover and Vernon (1960, p. 49), "All in all, it is doubtful that wage differences will play much of a role in the future shift of industry within the ... Region." Labor availability, however, is a different matter.

> ... it is not at all unlikely that the relative attractiveness of ... Newark's downtown area will be reduced. ... the changing distribution of population within the Region, the impairment of mass transit facilities, and the ubiquity of the automobile are all reducing the relative strength of the old central points of the Region as gathering places for workers. (Hoover and Vernon, 1960, p. 97).

Thus the spread of the labor force to the suburbs is seen as one reason for the movement of jobs out of the central city.

External economies are those advantages which accrue to a business because of the nearby location of useful services or facilities. For example, nearby locations of suppliers, consultants or other services are external economies. An adjacent river in which to dump industrial waste used to be an external economy. In general, recent years have witnessed the spread of external economies to the point where, at least in the Newark Metropolitan Area, they are not much of a locational factor. Increased personal mobility and better communication systems have tended to equalize the external economies throughout the area.

There is, however, a serious diseconomy connected with a central city location: municipal property taxes. Property taxes are much higher in Newark than in some surrounding suburbs. As far back as 1955, Newark's property taxes were 1.4 times as great as the New Jersey average. (Hoover and Vernon, 1960, p. 57). Speaking in general terms, Vernon (1960, p. 132) says, "... local tax differences will persist, creating a modest outward push for industry." More specifically, he says,

> ... the New Jersey cities ... must be wary of the possibility that their measures (to raise revenue) may drive enterprises and homes out of the jurisdiction. ... many activities in New York City's central business district are pinned down in that location for compelling reasons; but this cannot be said for so large a portion of the activities found in the central business districts of Newark, Jersey City, and Hoboken. (Vernon, 1960, p. 177).

One factor not mentioned in the list of national locational factors but which forms a large part of the discussion on intraregional job migration in the New York Metropolitan Region study is the search for more efficient manufacturing space (Hoover and Vernon, 1960, pp. 29-36). The argument is that many older manufacturing plants in central city locations move to suburban locations for three reasons. First, their space is inefficient. With modern manufacturing equipment a spacious single-floor plant is desirable. Second, any attempt to expand in the central city location is hampered by the problem of buying adjoining property. Third, most central city plants were built before zoning, so their neighborhoods contain commercial and residential buildings whose owners consider the manufacturing plant a local nuisance. Thus there is a push for these plants to move to the suburbs.

This type of argument is persuasive in the case of Manhattan, for which it was formulated, but it is incorrect in the case of Newark. It is true that these pressures may compel plant management to seek other space. But unless the entire city is built up, that space does not have to be in the suburbs. In fact, the city of Newark has one of the largest Urban Renewal tracts in the country, 1,528 acres, of which nearly 1,000 acres is slated for industrial development (City of Newark, 1970). These industrial sites are convenient to highway, rail, air, and water transportation. Yet much of the acreage remains vacant.

The answer to this seeming paradox is that factors other than the need for space have forced manufacturing plants out of Newark. Certainly the space restrictions of older plants generate a need to move to a new location. But the choice of the new location, the Newark Industrial Urban Renewal tract or the surburban industrial park, is dictated by other factors. Thus the space problem contributes to the flight of jobs from Newark only in that it amplifies the effects of other outward forces.

One further outward force is caused by the problem of central city crime. Although the subject of urban street crime is a popular one, very little, if any, quantitative work has been done on the effects of crime, other than on the immediate victims. One can, however, certainly sense an attitude of fear among suburbanites concerning central cities, and it would be reasonable to assume that such a fear affects the locational decisions of businesses. At this time the magnitude of the influence is not in question; only the logic that such an influence exists is postulated.

To summarize, the locational decisions of businesses, which affect the rate of job growth or decay in the central city, are influenced by two types of factors. The first type considers the attractiveness of the particular urban region relative to the entire country. Factors of this type are exogenous to this model and will be accounted for by the values of "normal" migration rates. The second set of factors determines the attractiveness of the central city compared with suburban locations. Factors influencing this choice appear to include labor availability, property tax rates, and central city crime. These factors are endogenous to the model and are included as attractiveness multipliers on the normal migration rates.

Unemployment. The unemployment section of the job sector is based on the premise that decreasing numbers of jobs available in the city without a corresponding decrease in households living there will result in some households becoming unemployed. This effect will be most strongly felt among low income unskilled workers, whose low transportation mobility makes jobs in suburban locations inaccessible. The logic of this section of the model will be more fully developed in the worker changes algorithm.

Inputs and Outputs

The job sector has two state variable outputs: jobs (JOB) and worker changes (WCH). The rationale for these was presented in Chapter III. The job state variable represents the number of job positions within the city in each year in each of the three categories: white collar, blue collar, and unskilled. The worker changes state variable represents the change (for that year) in household category because of unemployment. It is used by the household sector.

The state variable inputs to the job sector include:

Jobs	JOB
Households	HSD
Tax Rate	TR
Crime Rate	CR

There are, in addition, several exogenous inputs which will be examined when the algorithms which use them are presented.

Job Sector Algorithms

The block diagram of the job sector is shown in Figure 6.1. The sector contains four algorithms and one calling program.

Worker effects on jobs	WEBJ
Government effects on jobs	GEBJ
Job computer	BASJ
Worker change computer	WCHG
Jobs (calling program)	JOBS

The computation of job migration is performed by the BASJ, GEBJ, and WEBJ algorithms. The effects of labor force are determined by WEBJ, while the effects of taxes

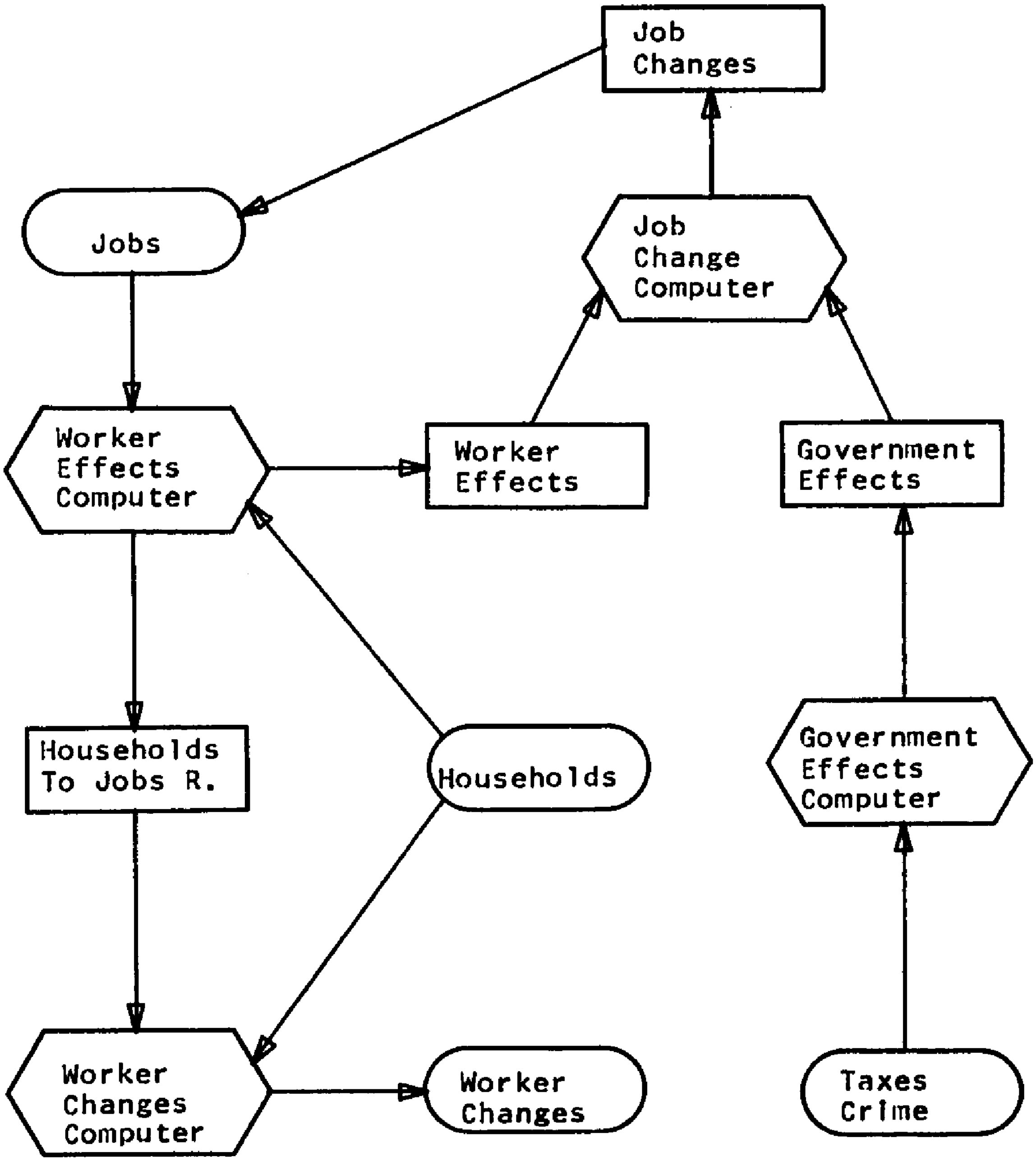

Figure 6.1 Job Sector

and crime are determined by GEBJ (government effects on jobs). The actual computation of job migration is performed by the job computer (BASJ).

Unemployment is accounted for by the worker changes (WCHG) algorithm, whose output is the worker changes state variable (WCH). It might be noted at this time that no algorithm is included for the reduction of aggregate unemployment because that situation never arose in the simulation of Newark. Such an algorithm could be easily introduced if the need arose. Alternatively, one could introduce a "make work" program simply by changing values of the job and household state variables at some point in the simulation. For example, one could simply add 5000 jobs to the number of unskilled jobs and move 5000 households from the unemployed to the unskilled category. No structural change would be required.

The following sections deal with the job sector algorithms.

Worker Effects on Jobs

Logic. The Worker Effects on Jobs (WEBJ) algorithm is designed to replicate the effects of labor force availability on job migration decisions.

A concept which is used here, and which has not previously been explicitly incorporated into a model of this type is the idea of a balance, or equilibrium, between the central city job market and the number of central city households. This concept is used instead of trying to build explicit algorithms for commuting and multi-job households. Basically, it uses existing data to calibrate an equilibrium point between central city jobs and central city households. This point is calibrated during a stable period in the city's history (neither growth nor decay). In the case of Newark, this calibration point was taken as 1950, when the ratio of jobs to households was 2, 1.5, and 1.8 for white collar, blue collar, and unskilled. For example, in 1950 there were twice as many white collar job opportunities in Newark as there were white collar households. Of course some of the white collar workers living in Newark did not work there, but commuted out. Some white collar households had more than one worker, and the rest of the jobs were held by commuters. The exact numbers in each case are unknown, but what is known is that a balance point of two jobs per household existed under stable conditions. Similar balance points exist at 1.5 and 1.8 for blue collar and unskilled households.

The assumption is that if households move out of the city, increasing the ratio of jobs to households, the city will be less attractive to industry because of the reduced labor pool, and the industry will also migrate out. The reverse is also true, since an increased labor pool would be more attractive to industry. This assumption of a constant ratio between households and jobs is suggested by Newark data, but close examination reveals that two opposing forces are at work.

First, the labor force participation rate has declined continuously since 1950. In that year, there were 183,800 working persons supporting 122,400 households. In 1970 there were 137,000 working persons supporting 121,000 households (see Appendix II). The slack, however, has been taken up by increased commuting, since the total number of employment positions in Newark has only declined from 209,000 to 200,000. Thus, although the ratio assumption is used here, its validity in general is doubtful. Obviously, further work must be done in this area.

Mathematics. The first step in the computation of the worker-job function (WJF), which is the output of the algorithm, is the formulation of the household to job ratio (HJR). That is, for each job category (white collar, blue collar, and unskilled) the ratio of total resident households in that category to jobs in that category is formed. The resulting HJR is a three element vector.

The worker-job function (WJF) represents the attractiveness of the city to jobs on the basis of labor force availability within the city. In effect, the WJF is a function of spatial mobility. If workers were infinitely mobile, employers would not have to consider labor availability in their locational decisions. Such is not the case, however.

Thus the WJF for each type of job is modeled by the equation:

$$WJF = 1 + M(HJR - E)$$

where E is the equilibrium point of the household to job ratio and M is a mobility index. The more mobile the workers, the less their supply will affect locational decisions. The values in Table 6.1 have been used in the computation.

TABLE 6.1 VALUES FOR WORKER-JOB FUNCTION COMPUTATION

	Equilibrium Point E	Mobility Index M
White Collar	.5	.5
Blue Collar	.67	.75
Unskilled	.56	1.0

Note that the equation for the WJF contains no upper limit. It was found in running the simulation that none was necessary since HJR varied only slightly from the equilibrium point. The resulting WJF, a three element vector, is used in the computation of job migration in the BASJ algorithm.

Calibration. The equilibrium points in Table 6.1

were derived from the 1950 census data. The numbers here are the inverses of the job to household ratio. The mobility index M is an assumed quantity. The gradation of mobility index from low to high for the range of white collar to unskilled workers has logical appeal, since the low income workers who depend on public transportation are the least mobile. (A high mobility index indicates that job locations are sensitive to worker mobility.) However, no calibration has been performed on the mobility index.

In performing the simulation, it should be noted that the WJF varied very little from unity. Thus the simulation is quite insensitive to the household to job ratio, which means that the exact calibration is not as important as for sensitive relationships. Nonetheless, further work should be done to gain increased understanding of the importance of labor availability in job locational decisions.

Government Effects on Jobs

Logic. The government effects on jobs algorithm (GEBJ) determines the value of a variable (GF) which indicates the relative attractiveness of the city to job migration as a function of the property tax rate and the crime rate.

Mathematics. The attractiveness function due to government (GF) is the product of two quantities: a tax rate attractiveness and a crime rate attractiveness. As a first step, both tax rate and crime rate are normalized; tax rate to its normal value of $5/100, and crime rate to an exogenous normal crime rate.

Next the form of the attractiveness function must be considered. Obviously, the attractiveness of the city as a location for jobs decreases with an increase in either taxes or crime. The curves shown in Figure 6.2 have been used.

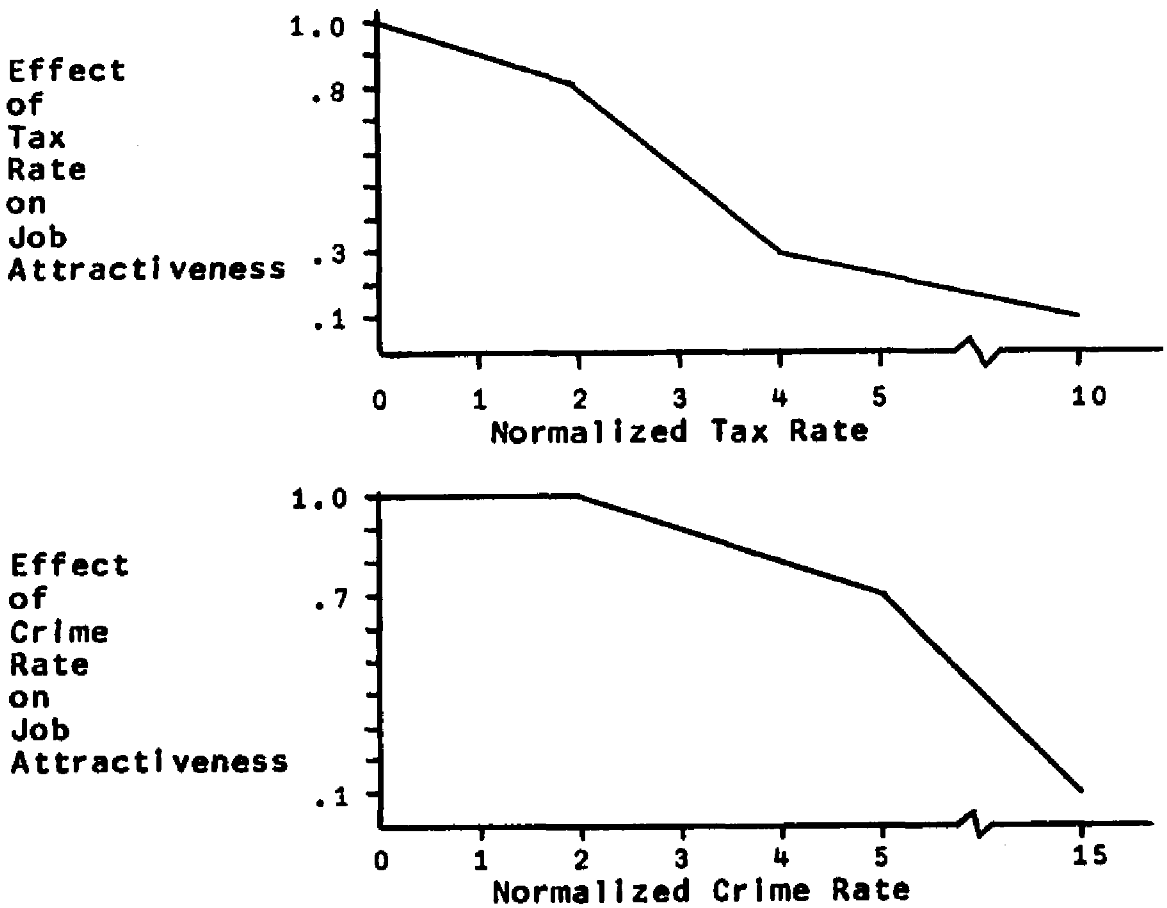

Figure 6.2 Government Effects on Job Attractiveness

In Figure 6.2, the sections of the curves below a normalized tax or crime rate of unity are included for completeness, but the Newark simulation never produced values in this region. Also, the relative attractiveness with a normalized tax rate of unity is only 0.9. This reflects the greater attractiveness of suburban locations with lower than normal tax rates.

Calibration. The calibration of two interacting functions is very difficult. Since the effect of the crime rate is being postulated, its influence was modeled as very small. Note that the attractiveness of the city decreases only to .5 when the crime rate is 5 times normal.

The tax rate was found to account for the main governmental reason for a decrease in the city's attractiveness for jobs. Its influence is mild at first, but becomes more important as it becomes several times normal. An arbitrary value of .1 in attractivenss is used as a lower limit.

The graph of tax rate influence was adjusted to provide the real job migration rates, as determined by data.

Job Computer

Logic. The function of the job computer algorithm

(BASJ) is to determine the overall attractiveness of the central city for job locations, as compared with the suburbs, and to modify the normal job migration rates, which are regional averages, by using the attractiveness function. The net yearly change in central city jobs is produced and added to the job state variable.

Mathematics. The mathematics of the BASJ algorithm are simple. The attractiveness of the city for jobs as a function of labor supply (WJF) and the attractiveness as a function of taxes and crime (GF) are multiplied to give the net attractiveness for job in-migration (a three element vector AF). The number of in-migrating jobs is then:

$$\underline{JOB}(I) \times \underline{NI} \times \underline{AF}$$

where NI is the vector of normal in-migration rates, one for each of the three job categories. Similarly, the number of out-migrating jobs is:

$$JOB(I) \times NO \div AF$$

In this case the unattractiveness of the city, which leads to out-migration, is the inverse of the attractivness of the city. NO is the vector of normal out-migration rates.

Combining the numbers of in and out migrating jobs yields the net migration, which is then added to the JOB state variable.

Calibration. The normal in and out job migration rates for the region are supplied exogenously, and are the only quantities in the BASJ algorithm requiring calibration. These rates, however, are difficult to estimate, since generally only the net growth rate is reported. It is known that the region's growth rate in jobs is roughly equal to the national average, which is 1.5% per year, with white collar jobs increasing at a slightly faster rate. But this net growth rate tells only the differences in rates between job creation and job extinction. Thus, for the purposes of the simulation, an average job lifetime of 50 years is assumed. This assumption would result in a job in-migration or generation rate of .035, and a job out-migration or extinction rate of .02. Combining this with the fact that white collar jobs are increasing faster than manufacturing jobs gives as an estimate of the normal rates NI and NO:

	white collar	blue collar	unskilled
NI	.035	.03	.03
NO	.02	.02	.02

However, the effect of obsolete physical space acting as an accelerator for out-migration has already been discussed. In Newark, almost all of the manufacturing plants could be placed in this category. Thus a 50% increase in the out-migration rate seems reasonable.

Similarly, the white collar job concentration in Newark is relatively recent, so it is natural to decrease this out-migration rate slightly. The resulting rates are:

	white collar	blue collar	unskilled
NI	.035	.03	.03
NO	.015	.03	.03

These are the regional rates, modified to account for the age and obsolescence of Newark facilities. These rates have been used in the simulation, and have produced levels of the JOB state variable which compare well with data.

Worker Changes

Logic. The worker changes algorithm (WCHG) uses the equilibrium concept between households and jobs to determine when unemployment will occur, and generates the worker changes state variable (WCH) which reports these category changes to the household sector. The algorithm uses the job to household ratio (JHR), a three element vector which is the inverse of the household to job ratio (HJR), already discussed. The assumption is that when JHR falls below its equilibrium value, because of losing jobs or adding households, workers begin to find themselves out of work. The number of workers rendered unemployed each year is expressed as a fraction of the total workers in that category and is called Fraction Unemployed (FLO). This fraction for the three job categories is then multiplied by the total number of workers in that category to find the number of workers becoming unemployed. The households which these workers represent are then subtracted from their employment category and added to the unemployed category in the worker changes (WCH) state variable.

Mathematics. Once the inverse of the household to job ratio (HJR - supplied by the WEBJ algorithm) is found and called the job to household ratio JHR, the fraction unemployed (FLO) in each job category is found by means of the three graphical relationships in Figure 6.3.

Note that, in Figure 6.3, the equilibrium point at which no workers are laid off is with a JHR of 2 for white collar, 1.5 for blue collar, and 1.8 for unskilled, the values obtained in the stable year 1950. The .15 ordinate was obtained empirically.

It must be pointed out that in running the simulation, no white collar or blue collar workers were ever made unemployed, so everything pertaining to these categories is included for completeness but has not been calibrated. The reason this occurs is simply that the number of white and blue collar households within the city has declined faster than the number of jobs, so that the JHR was always

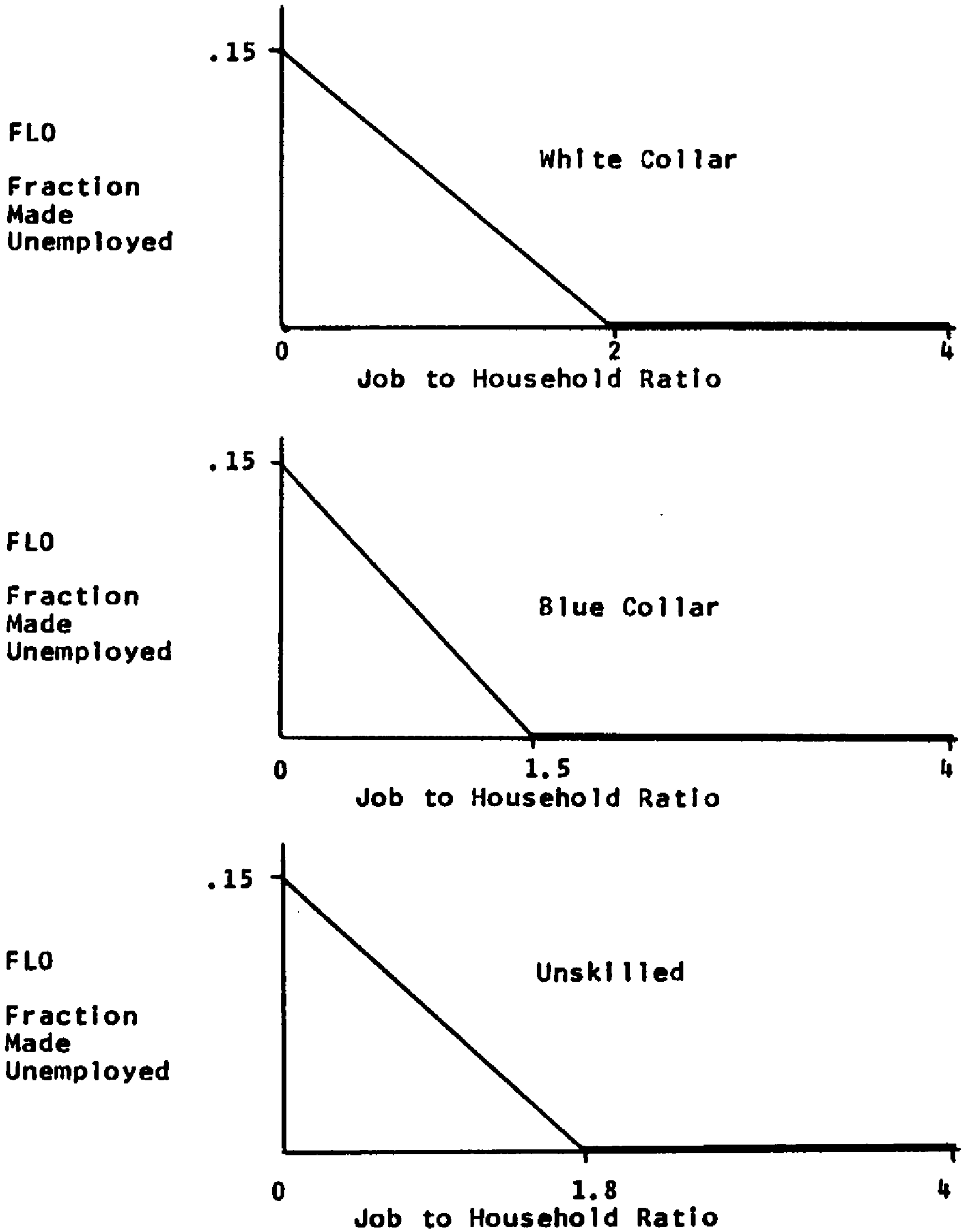

Figure 6.3 Unemployment Relationships.

above the point where unemployment would begin.

This is not the case with unskilled workers. Their numbers have increased and their job opportunities have decreased. Moreover, their low spatial mobility means that job opportunities in the suburbs are largely inaccessible. Thus these people tend to become chronically unemployed.

In order to determine the number of households each year which move from unskilled to unemployed, it is necessary to multiply the fraction unemployed (FLO) for unskilled workers by the number of households in the unskilled (white and black) category. This yields the number of households losing jobs (NLO). However, a data analysis revealed that this computation resulted in too large a number of white workers and too small a number of black workers becoming unemployed. For whatever reasons, the number of white workers losing jobs was roughly 0.4 times the expected number, and the number of black workers 1.7 times the expected number. Thus these figures have been used in the computation of the number losing jobs (NLO).

The number becoming unemployed is translated into an eight element vector which becomes the state variable WCH. In this variable those households losing jobs are subtracted from the unskilled category and added to the unemployed.

Calibration. As previously stated, the WCHG algorithm was never used for white or blue collar workers, so those relationships are purely arbitrary.

The calibration for the unskilled workers, besides the racial correction just described, involved only the setting of the intercept in the relationship between the job to household ratio (JHR) and the fraction losing jobs (FLO). This was done by adjusting the intercept until the aggregate unemployment levels corresponded with those in the data.

Jobs

The jobs (JOBS) calling program has the sole function of calling the other algorithms of the job sector. No computations are performed in this program.

Overall Calibration

The calibration of the job sector is performed directly on the JOB state variable and indirectly on the WCH state variable. That is, employment data to determine the number of job opportunities in Newark is directly available. However, there is no data on the number of households becoming unemployed, only on the number of unemployed households. This number does not include those who have out-migrated, but does include those who have in-migrated. The situation is not unlike trying to adjust the size of one of several holes in a leaky bucket to obtain a certain level of water while someone else is pouring water into the bucket at a variable rate. Nevertheless, a calibration of the WCHG algorithm which generates the correct number of households was achieved, so this algorithm can be called at least partially calibrated.

The calibration of the JOB variable is achieved using job data on employment covered by state unemployment insurance, which includes most, but not all jobs. This data was expanded to total jobs using information from the Newark Division of City Planning and the Newark Chamber of Commerce and is discussed in Appendix II. A reduction of this data produced the following values which the JOB state variable should reproduce:

TABLE 6.2 JOB DATA (THOUSANDS OF JOBS)

Year	White Collar	Blue Collar	Unskilled
1950	65	50	92
1960	70	47	92
1970	75	42	83

The accuracy of this sector will be discussed in Chapter VIII, which deals with the overall calibration and the standard model run.

VII. GOVERNMENT SECTOR

Logic

The government sector of the central city model is concerned with two variables: the tax rate and the crime rate, as discussed in Chapter III. No other performance indices of municipal government functions are included. Hopefully, as more data become available, it will be possible to build a more comprehensive model of the municipal government process. Indeed, more complete models of governmental systems have been developed (Crecine, 1967). But the effect of the performance or non-performance of the municipal government on the other sections of the urban system is not well known. Thus this governmental model has been confined to the effects of taxes and crime, which are developed in the other sectors, and to the generation of the tax and crime rates, as carried out by this sector. The generation of the two rates divides the computations of the sector into two parts.

Tax Rate generation. The logic of the tax rate generating section is simple. The level of total municipal expenditures for a given year is developed by an algorithm called demand computation (DEMC). Another algorithm (PROP) determines the total assessed value of the housing stock and commercial and industrial space in the city. After applying correction factors for external aid and county taxes collected by the city, the property tax rate is computed by dividing the municipal expenditures by the total assessed valuation.

Crime Rate generation. The generation of the crime rate is performed by an algorithm which uses a multiple regression analysis of demographic variables to produce the city's crime rate in crimes per year per 100,000 persons. The regression equation was developed from an analysis of data from eight northern industrial cities. (See Appendix II).

Inputs and Outputs. The state variable outputs of the government sector are the tax rate and the crime rate. The state variable inputs to the government sector are the primary outputs of the other sectors:

Housing	HSG
Households	HSD
Jobs	JOB

The exogenous inputs will be discussed under the relevant algorithms.

Algorithms

Following the above logic, four algorithms and a calling program are used in the government sector computations. These are listed below and illustrated in Figure 7.1.

Demand Computer	DEMC
Property Evaluator	PROP

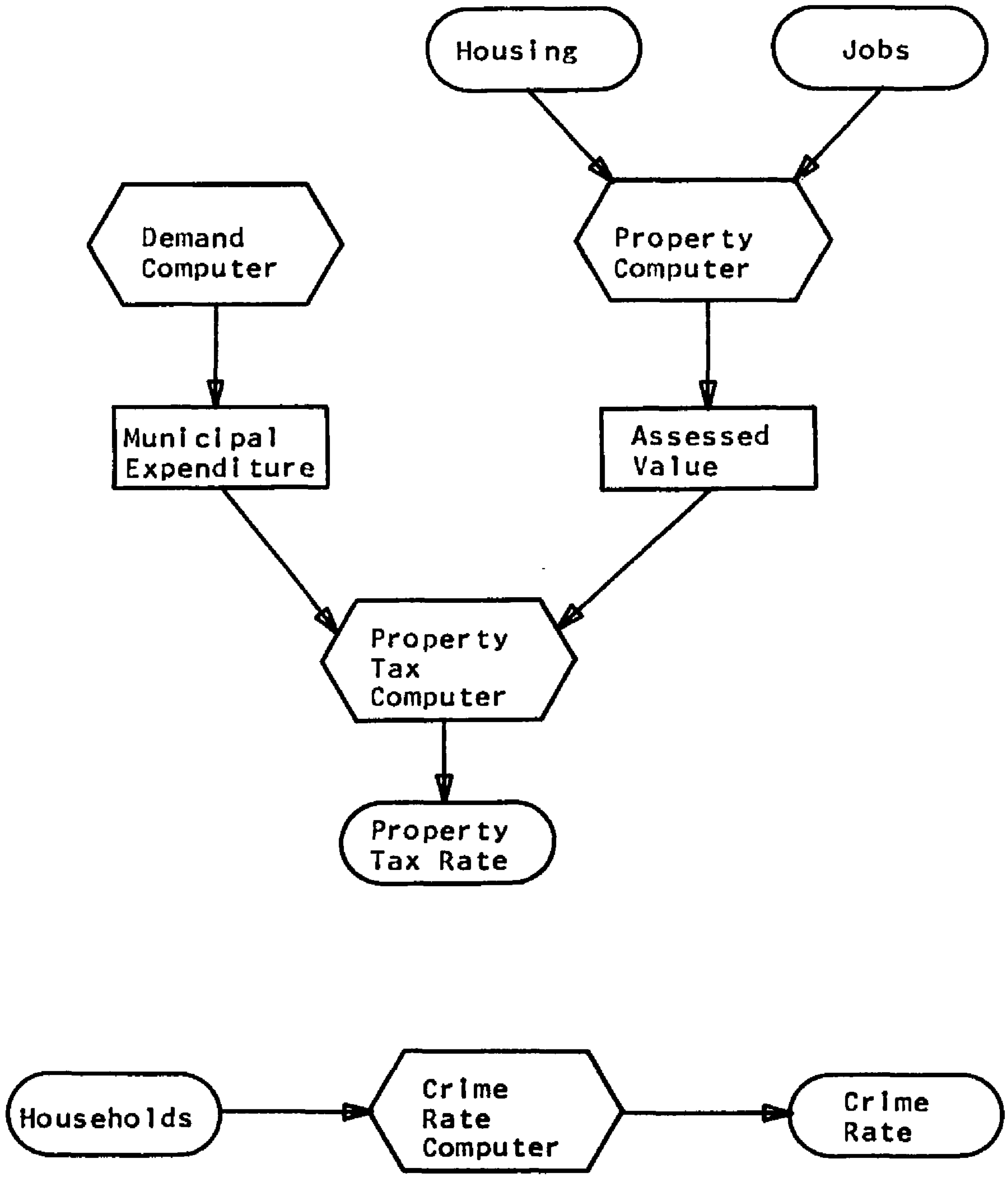

Figure 7.1 Government Sector

Property Tax Computer	PRTX
Crime Computer	CRIM
Government (calling program)	GOVT

Demand Computer

Logic. The original goal of the Demand Computer (DEMC) was to have been a predictive equation which would yield an estimate of a city's total municipal expenditures (TEX) per year based on various socio-economic variables such as population, percentage of black population, number of school children, unemployment rate, etc. In fact a multiple linear regression analysis using several cities in New Jersey was performed with this goal in mind. The idea was to use an ensemble of data from different cities with different conditions to develop the equation, and then to use the equation to predict the municipal expenditures of Newark from 1950 to 1990. This reasoning would work if municipal expenditures were a stationary process, that is, if the same conditions produced the same expenditures at different points in time (after correcting for inflation, of course). Such is not the case. Figure 7.2 depicts Newark's municipal expenditures (in constant 1967 dollars) from 1950 to 1970. During this period the city did not grow. Its population in 1970 was 57,000 less than in 1950.

As Figure 7.2 shows, for this 20 year period the municipal budget, in non-inflated dollars, rose 3.8 percent per year. An algorithm attempting to correlate this

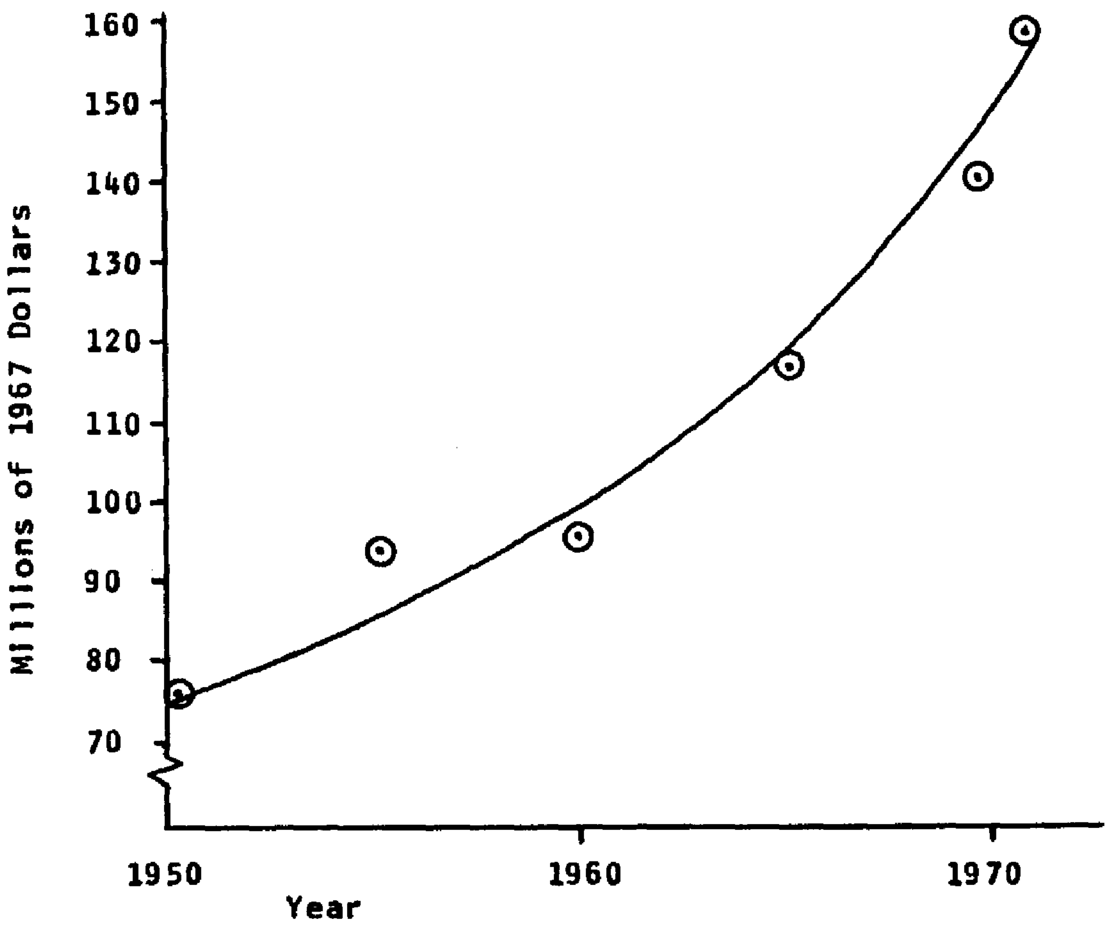

Figure 7.2 Newark's Municipal Expenditures

increase with a performance index for municipal services or with socio-economic variables was found to be unsuccessful.

With what can these rises in expenditures be correlated? Downs (1968, pp. 1331-1378) points out that rises in government expenditures are due mainly to the real salary increases of service workers; increases which are not accompanied by rises in productivity. These pay increases, characteristic of all service workers, come about because service workers demand pay parity with their counterparts in manufacturing, whose wage increases, after inflation, are somehow tied to increased productivity. No such productivity increase occurs for the service workers of municipal government.

The one variable, then, which seems to correlate with Newark's total municipal expenditures is time, so the DEMC algorithm uses a standard interest formula for the computation of municipal expenditures.

Mathematics. The output of the DEMC algorithm is the total municipal expenditure level (TEX), which is found by the following equation:

$$TEX = (75 \times 10^6) \times 1.038^I$$

This is the 75 million dollar 1950 budget compounded yearly at 3.8% per year. (I is the yearly index.) In effect this formulation makes TEX an exogenous quantity, but its generation has been included in the government sector in case a better formulation is found.

Calibration. Since the formula for TEX was derived from data, it is already calibrated for 1950 to 1970. However, the validity of projecting such a rise into the future is certainly open to question. But in a simulation algorithms can be changed. If the simulation results are absurd changes can be made and the effects of those changes determined. The 3.8 percent rise each year, however, appears to fit the data, and is included in the "standard" formulation of the model. Where this leads will be discussed in the next chapter.

Property Evaluator

Logic. The job of the Property Evaluator (PROP) algorithm is to find the total assessed value (TAV) of all residential and commercial property in the city. The assessed value of residential property is easily determined. The number of the different types of housing units (HSG) is known, as is the assessed value of each (AV). Multiplying these two vectors and summing yields the assessed value of residential property (AVR).

The assessed value of commercial property is somewhat more difficult, since without a detailed investigation of tax roles, nothing is known about the number of commercial or industrial firms, the size of their buildings, or their total floor space. What is known is the total number of jobs in the city, and if the assumption is made that each worker takes up an average amount of commercial floor space and that commercial space is valued at some average rate, the assessed value of commercial space (AVC) can be related to the total number of workers. Summing the commercial and residential assessed values yields the desired total assessed value (TAV).

Mathematics. The residential assessed value (AVR) is found by multiplying the current value of the housing state variable by the assessed value of each type of unit. (These are both 10 element vectors.) The sum of the resulting vector yields AVR.

$$AVR = \sum_{1}^{10} \underline{AV} \times \underline{HSG}(I)$$

The commercial assessed value (AVC) computation assumes an average assessed value per worker. Thus AVC is related directly to the total number of jobs:

$$AVC = K \times \sum_{1}^{3} JOB(I)$$

The total assessed value is the sum of AVC and AVR.

Calibration. The only calibration involves the constant K in the preceding equation. Using data on total numbers of workers, total non-residential taxes paid and tax rates, K was determined to be 1300.

Property Tax

Logic. The function of the Property Tax (PRTX) algorithm is to find the local property tax rate (TR), a state variable. At this point the total municipal expenditures (TEX) and the total assessed value (TAV) are known. There are, however, two factors, one which tends to raise the tax rate and the other to lower it.

The tax rate is raised because not all of the property taxes go to the city; some go to the county which finances, among other things, welfare. County taxes in Newark account for roughly 25% of the property tax. Thus, the tax rate will be increased by a factor of 1.33 over the rate which would be obtained if only municipal expenditures were paid for out of property tax revenues. This factor of 1.33 is supplied exogenously as the county tax factor (CTF).

The tax rate is also lowered because not all municipal revenue comes from property taxes. Some comes from other local taxes and some from state and federal aid. In New Jersey, the average fraction of revenue raised by property taxes in the large cities is about .6, and this is also supplied exogenously in a variable called property tax factor (PTF). Of course these factors would differ for different cities in different states.

The total amount of property taxes raised (TPT) is the product of the total municipal expenditures (TEX), the county tax factor (CTF), and the property tax factor (PTF). The tax rate is then the quotient of the total property taxes divided by the total assessed value. The mathematics of this algorithm are trivial, and it requires no calibration.

Crime Computer

Logic. The Crime Computer (CRIM) determines the overall city crime rate for the year in question as a function of demographic variables derived from the household state variable. (The crime rate is defined as crimes per year per 100,000 population.) The equation which performs this computation was obtained from a multiple linear regression analysis of nine northern cities (see Appendix II) whose size ranged from less than 100,000 to nearly one million. Many explanatory variables were tried, but an equation based on total population, black population, and male unemployment rate gave the best fit with an R^2 of .88.

Mathematics. The equation used in the crime rate computation is:

Crime Rate = 1393 -(.0121 x total population)+ (.028 x black population) + (1020 x % male unemployment)

The quantities used in this equation can be found from the household state variable if several corrections are made. The total population is obtained by multiplying total households by the average household size of 3.3. Black population is obtained in the same way from total black households. The male unemployment rate obtained from data was compared to the unemployed household rate (household categories 7 and 8). The male rate was found to be one-half the unemployed household rate, since so many of the unemployed households have female heads.

Calibration. This algorithm, based on ensemble data for 1970, has inaccuracies in the early years of its operation. But during those years the crime rate was low compared to the average and thus was not important in the simulation results. In the later years when crime became significant the algorithm is more accurate and has therefore been used in this form. Of course further work is needed to produce a more accurate equation.

Results

The government sector of the model reproduces Newark's municipal tax rate and crime rate with reasonable accuracy. The difficulty lies in measuring the effects of these and other municipal government variables on the other sectors of the model. These problems have been discussed in Chapters V and VI. Needless to say, much more work needs to be done in defining the total impact of municipal government on the composite urban system. Extensions of the present work will be discussed in Chapter X.

VIII. THE STANDARD MODEL RUN

The last four chapters have discussed the logic and calibration of the four sectors which make up the central city simulation model. This chapter will discuss the "standard" run of that model, that is, the computer run which replicates the twenty years in the history of Newark from 1950 to 1970, and then projects the future of Newark until 1985.

At this point the reader must be cautioned most strongly that even though the model replicates the history of Newark fairly well, any projections made in this or the next chapter must not be regarded as definitive. The relationships used in the model algorithms are at best partially calibrated; much more work needs to be done with data from other cities before these relationships can be considered valid. Even then, when these relationships are projected beyond the range of human experience they are only justified by their logic, and logic has failed many times in dealing with complex systems.

But the reader is also cautioned against dismissing the results which follow with a wave of the hand. Even though there may be errors in calibration, the urban system, as will be shown in the next chapter, is remarkably insensitive to even major institutional changes. Thus the numerical details may be wrong and the time scale may be wrong, but the slopes of the curves are probably not wrong, and the conditions which they generate cannot be lightly dismissed.

Additional Programs

Before discussing the standard run of the model there are several additional programs used in the simulation which must be described. The listings for these programs as well as all of those described in the last four chapters are found in Appendix I. The programs described here deal with the initiation, control, and output of the simulation.

Initiation. The program INIT is used to begin the simulation when starting from Year 1 (1950), and has four functions. First, it sets up the state variables as vectors or matrices. This is similar to a Dimension statement in Fortran. Second, it stores the state variable data for 1950 as Year 1 of the simulation. (The simulation, being iterative, always needs a previous year's state variable to operate.) Third, it establishes the initial values of those exogenous variables which change with time. Fourth, it establishes values for the fixed exogenous quantities required by the simulation. This program is only used if the simulation is to begin in 1950.

Control Program. The program CITY is the master calling program for the simulation. It is the program which increments the value of I, the time variable, calls the sector calling programs and the exogenous variable program, reports on progress, and terminates the simulation after 40 years.

Exogenous Variables. The program EXOG computes the values of the time dependent exogenous variables for each year of the simulation. It is executed by CITY before the sector calling programs, and is constructed so that the values of the exogenous variables depend only on the value of I, not on how many times EXOG has been executed. This feature allows the simulation to begin at any year as long as values for the state variables have been computed up to that year. For example, once the state variable values for 1950 to 1970 are computed using the "standard" run and it is desired to change some relationships or institute some new program in 1971 to determine the future effect, it is unnecessary to run the simulation from 1950 to 1970 again. The program changes are made, I is set to 21, and CITY is run from 1971 until the desired year.

Intermediate Output. The program REPT is called by CITY at five year intervals and is used for diagnostic and informative purposes. First, the year is indicated (i.e., YEAR 20). The year number refers to the number of years from 1950. Then the program produces the current values of the variables listed in Table 8.1, all of which have been discussed in the chapters dealing with the individual sectors.

TABLE 8.1 REPT OUTPUT

Housing Sector	
Housing State Variable and Total	HSG
Unused Supply Vector	US
Unmet Demand Vector	UD
Change in Housing from Racial Effects	CHS
Change in Housing from Abandonment	CHA
New Units Built	NUB
Welfare Housing	WFH
Household Sector	
Household State Variable and Total	HSD
Household (Racial) Migration Effects	HME
Job Migration Effects	JME
Crowding Migration Effects	CME
Government Migration Effects	GME
In-Migration	NMI
Out-Migration	NMO
Household Income and Average	INC
Household Dissolutions	HDR
New Households	NHD
Worker Changes State Variable	WCH
Job Sector	
Job State Variable and Total	JOB
Worker-Job Function Vector	WJF
Government Factor	GF
Net Job Change	BJC
Government Sector	
Total Assessed Value	TAV
Total Municipal Expenditure	TEX
Tax Rate State Variable	TR
Crime Rate State Variable	CR
Normal Crime Rate	CRN

In all of the variable outputs, the REPT program gives the variable name followed by the elements of the variable if the variable is a vector, or a single number if the variable is a scalar. The state variables printed out are the values for the year indicated, and the intermediate variable values are those used during the computations for the indicated year. All variables are printed in the order in which they were defined. For example, a typical output on the job line is:

JOBS 75982 43419 84594 TOTAL 203995

The interpretation is that, for the year specified, there were 75982 white collar jobs, 43419 blue collar jobs, and 84594 unskilled jobs, for a total of 203995. Variables with more elements (8 or 10) may print on two lines if they cannot fit on one line. (The output width has been adjusted to fit on eight inch wide paper.) In this case the elements of the vector are simply continued in order.

A typical output of REPT is shown in Figure 8.1. Outputs of this kind are essential in model calibration, since the moving forces of the simulation can be immediately determined by examining the values of the various coefficients.

Graphical Output. The programs PLOT and PLTS are used to display the values of state variables graphically once the simulation run has been completed. The state variable plots for the standard run are found later in this chapter. The scale value specified for the various

```
YEAR 25
HOUSING 23619  24620  19478  21567  12452  2993
      261  7000  0  8636 TOTAL 120626
UNUSED SUPPLY 0  314  0  0  0  0  0  0  0  8636
UNMET DEMAND 0  0  0  0  0  0  0  3609
CHS 0  0  0  0  0  0  0  0  0  0
CHA ¯1484  ¯195  ¯362  ¯832  ¯1060  ¯362  ¯36
      0  0  1677
NUB 0  0  0  0  0  0  0  0  0  0
WFH 6511
HOUSEHOLDS 13035  12252  6949  15689  18360
      29333  3605  16062 TOTAL 115285
HME 0.55484  1.4183  0.19581  1.4183  0.55484
      1.4183  0.55484  1.4183
JME 1.2622  1.2622  1.0605  1.0605  0.89615  0.89615
      1  1
CME 1  1  1  1  1  1  1  0.73
GME 0.72764  0.72764  0.72764  0.72764  0.85305
      0.85305  0.85305  0.85305
NMI 245  590  31  515  233  954  51  425
NMO ¯1098  ¯404  ¯1269  ¯396  ¯893  ¯558  ¯176
      ¯306
INC 11607  10156  8705  8705  5129  5129  2265
      2265 AVERAGE 6610
HDR ¯431  ¯307  ¯230  ¯393  ¯606  ¯880  ¯119
      ¯482
NHD 224  466  188  644  397  1136  21  438
WCH 0  0  0  0  ¯102  ¯655  81  523
JOBS 77096  38063  77923 TOTAL 193082
WJF 0.914  0.94356  1.0521
GF 0.56213
BJC ¯865  ¯1332  ¯2176
GOVERNMENT  TAV 1153528600  TEX 75000000
TAX RATE 12.351
CRIME RATE 11796 NORMAL 3400
```

Figure 8.1 Typical REPT Output

indicators is always the maximum value of the variable which would fit on the graph.

The PLOT function was designed to plot up to ten variables on one set of axes, but the graphs become too confusing if more than four or five are plotted at once, so the Housing and Household state variables are each plotted on two graphs.

The Standard Run

Calibration. Calibration, in the case of this model, means entering the data for 1950 by means of the INIT program, running the simulation, and obtaining simulation results for 1960 and 1970 which are to be matched with the data for those years for the Housing, Household, Job, Tax Rate and Crime Rate state variables. This match was achieved only after numerous runs of the simulation in which discrepancies were noted and adjustments made in the appropriate algorithms. For example, in calibrating migrating households, the four influences of race, job availability, crowding, and government effects had to be considered. The job and crowding effects were relatively unimportant, since their attractiveness factors remained close to unity. The changes in the household variable were thus the result of the racial and government factors. Since these factors differed for different cross sections of the eight household categories, manipulation of the graphical relationships which generate the attractiveness factors produced the best fit in all eight categories. Similar manipulation of other relationships was used to fit the other state variable values to the data.

There were no hard and fast criteria which determined when the variables were in agreement. Generally the refining of the model stopped when values of the state variables agreed to the nearest thousand (housing units, jobs, households) or when errors were under 5%. There is little point in further refinement since much of the data is itself estimated (See Appendix II). Improvements from this point on should be directed toward broadening the scope of calibration through background studies and work with data from other cities. (See Suggestions for Further Work, Chapter 10).

Results of the Standard Run. The results of the standard run are shown in the graphs of the important state variables (Figures 8.2 to 8.7). The results from 1950 to 1970 are more accurate than can be shown on a computer generated graph of this resolution, so the tabular results have been included in Appendix I. The graph, however, is much easier to comprehend quickly. The only caution to be observed is that the scale factors for several items plotted on one graph may not be the same, due to the automatic scaling provision of PLOT.

The graph of high cost housing shown in Figure 8.2 includes both owner occupied housing and rental units with rents above eighty dollars per month. From 1950 to 1970 the increase in members of rental units in these categories is due to two factors: new construction and upward shifts in the price of units as described in the UPPR algorithm. During this period there is a small but steady decline in the number of owner occupied units. During the late 60's the rising municipal costs combine with the lack of new construction and result in a steadily increasing tax rate. The effect of this on the real estate picture is to increase the already high rate of abandonment ($\sim$2% in 1970) in the mid 1970's.

Most of the low cost housing (Figure 8.3) has already been either abandoned or raised in price by 1970. Thus all private rental categories with low rents show a decline in the calibration period. The low cost housing, unless it is raised in price because of racial patterns, becomes unprofitable and is abandoned even before the tax rate becomes excessive. The increasing abandonment is reflected in the growing number of standing abandoned units, even though some abandoned units are being demolished each year. This figure does not decrease until after 1980, when few units remain which can be abandoned.

During the calibration period from 1950 to 1970, the

HIGH COST HOUSING

° = *OWNER OCCUPIED HOUSING*
Δ = *RENT* >120/*MONTH*
∇ = *RENT* 100-120/*MONTH*
○ = *RENT* 80-100/*MONTH*

THE SCALE FOR INDICATOR ° *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR ○ *IS* 40000

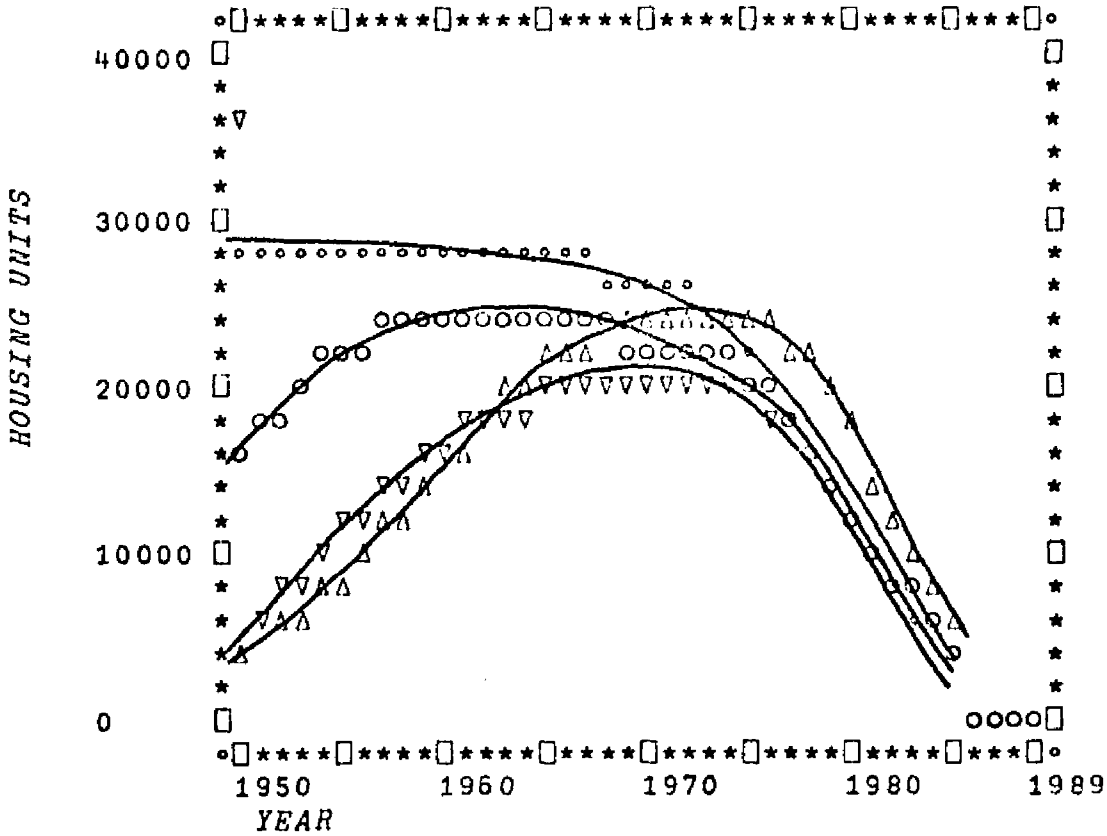

Figure 8.2 Standard Run. High Cost Housing.

LOW COST HOUSING

∘ = *RENT* 60-80/*MONTH*
Δ = *RENT* 40-60/*MONTH*
∇ = *RENT* <40/*MONTH*
○ = *STANDING ABANDONED UNITS*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Λ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR ○ *IS* 40000

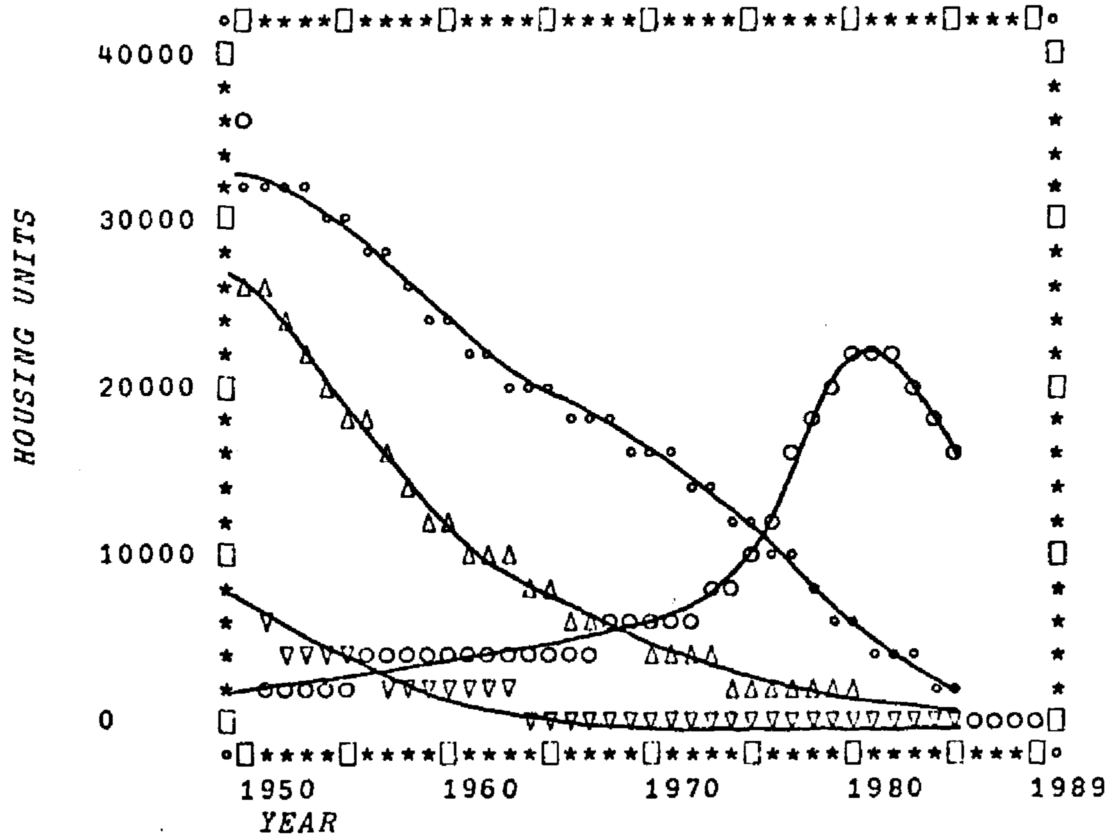

Figure 8.3 Standard Run. Low Cost Housing.

number of black households has steadily increased, as shown in Figure 8.4. During this period a black majority was building in the city. By the mid 1970's the model predicts that worsening job opportunities and high tax and crime rates reverse the increase in black households in the three upper classes. The unemployed households are kept in check only by a shortage of housing. By the 1980's enough households have fled the city so that the number of unemployed households can again increase.

Figure 8.5 appears to show a nearly linear decline in the number of white households. In reality the decline could be described as "super exponential". A fixed out-migration rate would produce an exponential decay in the affected variable. But in this case the out-migration rate is increasing, because of worsening conditions, and the curve in the exponential is straightened out, making it appear linear. An analysis of the migration effects printed out by the REPT program reveals what is really taking place.

The number of available jobs in Newark is shown in Figure 8.6. During the calibration period the number of blue collar and unskilled jobs is decreasing, as old manufacturing plants close or move to the suburbs. White collar jobs continue to increase since Newark is still an important commercial center. But as the growing tax rate

BLACK HOUSEHOLDS

∘ = *WHITE COLLAR*
Δ = *BLUE COLLAR*
∇ = *UNSKILLED*
o = *UNEMPLOYED*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR o *IS* 40000

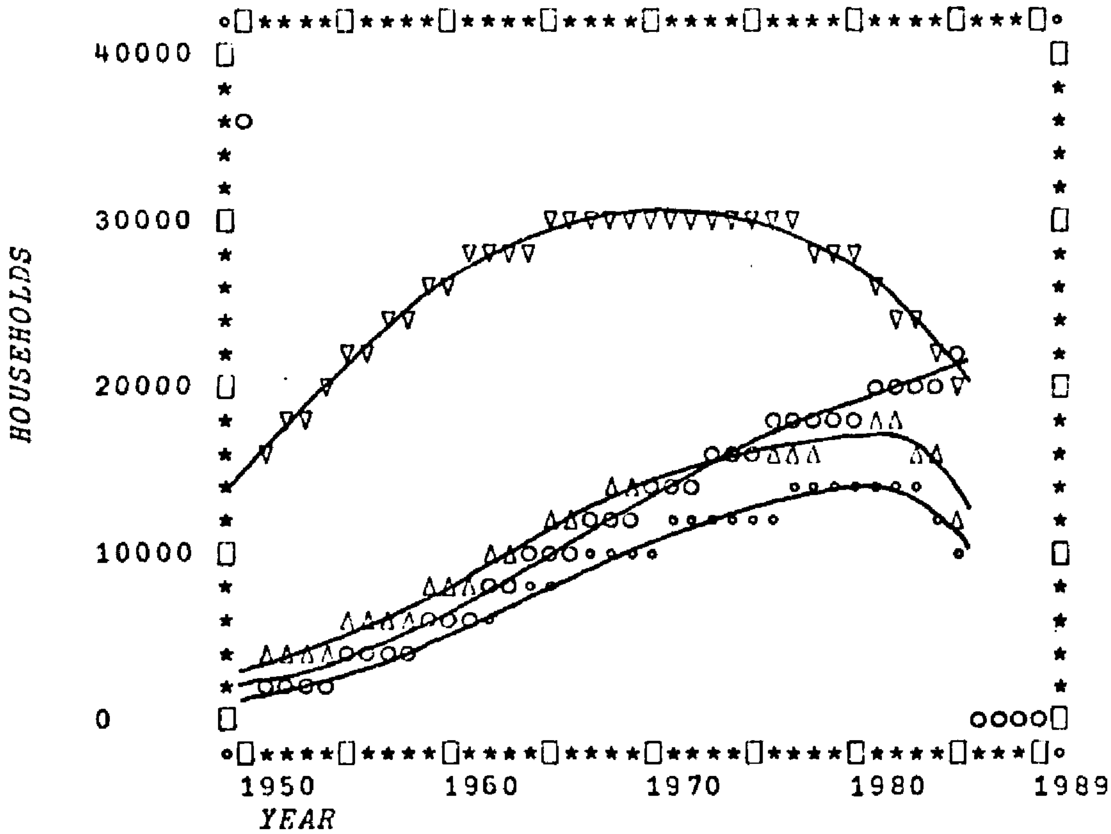

Figure 8.4 Standard Run. Black Households.

WHITE HOUSEHOLDS

∘ = *WHITE COLLAR*
Δ = *BLUE COLLAR*
∇ = *UNSKILLED*
o = *UNEMPLOYED*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR o *IS* 40000

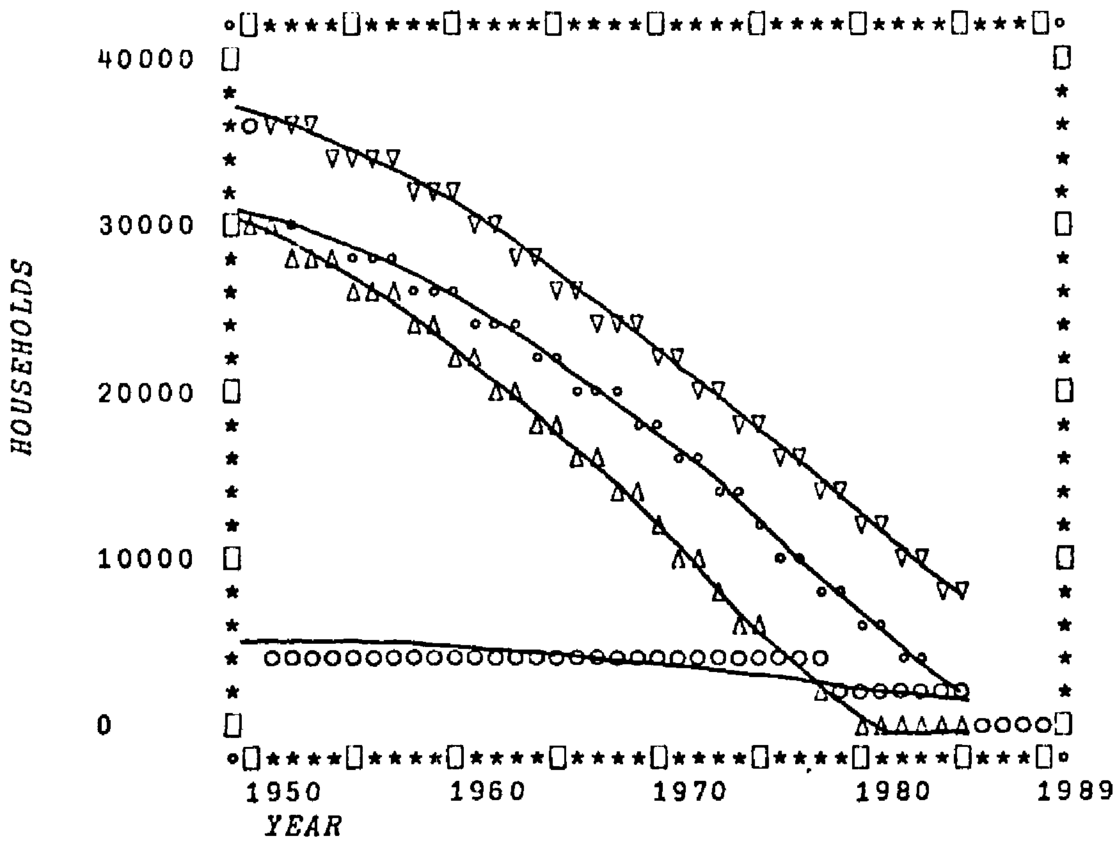

Figure 8.5 Standard Run. White Households.

JOBS

∘ = *WHITE COLLAR*
Δ = *BLUE COLLAR*
∇ = *UNSKILLED*

THE SCALE FOR INDICATOR ∘ *IS* 100000
THE SCALE FOR INDICATOR Δ *IS* 100000
THE SCALE FOR INDICATOR ∇ *IS* 100000

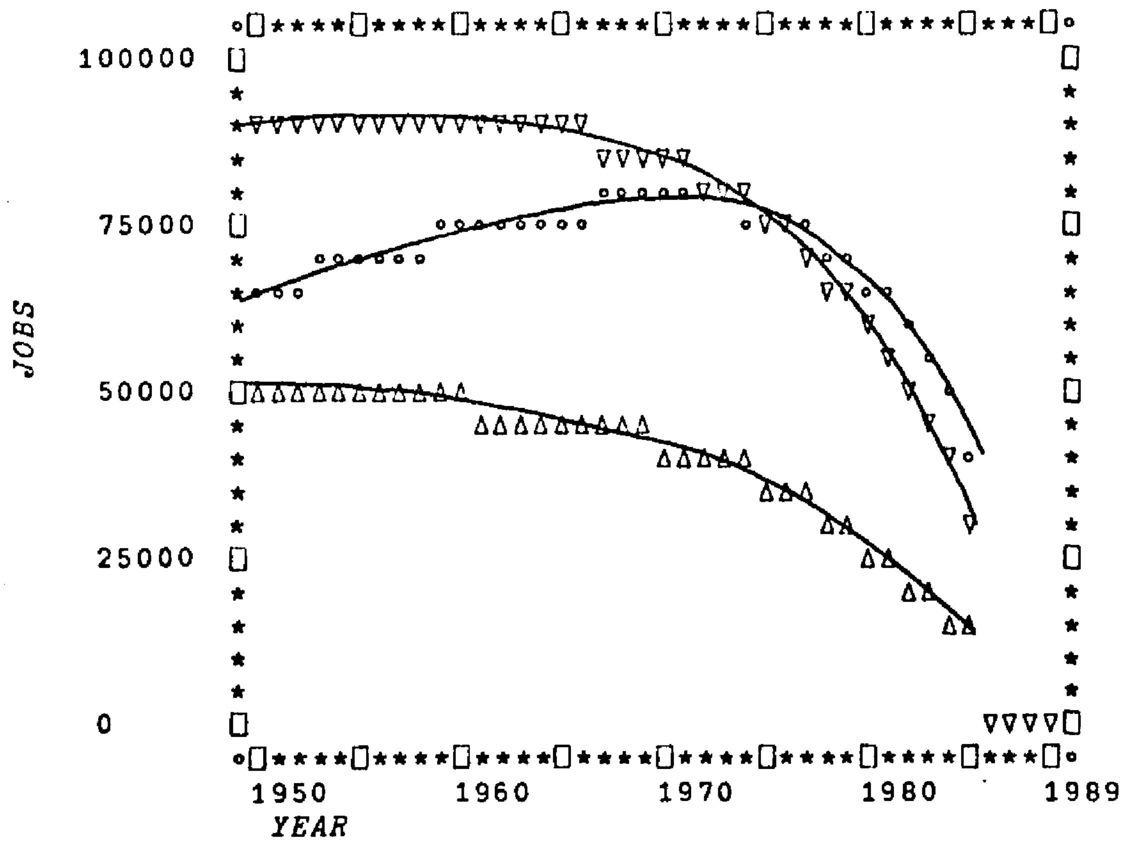

Figure 8.6 Standard Run. Jobs.

makes doing business in Newark less profitable than doing business elsewhere, and the continuing white out-migration makes skilled labor scarce in Newark, the model predicts a decline in all job categories.

Figure 8.7 reveals the reasons for the predicted disaster; the increasing crime rate, but most important, the spiraling tax rate. The tax rate is a result of a positive feedback loop with no limits. Total municipal expenditures increase 3.8% per year; the tax base decreases because of abandonment and the lack of new construction; the tax rate rises, accelerating abandonment, etc.

This ultimate result of the standard run is not meant as a prediction of the future. Its only use is to show the extreme results of the continuation of present policies. These policies must change if the city of Newark is to remain. viable. But policy changes are not built into the model, since they represent, in effect, exogenous changes in the model structure. Just as they are imposed from outside the real system, they must be imposed on the model. Then the model can continue to run to determine the effects of the proposed changes. Several possible alternatives are tested in this way in the following chapter.

One final word of caution: although the model has been partially calibrated, the emphasis must be on <u>partially</u>. There are still many untested relationships

TAX RATE AND CRIME RATE

∘ = *TAX RATE IN DOLLARS*/100
Δ = *CRIME RATE IN CRIMES*/100,000 *PEOPLE*

THE SCALE FOR INDICATOR ∘ *IS* 50
THE SCALE FOR INDICATOR Δ *IS* 20000

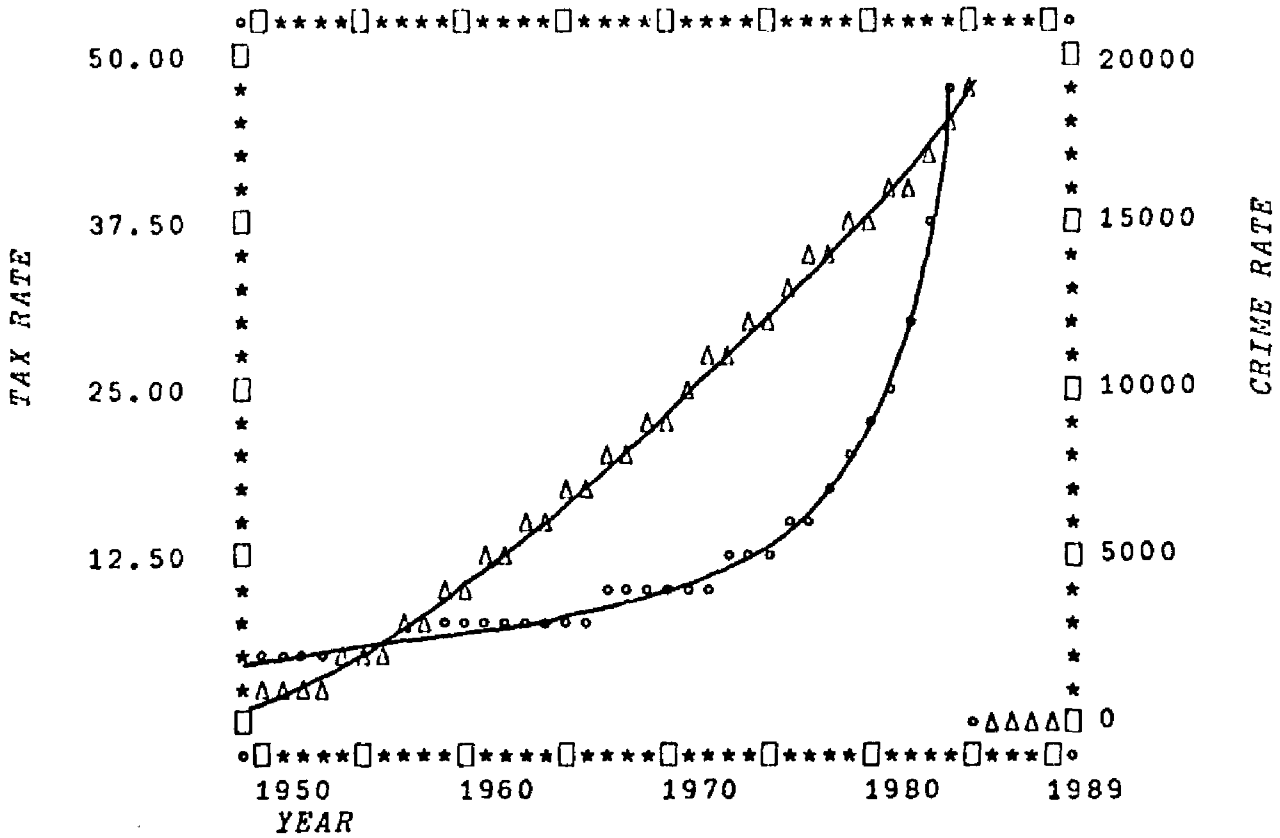

Figure 8.7 Standard Run. Tax and Crime Rates.

and assumed values which could cause significant errors, especially in predictive extrapolations. Thus, although the model represents the state of the art in urban simulation work, the predicted outcomes which it yields must still be regarded as preliminary. Yet it would be absurd to bring a model to the level of sophistication achieved here without trying to get some feeling for the magnitude of the programs which would be necessary to reverse the continuing decay of Newark. This is the purpose of the following chapter.

IX. FUTURE ALTERNATIVES

The standard run of the simulation model of Newark from 1950 to 1985 projects disastrous consequences if the present trend of governmental spending, housing abandonment, and other factors is continued. An examination of the migration coefficients for years 20, 25, 30, and 35 (Appendix I, Part G) reveals that the sensitive parameters, the parameters which most strongly affect the simulation results, are the migration coefficients relating to the effects of government, and thus to the tax rate and crime rate. (This direct observability of factor effects makes the traditional sensitivity analysis unnecessary.)

Unfortunately, the tax rate and crime rate, besides being the most sensitive parameters, are also the ones whose future projections are most in question. The tax rate is based on a municipal expenditure algorithm calling for a 3.8% increase in expenses per year, regardless of other factors. This algorithm was accurate between 1950 and 1970, but its extension to 1990 is questionable. The crime rate computation is based on a regression equation obtained from data from several cities, of which Newark already had the highest crime rate. Use of this equation to predict even higher crime rates could introduce substantial errors. Moreover, even if the tax and crime rates which are predicted are accurate, their effects, measured by the PGEN, GMEC, and GEBJ algorithms, are only logical extrapolations of effects which produced the correct values of state variables between 1950 and 1970. There is no guarantee that the effects of higher tax and crime rates might not be more or less severe than predicted.

Nonetheless, the simulation, even with these drawbacks, presents a far more realistic picture of the future than a mere guess, or a straight line extrapolation of existing conditions. It is possible to obtain not exact forecasts, but at least a reasonable idea of the magnitude of the changes which will produce desired results. This has been tested by altering the sensitive variables in a series of alternative simulations.

Goals

In the case of alternatives for the Newark simulation, there were two arbitrary goals.

1. To achieve moderate increases in the housing stock instead of wholesale abandonment.

2. To stem the outflow of jobs.

These goals were to be achieved by actions which would affect the public sector variables: taxes and crime.

Alternatives

The three alternatives tested are presented in order of increasing success. These alternatives are not to be taken as an advocacy of certain policies, but only as an indication of the magnitude of the changes which would be necessary to achieve these arbitrary goals. The three sets of graphs presented should be compared with the graphs for the "standard run," Figures 8.2 through 8.7.

Alternative 1. Municipal Budget Ceiling. In this alternative the total municipal expenditures have been held at the 1970 level of $158 million (in real dollars) after 1975. (The year 1975 was chosen as the starting point for this and other tested alternatives since no meaningful programs could be implemented before that date.) The budget could be held at this level either through economy measures or the additional funds could come from State or Federal Governments, but for the purposes of computing the property tax rate the budget would appear to have a ceiling at the 1970 level.

The results of this alternative are shown in Figures 9.1 through 9.6. No tabular output is given since a reasonable idea of the form of the state variables is obtained from the plots, and since the numbers only represent approximate projections. The graphs indicate that the disastrous decline in numbers of jobs, households and housing units predicted by the standard run is not avoided, but only postponed for several years. Even with the budget frozen at the 1970 level, the tax rate is still high enough so that jobs move elsewhere, population

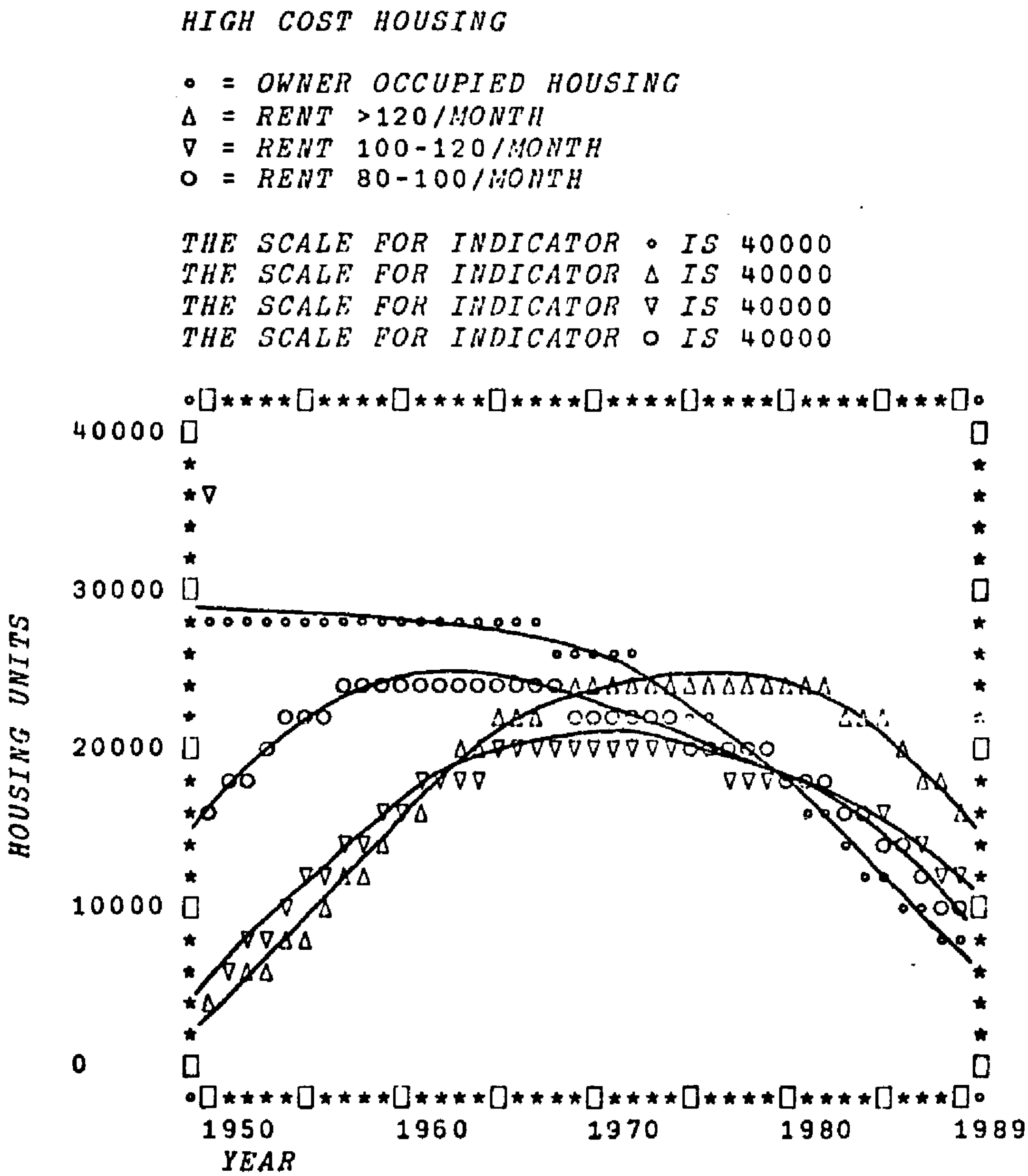

Figure 9.1 Alternative 1. High Cost Housing.

LOW COST HOUSING

∘ = *RENT* 60-80/*MONTH*
Δ = *RENT* 40-60/*MONTH*
∇ = *RENT* <40/*MONTH*
o = *STANDING ABANDONED UNITS*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR o *IS* 40000

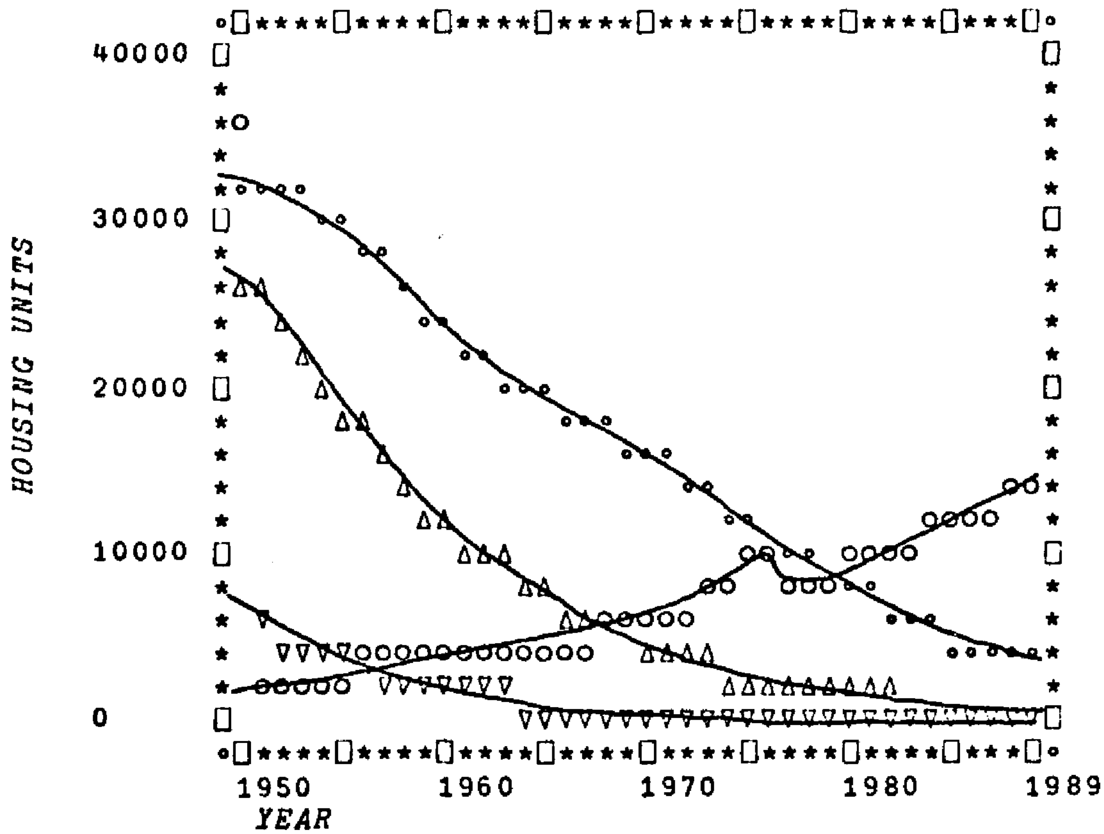

Figure 9.2 Alternative 1. Low Cost Housing.

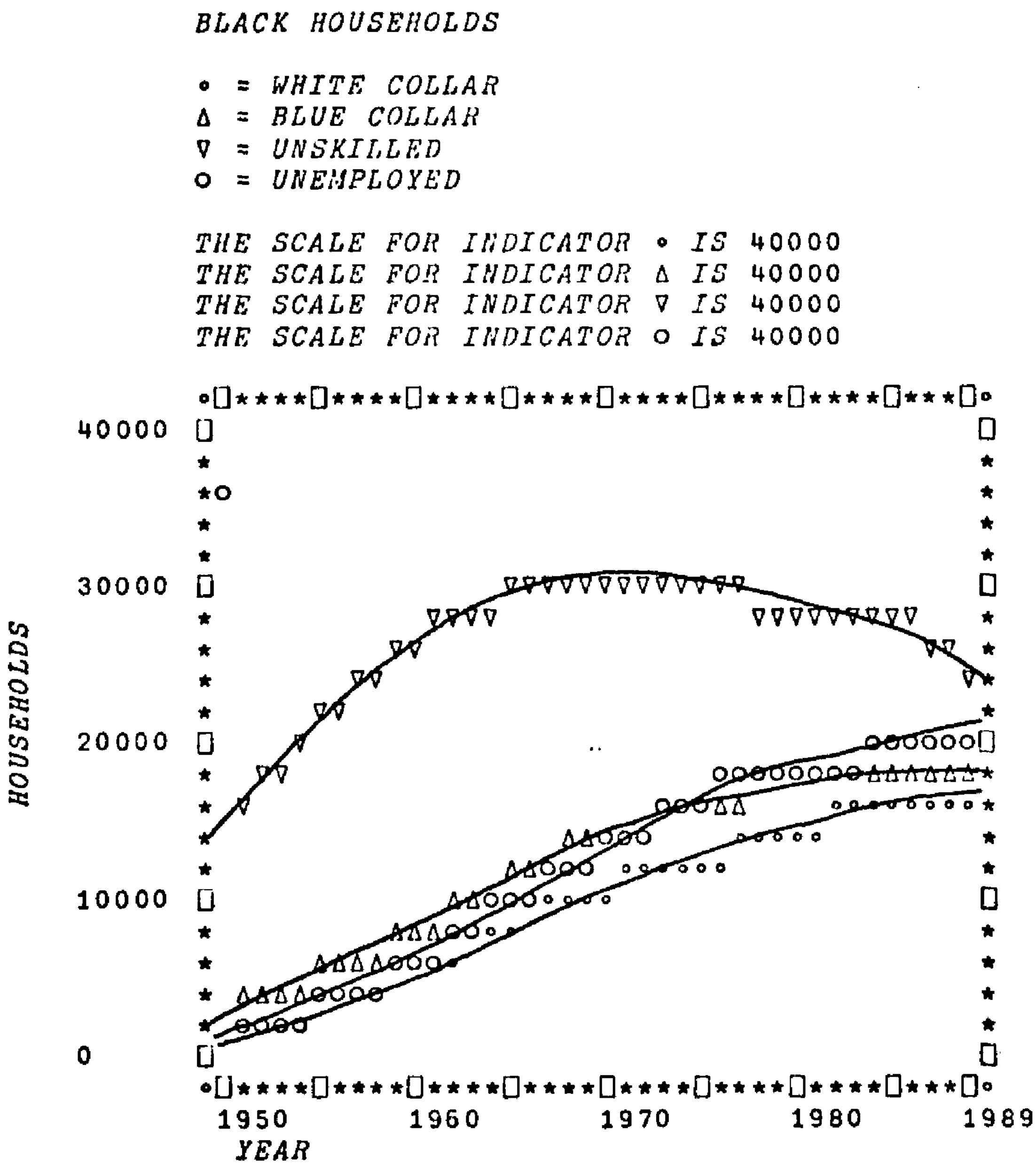

Figure 9.3 Alternative 1. Black Households.

WHITE HOUSEHOLDS

∘ = *WHITE COLLAR*
Δ = *BLUE COLLAR*
∇ = *UNSKILLED*
○ = *UNEMPLOYED*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR ○ *IS* 40000

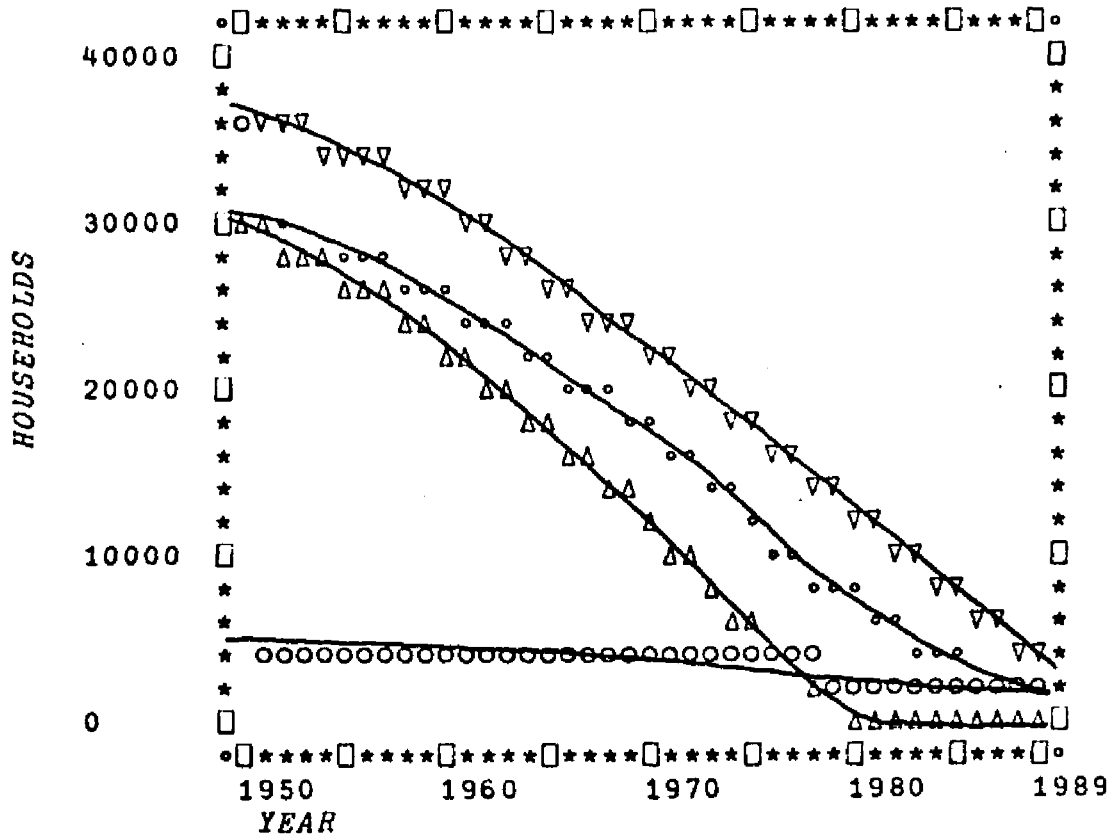

Figure 9.4 Alternative 1. White Households.

JOBS

∘ = *WHITE COLLAR*
Δ = *BLUE COLLAR*
∇ = *UNSKILLED*

THE SCALE FOR INDICATOR ∘ *IS* 100000
THE SCALE FOR INDICATOR Δ *IS* 100000
THE SCALE FOR INDICATOR ∇ *IS* 100000

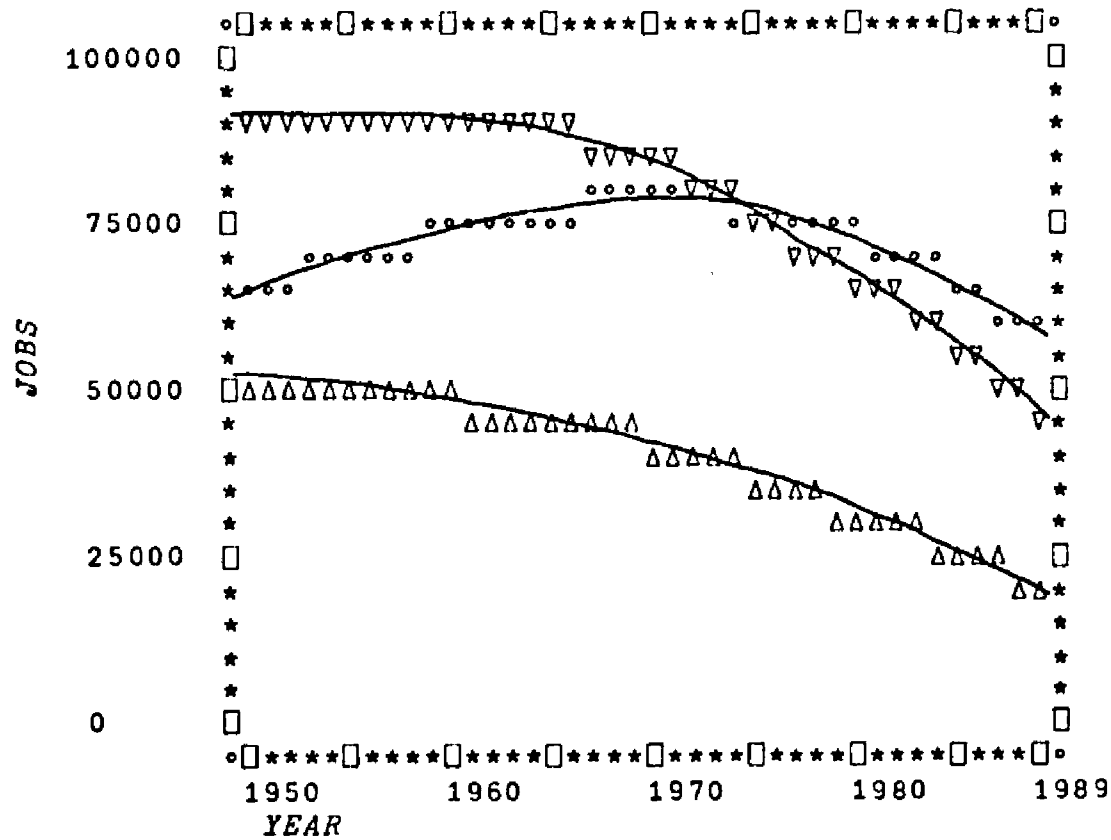

Figure 9.5 Alternative 1. Jobs.

TAX RATE AND CRIME RATE

∘ = *TAX RATE IN DOLLARS*/100
Δ = *CRIME RATE IN CRIMES*/100,000 *PEOPLE*

THE SCALE FOR INDICATOR ∘ *IS* 20
THE SCALE FOR INDICATOR Δ *IS* 20000

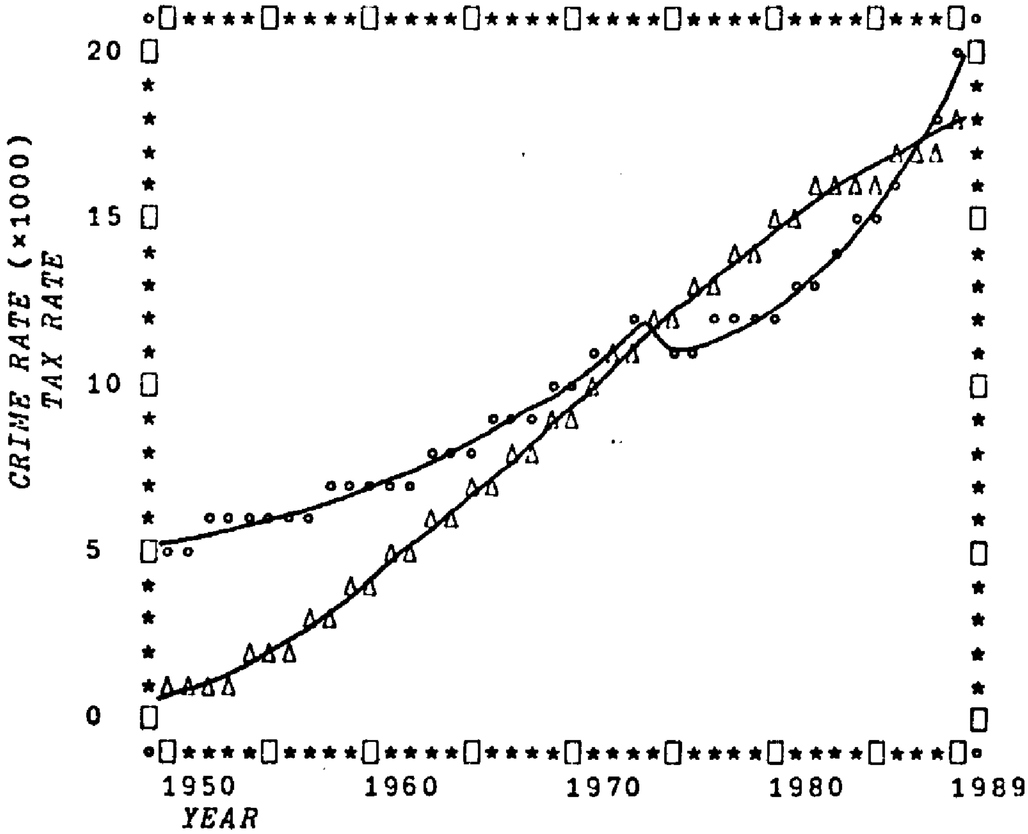

Figure 9.6 Alternative 1. Taxes and Crime.

declines, and massive housing abandonments continue to contribute to a decline in the tax base. Obviously this alternative is not significant enough to halt the spiral of decay.

Alternative 2. Municipal Budget Rollback. This alternative examines the impact of cutting back the municipal budget, for the purposes of property tax computation, to the 1950 level of $75 million. Again, this objective would have to be accomplished by a combination of economy measures and outside aid. No assertion is made that this alternative is either practical or even possible; it is simply tested in the simulation model.

The results of this alternative, shown in Figures 9.7 through 9.12, are encouraging. Because of the lowered tax rate housing construction, at least at the higher rent levels, is again profitable. The number of low cost units continues to decline, but this decline is from a normal rate of decay from fires and obsolescence. Because there is sufficient housing, the city retains its attractiveness for black households, and they continue to in-migrate, replacing the white households which continue to migrate to the suburbs. White collar jobs remain stable, but blue collar and unskilled jobs continue to decline. The total number of jobs also declines, but not significantly.

This alternative creates a condition of relative

HIGH COST HOUSING

∘ = *OWNER OCCUPIED HOUSING*
Δ = *RENT* >120/*MONTH*
∇ = *RENT* 100-120/*MONTH*
○ = *RENT* 80-100/*MONTH*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR ○ *IS* 40000

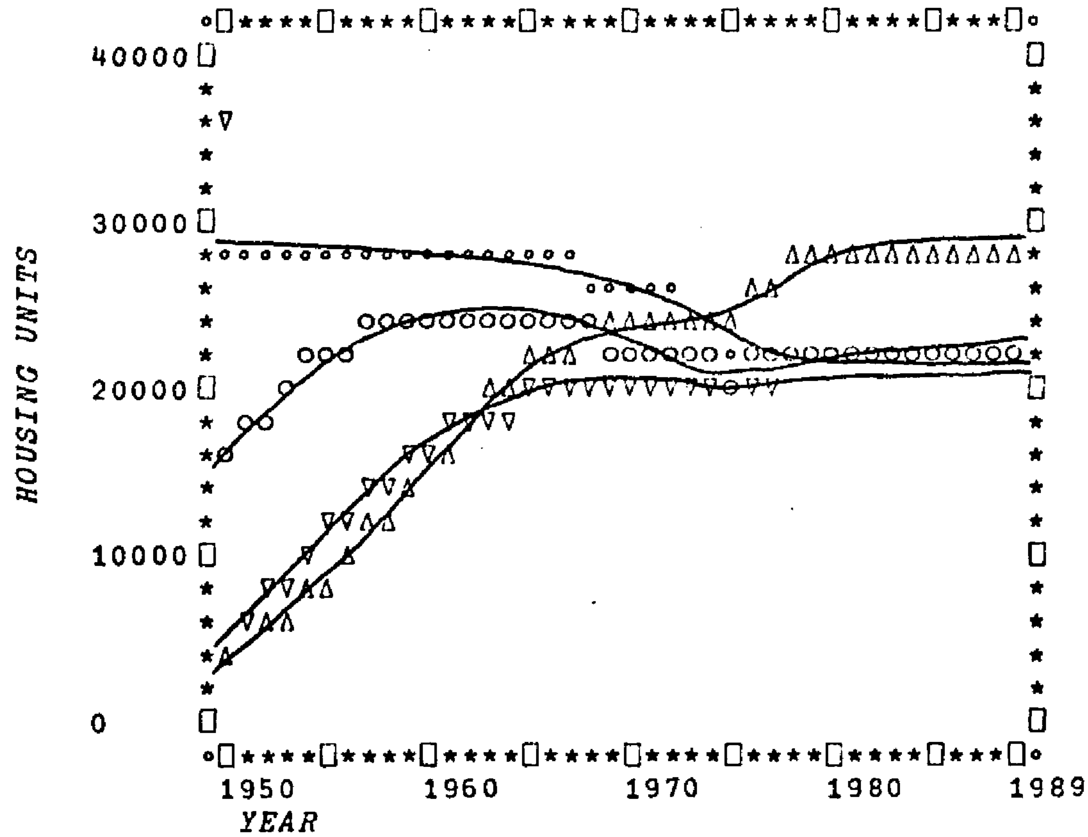

Figure 9.7 Alternative 2. High Cost Housing.

LOW COST HOUSING

∘ = *RENT* 60-80/*MONTH*
Δ = *RENT* 40-60/*MONTH*
∇ = *RENT* <40/*MONTH*
o = *STANDING ABANDONED UNITS*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR o *IS* 40000

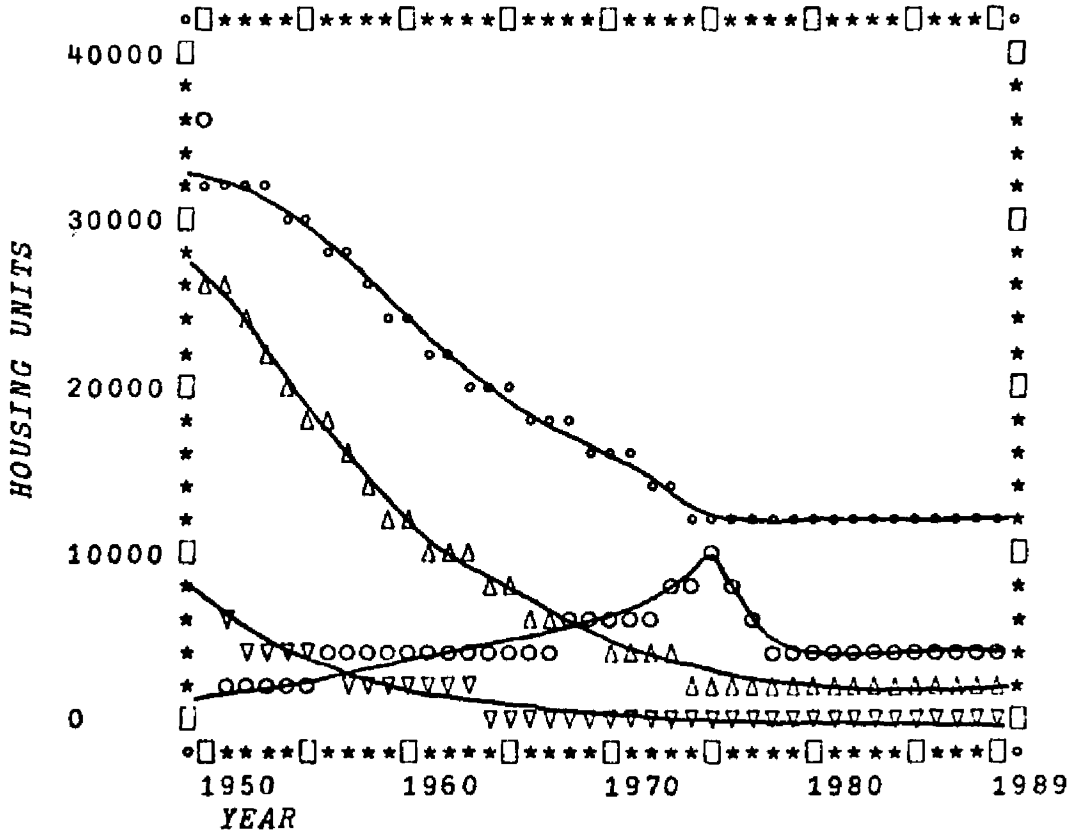

Figure 9.8 Alternative 2. Low Cost Housing.

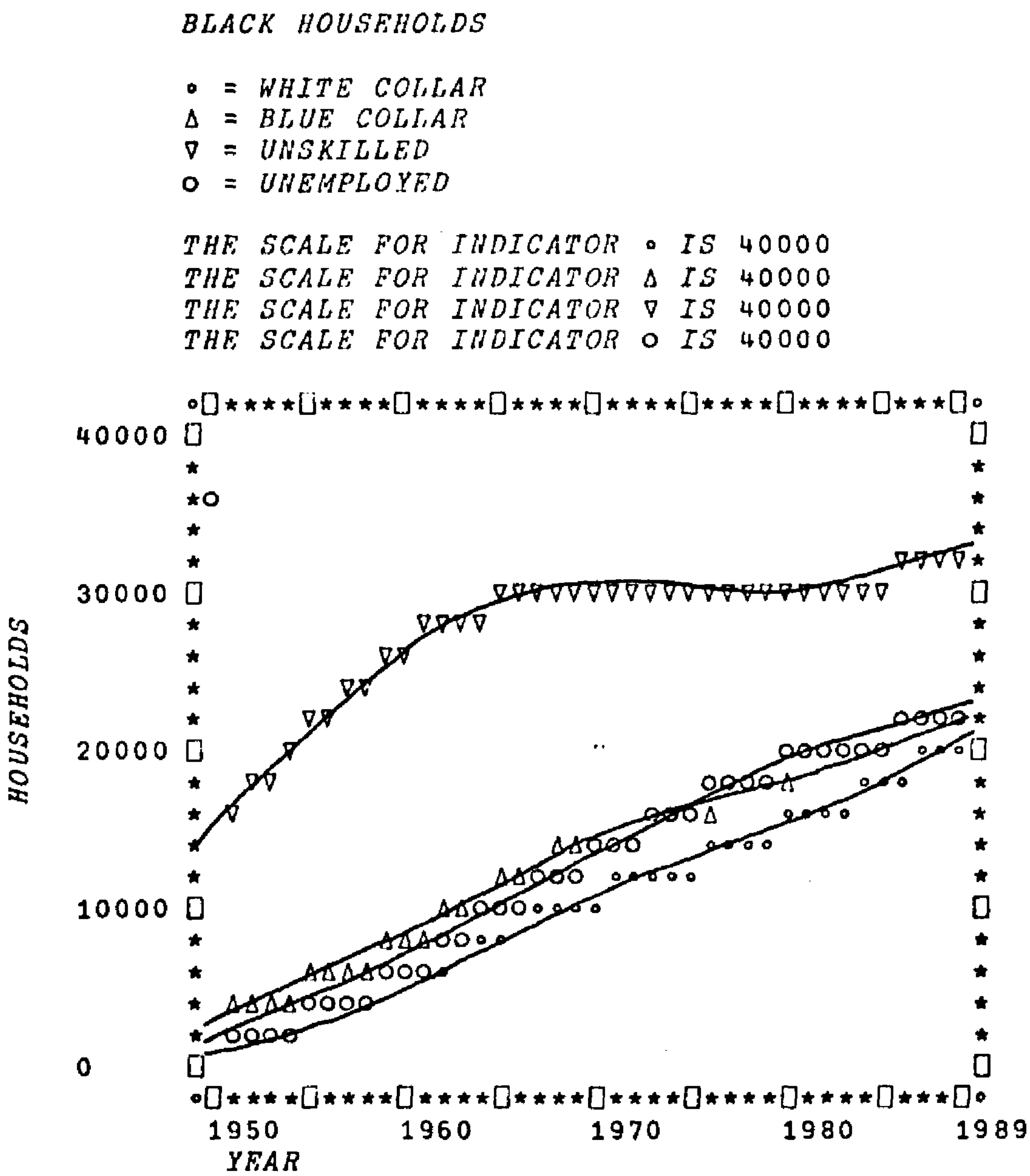

Figure 9.9 Alternative 2. Black Households.

WHITE HOUSEHOLDS

∘ = *WHITE COLLAR*
Δ = *BLUE COLLAR*
∇ = *UNSKILLED*
○ = *UNEMPLOYED*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR ○ *IS* 40000

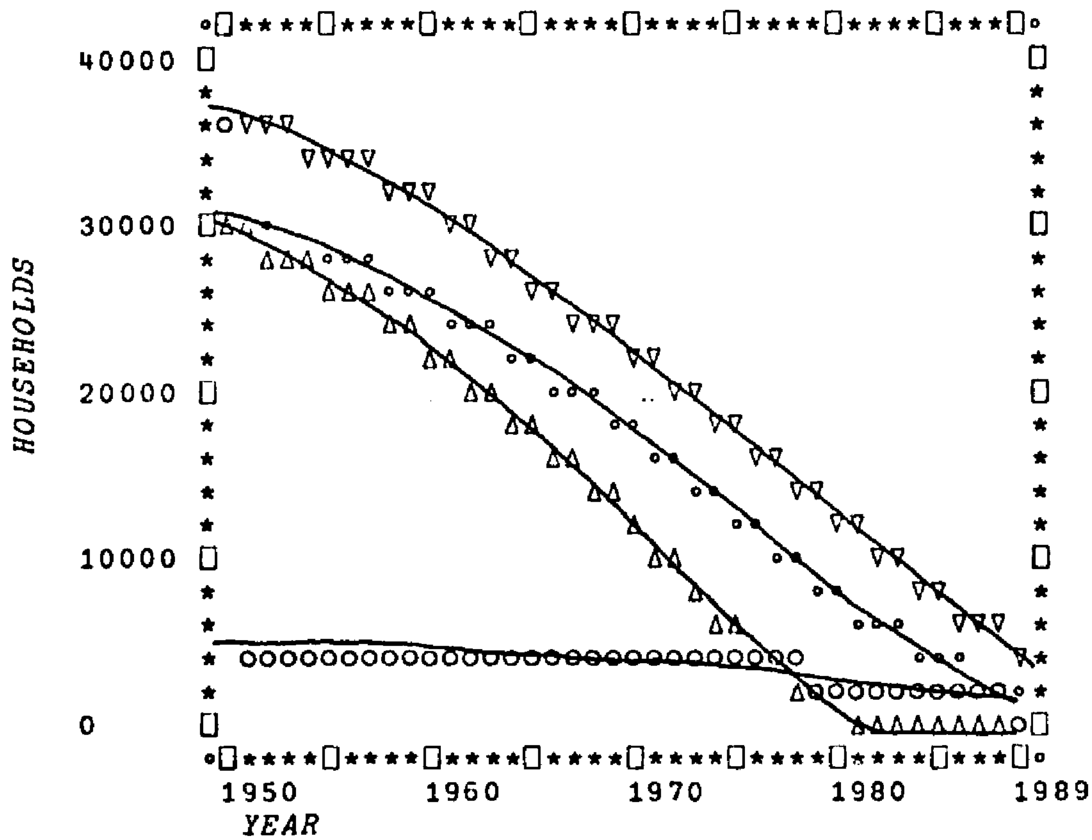

Figure 9.10 Alternative 2. White Households.

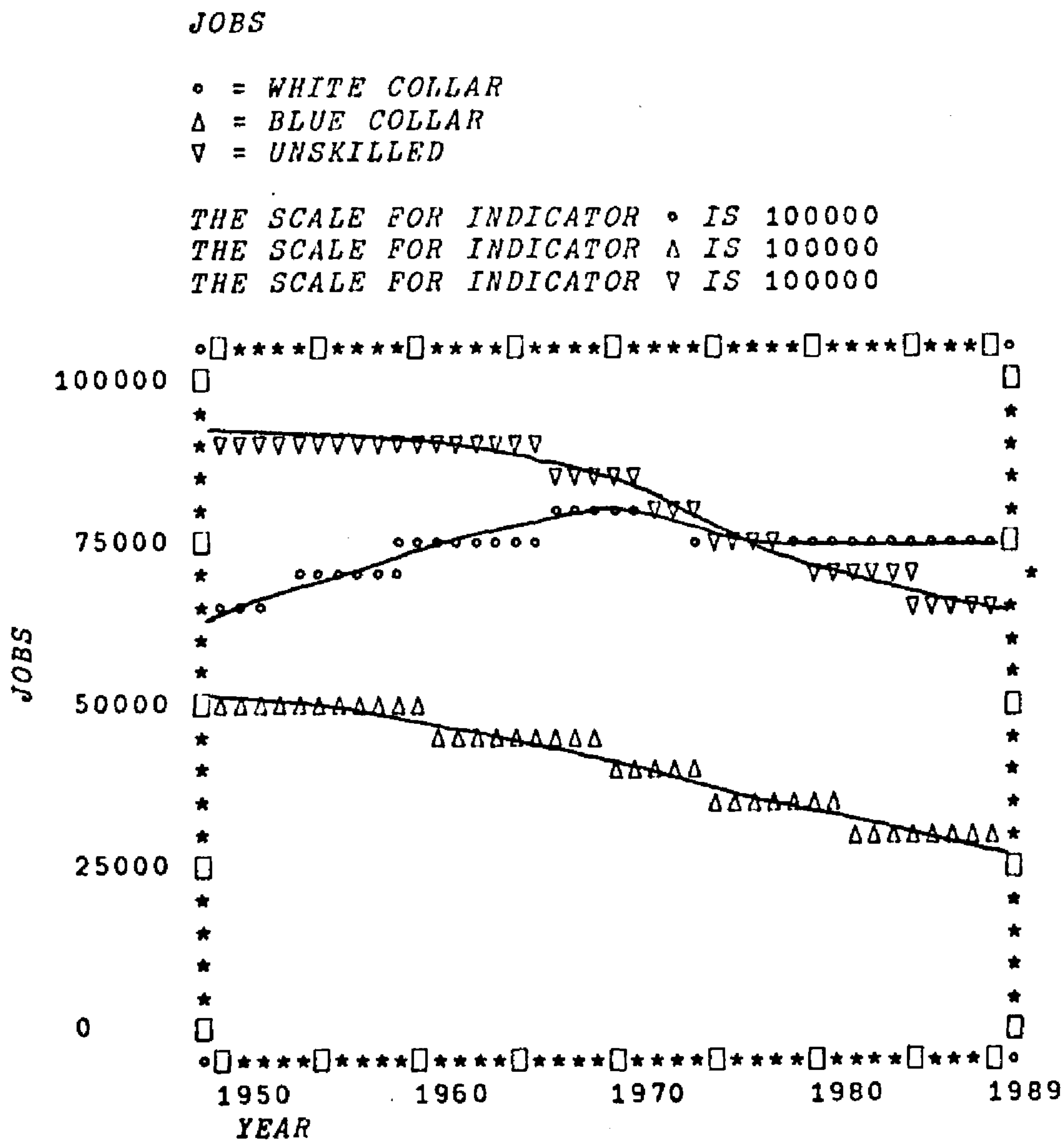

Figure 9.11 Alternative 2. Jobs.

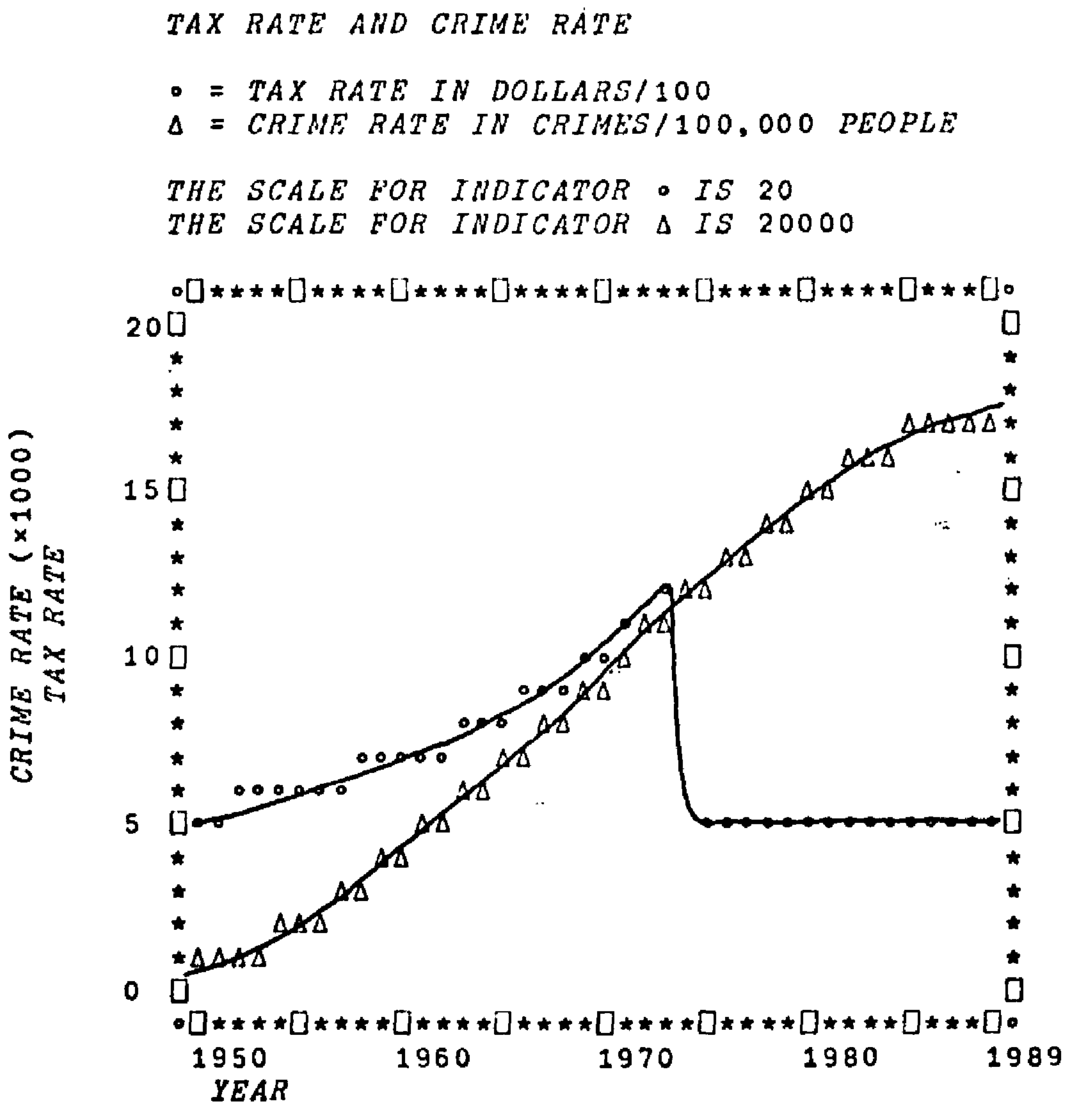

Figure 9.12 Alternative 2. Taxes and Crime.

stability. However, there are still long term effects which make that stability tenuous: the slow decline in jobs and the rising crime rate. The next alternative deals with this problem.

Alternative 3. Budget Rollback and Crime Rate Reduction. This alternative combines the budget rollback of alternative 2 with a reduction in the crime rate, starting in 1975. By some unspecified means the crime rate is cut to one-half of that predicted by the CRIM algorithm. As shown in Figure 9.13 to 9.18, this variation produces significant changes in the graphs of high cost housing, black households, jobs, and of course tax and crime rates. The effect on the construction of housing is indirect. The lowered crime rate makes the city more attractive to black households, creating a demand for more housing. This results in increased housing construction in the upper rent levels. This housing availability coupled with the increased attractiveness causes a greater in-migration of black households. The moderate job decrease of alternative 2 has been replaced by a moderate job increase in total jobs, with white collar jobs increasing and blue collar and unskilled jobs nearly stable.

This alternative appears to yield a reasonably healthy city in terms of a stable, or slightly growing number of housing units, jobs, and households.

HIGH COST HOUSING

∘ = *OWNER OCCUPIED HOUSING*
Δ = *RENT* >120/*MONTH*
∇ = *RENT* 100-120/*MONTH*
○ = *RENT* 80-100/*MONTH*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR ○ *IS* 40000

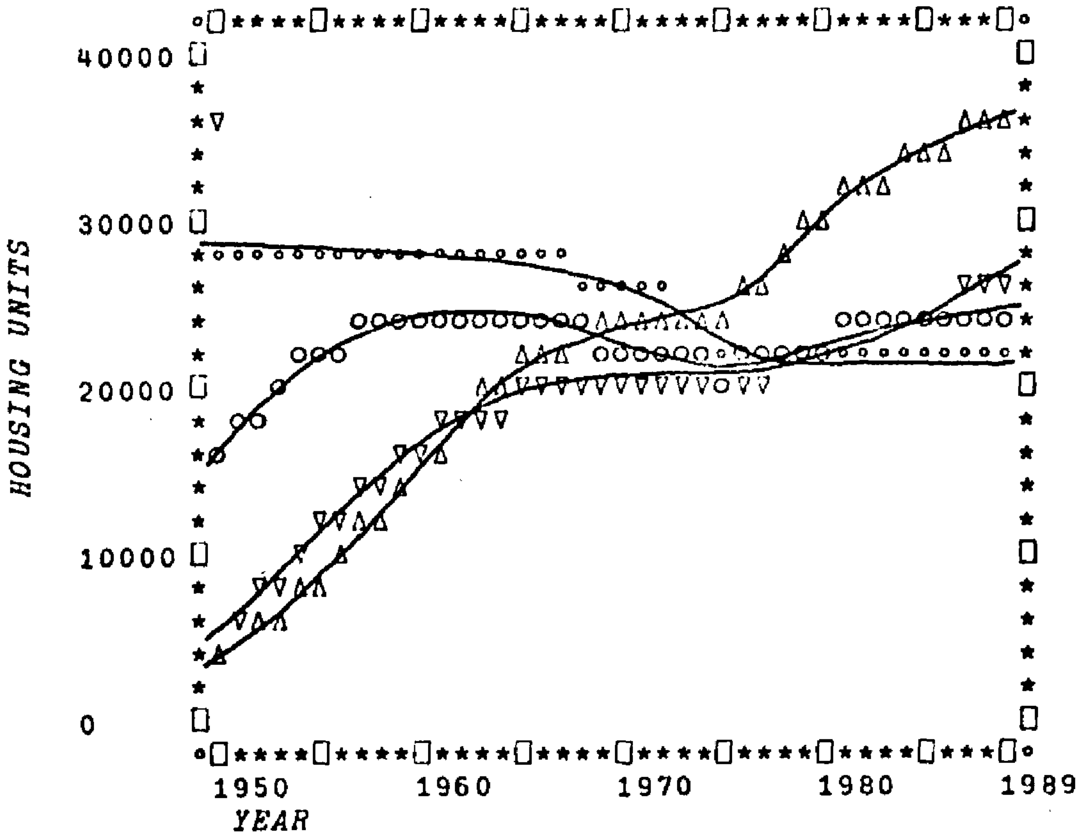

Figure 9.13 Alternative 3. High Cost Housing.

LOW COST HOUSING

∘ = *RENT* 60-80/*MONTH*
Δ = *RENT* 40-60/*MONTH*
∇ = *RENT* <40/*MONTH*
○ = *STANDING ABANDONED UNITS*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR ○ *IS* 40000

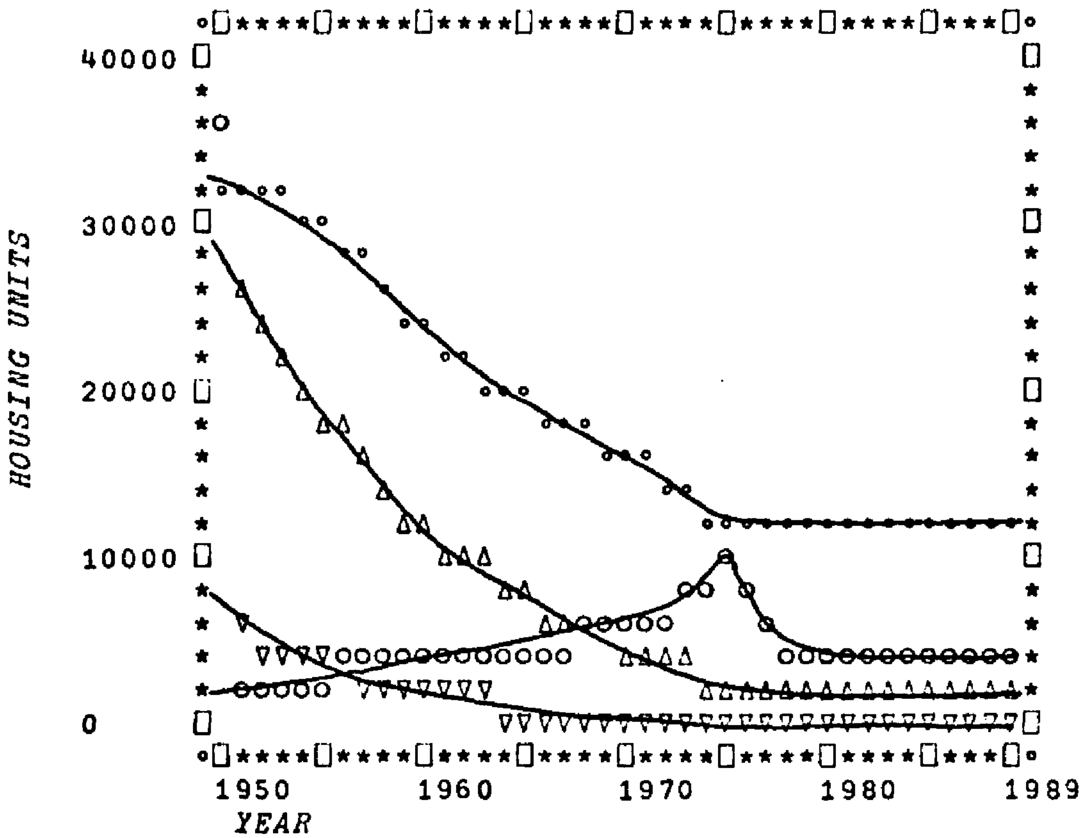

Figure 9.14 Alternative 3. Low Cost Housing.

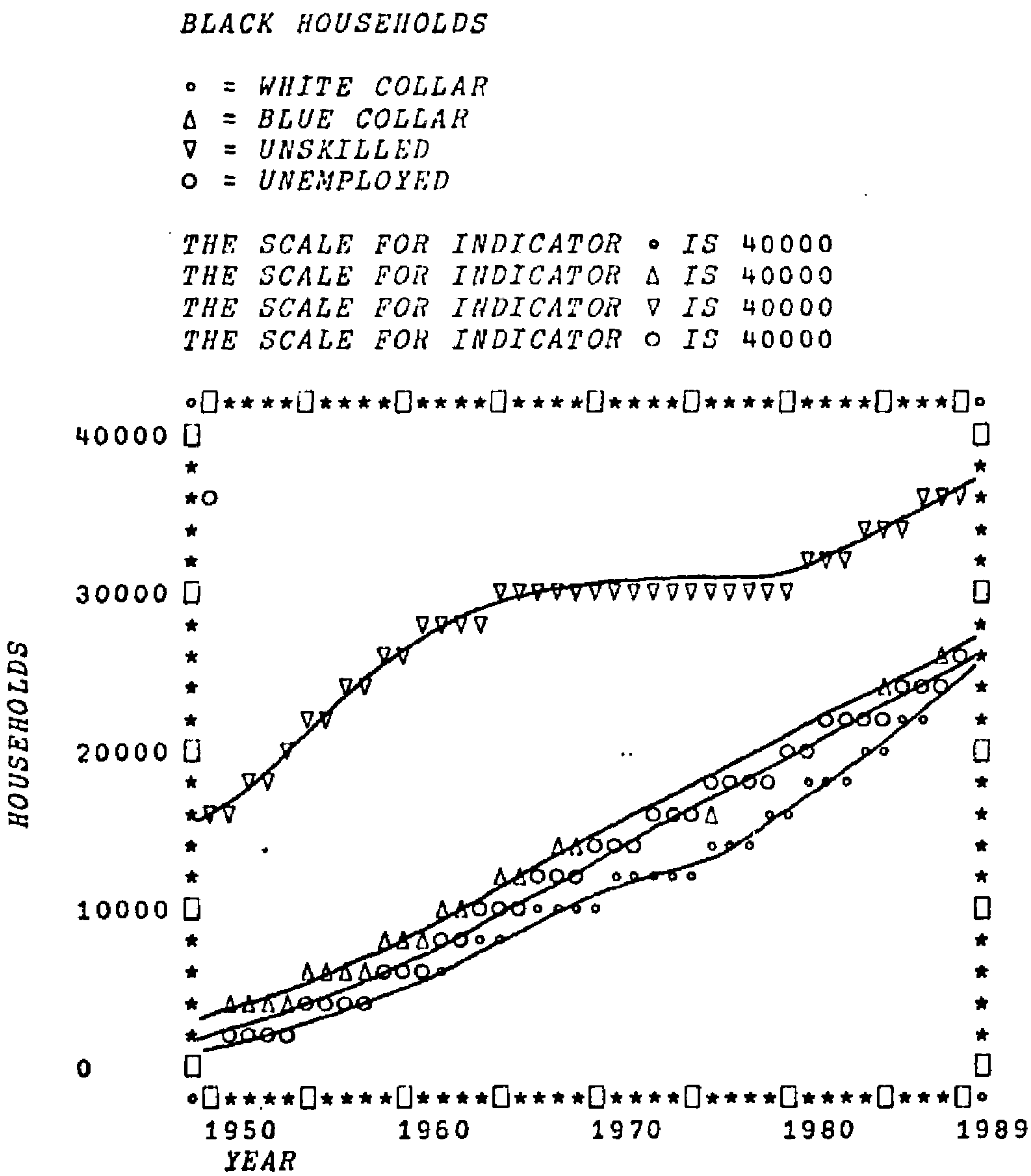

Figure 9.15 Alternative 3. Black Households.

WHITE HOUSEHOLDS

∘ = *WHITE COLLAR*
Δ = *BLUE COLLAR*
∇ = *UNSKILLED*
○ = *UNEMPLOYED*

THE SCALE FOR INDICATOR ∘ *IS* 40000
THE SCALE FOR INDICATOR Δ *IS* 40000
THE SCALE FOR INDICATOR ∇ *IS* 40000
THE SCALE FOR INDICATOR ○ *IS* 40000

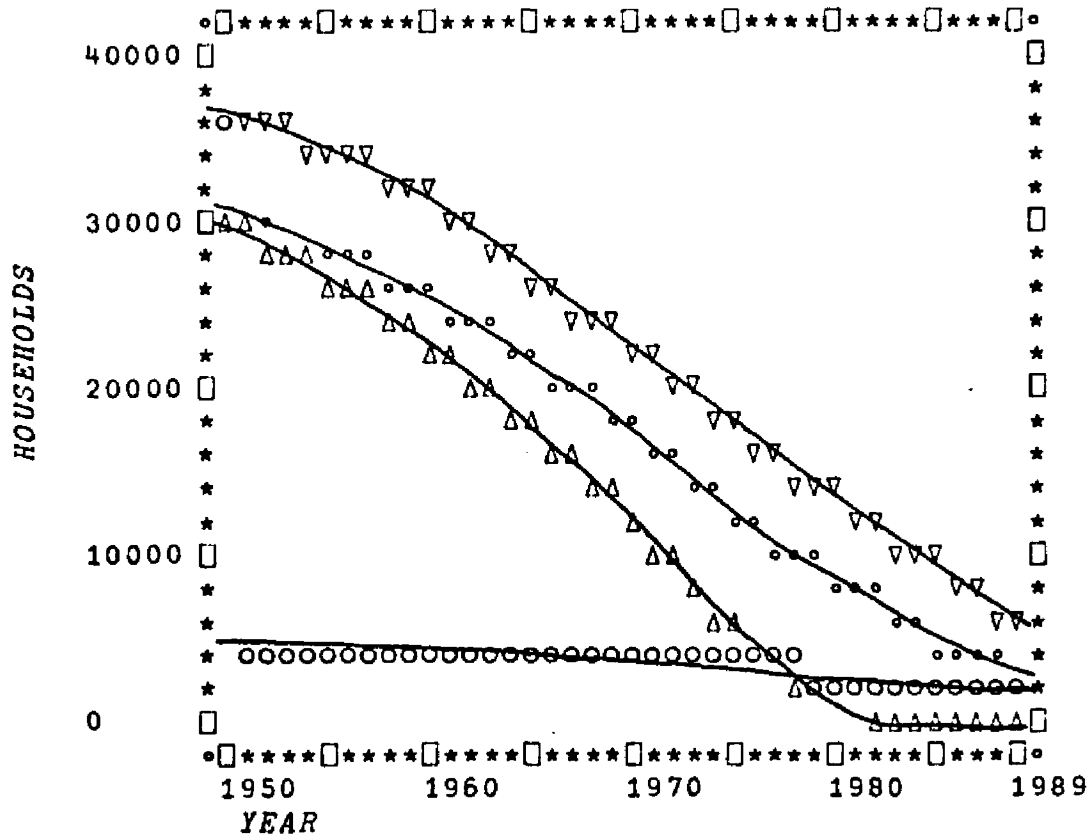

Figure 9.16 Alternative 3. White Households.

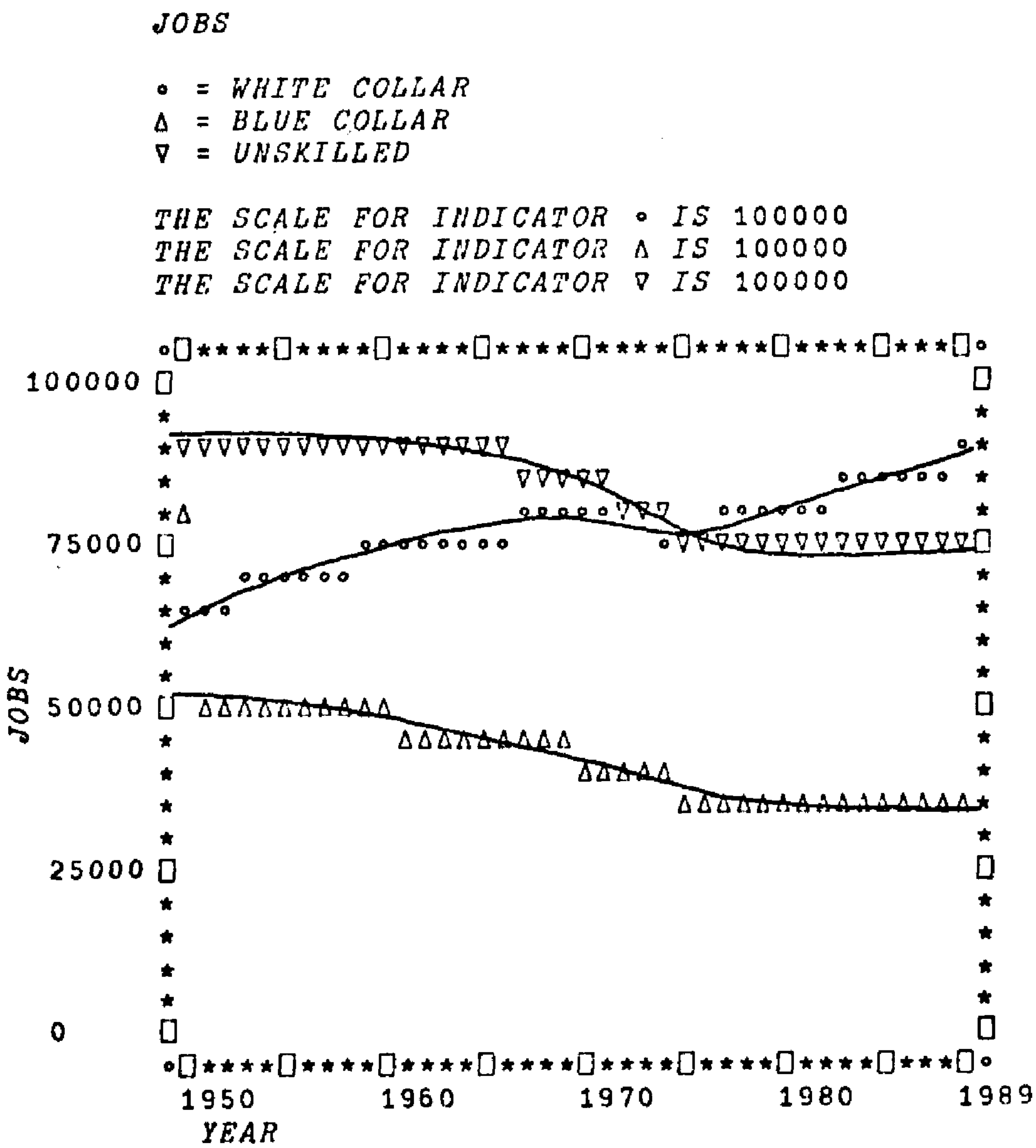

Figure 9.17 Alternative 3. Jobs

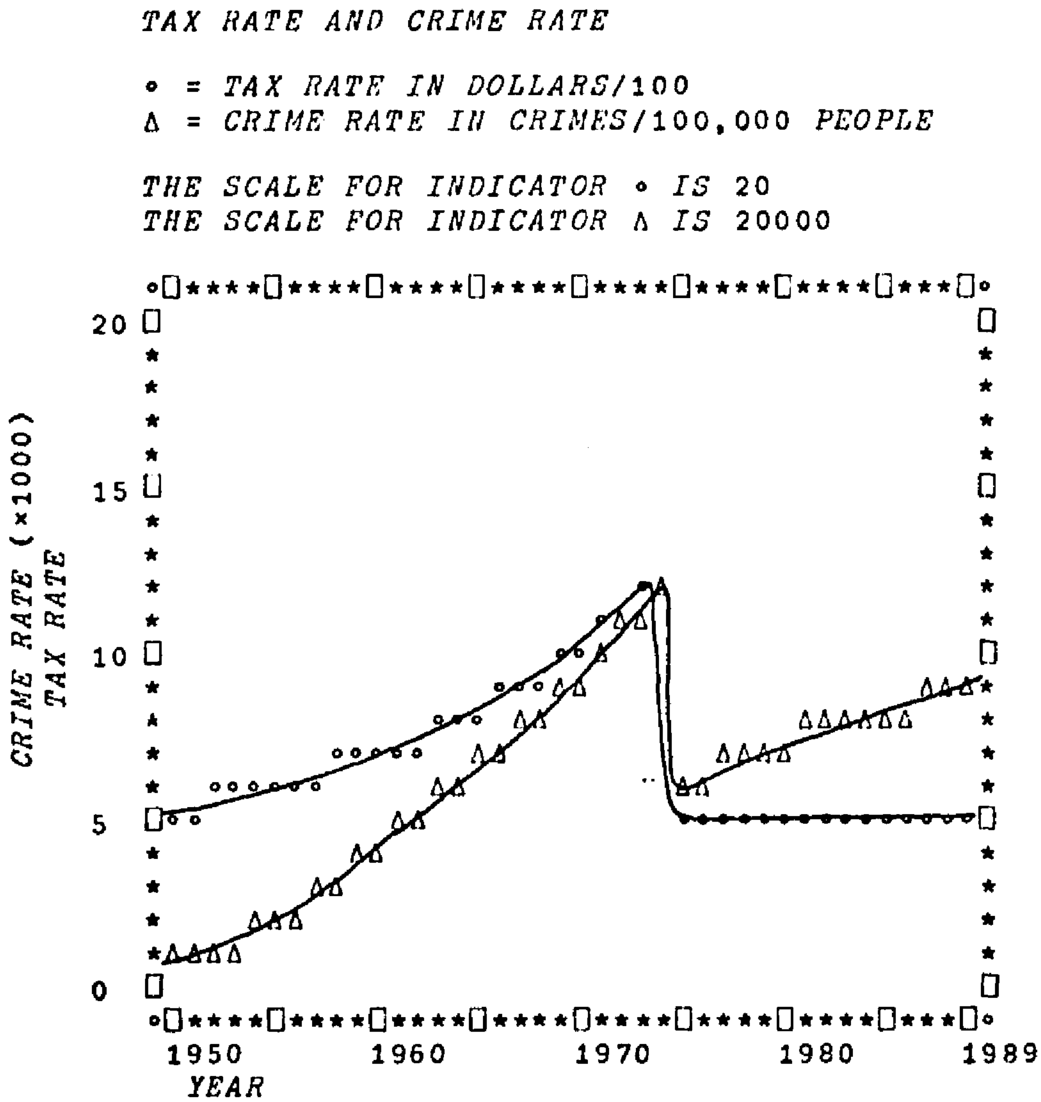

Figure 9.18 Alternative 3. Taxes and Crime.

Goals and Practicality

These three alternative futures for the city of Newark have been moving in the same direction: to a city of relative stability in housing stock, households, and jobs. These goals were stated before the alternatives were described. Yet the criteria developed in Chapter III said that the model should contain no hidden goals. In fact, there are no goals in the model, only in its application. The model has merely served as a predictor of the effects of tested policies. Those policies (alternatives 1, 2 and 3) have been developed the same way a decision maker would develop them using the model. That is, he would first set a goal. (In this case, the goal was a stable city.) Then various alternatives would be tested to see the predicted effects. If the effects were not strong enough or too strong, modifications to the policies could be made and tested. In this case, alternative 1 was too weak, alternative 2 was fairly close, and alternative 3 finally achieved the desired goal. But the model did not determine what the goal was or when it was achieved. It merely predicted the future impact of a policy change.

It is certainly premature to use this model in its present stage of calibration for any detailed policy recommendations to the city of Newark. But even at this stage it is easy to see that Newark will not become stable without major changes in public policy. Minor changes only postpone the decline predicted by the standard run. The scope of those major changes and the possibility of their implementation remain the subject of future research.

X. SUMMARY, CONCLUSIONS, AND SUGGESTIONS

Summary

This dissertation has described a computer simulation model of central city dynamics applied to Newark, New Jersey. The work began with a review of the Forrester Urban Dynamics model, the first attempt to simulate the entire system of a city. The objections to this model which have appeared in the literature were discussed, and a set of guidelines for a "second generation" model building effort were developed. A logical basis for the construction of a central city simulation model was presented, and the detailed algorithms representing housing, household, job, and government sectors of the model were described. The logic, mathematics, and calibration of each algorithm were presented. Next, a "standard run" used for partial calibration of the model to Newark, New Jersey was discussed. This standard run was extended to 1985 to examine the future impact of existing policies. Finally, various alternative programs leading to the arbitrary goal of "city stability" were tested. It was found that substantial changes in public policy would be necessary to achieve this particular goal.

Conclusions

On the basis of this work, it is possible to draw several conclusions.

The Forrester Model. From the discussion of the Forrester Urban Dynamics model in Chapter II and recent reports of failures in trying to fit this model to existing cities (Technology Review, 75-5:69), it is possible to conclude that the Forrester model is an inappropriate vehicle for describing the dynamic interactions of central cities. The model presented in Urban Dynamics, although useful as an illustration of the application of the system dynamics method to the urban scene, was never intended as a finished product which could be used to analyze existing urban areas. Forrester himself (1969, p. 115) says:

> This book is more an opening of a subject than it is a package of final results and recommendations. The primary objective is to improve understanding of the complexities of our social systems. However, one always draws conclusions as he goes along. ... As stated earlier, these conclusions should be accepted only after establishing that the assumptions used here fit the particular situation.

The System Dynamics Technique. Although the Forrester model per se is not applicable to the analysis of real cities, the system dynamics technique which it employs is an appropriate analysis method. Indeed, the present work has shown that a useful model of a central city can be built using the Forrester approach.

Sectors and Variables. An examination of the people, objects, and institutions within a city provides a logical basis for the selection of model sectors and variables.

The use of housing, household, job, and government sectors is justified by this analysis. Considering the level of aggregation employed, and the restrictions due to data availability, the state variable choice is appropriate.

Housing Sector. The market model of housing, with an economic basis for the construction and abandonment of the housing stock, provides a far more realistic model than Forrester's simple filtering algorithm. Work needs to be done in determining more precisely the determinants of housing construction and abandonment decisions. Particular attention should be paid to the effects of the lending policies of financial institutions on central city housing stock.

Household Sector. The use of race as one of the variables affecting migration decisions is a significant advance in the present model. The four migration effects, (race, housing availability, job availability, and government factors) appear adequate to explain migration decisions. These effects need more precise quantification, however. In addition, more work needs to be done on the types of households formed by young adults in ghetto areas.

Job Sector. Because of the importance of the central city as a source of jobs for both residents and commuters, the provision of a commutation algorithm was found to be essential, and has been included in the Newark model. The algorithm in use, although producing accurate results for Newark, contains some oversimplifications which should be corrected in the future. It will also be necessary to study more precisely the reasons for job migration.

Government Sector. The government sector was found to be one of the prime movers of the simulation. The structure used at the present time is quite limited, and must be expanded to include the influence of other pertinent variables. For example, in considering the effect of crime rate on migration, it is possible that "crime rate" is being used instead of a combination of various effects. Clearly this area needs much further work.

Practicality. Notwithstanding the fact that a great deal of work needs to be done before a reliable central city simulation model along the lines of the one described can be built, one can conclude from this work that such a model is both possible and practical in the near future. This model will not be generated as a completed entity, but as a series of successively more accurate attempts at a reliable model. The inaccuracies found at each step will indicate the areas of research necessary for the attainment of the next step, until a generally accurate model rests on a more solid theoretical and empirical foundation.

The Subject City. Finally, it would be impossible to perform the work described without coming to a conclusion about the subject of the model: the city of Newark, New Jersey. Torn by racial disharmony, and plagued with deteriorating housing, spiraling government costs and worsening government services, and middle class flight to the suburbs, Newark stands as the leader among large American cities in industrial decline and social stagnation. Only substantial changes in public policy can reverse this course.

Suggestions for Further Work

Some suggestions for further work have been made in the discussion of conclusions of the individual sectors. The following suggestions deal more with model calibration and extension, and proceed from specific work with the Newark model to more general considerations about generalized relationships and model structure.

Newark Data. As a first step toward achieveing a better model of Newark, some of the data which have been developed using estimates or rules of thumb can be substantiated with real empirical data. Such quantities include building costs, assessed value, tax factors, and public housing. Hard data on these and other quantities will enable refinements to be made in several algorithms.

Newark Studies. Several studies which could be conducted in the Newark area would be helpful in achieving a better quantification of certain algorithms. Of particular importance would be surveys to determine the reasons for migrational decisions of both households and businesses, in and out of Newark. Although attitudes are always difficult to quantify, a properly conducted survey could at least measure the relative importance of a series of factors in determining migration patterns. A quantitative formulation of migration effects could then be achieved through a correlation with the migration data. Thus the study would significantly improve the job and household migration sections of this model.

Another useful survey would involve specific examples of the housing stock and the reasons for decisions to build or abandon. Hopefully this work would lead to statistically accurate laws governing changes in the housing stock.

Other Cities. Once the Newark model is on a firmer theoretical base, an interesting extension would be to attempt to use the model for other cities. The same data required for Newark would be collected, and the model would be initialized with the 1950 data from another city, to see if the 1960 and 1970 simulation results replicated that city's data. Errors generated in the simulation would point out areas in which the model only represents forces particular to Newark.

Generalization. The results of the above experiment would lead to a study of the generality of the central city model. Data from many cities would be collected, and an effort would be made to determine which relationships in the model are general in nature and which have to be adjusted to fit each city modeled. Those relationships with general applicability could be more fully calibrated using the ensemble of data.

Factor Inclusion. The above studies, leading to a generalization of the existing model, should reveal imperfections in the model structure resulting from the omission of certain factors, for example, the quality of the school system. At this point the model could be broadened to include this and other factors not previously considered. Probably in-depth surveys would be required to quantify many of the omitted factors. However, care must be taken. One should not try to explain 100% of, for example, a migration rate variation with factors which account for only 75% of the variation in that rate. There will always be residual influences on modeled quantities which can only be accounted for by examining the "average" variations in those quantities. For example, in the present model, only worker availability, taxes, and crime were used to modify the job migration rates. Obviously these are not the only influences on this rate; those influences not modeled were absorbed into the "normal" migration rates. Such a technique is valid when differential attractiveness is the important variable. Of course the factors which contribute to the "differential" attractiveness must all be included. That is why these "factor inclusion" studies are necessary.

Disaggregation. Once the highly aggregated model as it is presently constructed is calibrated, tested for generality, and found accurate with data from several cities, consideration can be given to disaggregating some of the variables, if the need arises. One particular area where this may be necessary is in the consideration of the Spanish speaking minorities, whose numbers, in certain cities, would suggest a further diaggregation of the household variable. But the disaggregation must be done very carefully; each new variable introduced further complicates the calibration and data collection processes. That is why dissaggregation should not be attempted until the relationships used in the more aggregated model are very accurately known.

Language. The model, as presently constructed, has been written in the APL language, for reasons of computational simplicity which have previously been explained. Although the language, being user oriented, is inefficient in its use of machine time, the running of the simulation is not a problem. Each simulated year takes about 20 seconds. The constraint is the size of the APL workspace, or section of memory allowed. If the size of the simulation is significantly increased (by disaggregating variables) the workspace will run out of room. Thus it may be necessary, at some future date, to rewrite the model in a general language, such as Fortran, which can command a larger section of memory. There have, however, been recent proposals to modify the APL language so that information exchange among workspaces would be permitted during program execution. This would permit the enlarged simulation to remain in APL.

Other Extensions. Thus far this discussion of extensions has focused on the calibration of the existing model and the generalization of the model through the use of an ensemble of data from several cities. There are, of course, many other possibilities for the model. Of particular interest is the use of the model to determine the total impact of transportation improvements providing greater urban-suburban access. This would involve a more accurate model of that portion of the simulation dealing with commuting. Provisions would be made for both in and out commuting. Sensitivities of different groups to transportation changes would be measured, and the impact of such changes would be observed and modeled. The resulting simulation could show the long rang effects of transportation improvements far better than a conventional benefit-cost analysis.

There are numerous other avenues for research which would extend this model in both breadth and depth. As stated at the outset, the purpose of this research was not to develop a fully operational central city simulation model, but to produce a "second generation" model by combining the system dynamics technique with the results of previous work and certain new ideas which have not been previously applied to urban modeling. Only continuing efforts by many researchers will produce an accurate central city simulation model; a model which may help to reverse the tragic decay of many vital urban areas.

APPENDIX I

COMPUTER LISTINGS

A. Program Listings

INIT	NMIC
CITY	HDRC
EXOG	EDUC
HSNG	JOBS
HCST	WEBJ
PPOL	GEBJ
MARK	BASJ
WELH	WCHG
UPPR	GOVT
PGEN	DEMC
DBLD	PROP
DABD	PRTX
HSHD	CRIM
HMEC	TABL
JMEC	REPT
CMEC	PLOT
GMEC	PLTS

B. State Variables

C. Exogenous Variables

D. Intermediate Variables

E. Local Variables

F. State Variable Values for Standard Run

G. REPT Output for Standard Run

A. Program Listings

```
      ∇INIT[⎕]∇
    ∇ INIT
[1]   ⍝INITIALIZE STATE VARIABLES
[2]   CRI←HSD← 40 8 ⍴0
[3]   TR←40⍴0
[4]   TR[1]←5
[5]   HSG← 40 10 ⍴0
[6]   HSD[1;]←1000× 30 2 30 3 36 15 4 2
[7]   HSG[1;]←100× 281 47 60 157 325 268 55 20 0 20
[8]   CRI[1;]←0
[9]   CR←40⍴0
[10]  CR[1]←1000
[11]  WFH←40⍴0
[12]  WCH← 40 8 ⍴0
[13]  JOB← 40 3 ⍴0
[14]  JOB[1;]←1000× 65 50 92
[15]  I←0
[16]  ⍝TIME DEPENDENT EXOGENOUS VARIABLES
[17]  TEZ←75000000
[18]  INZ←1000× 8 7 6 6 4 4 2 2
[19]  ⍝FIXED EXOGENOUS QUANTITIES
[20]  PR← 150 130 110 90 70 50 40 40 0 0
[21]  BC←1000× 25 13 11 9 8 7 7 7 0 0
[22]  MAM← 50 35 30 25 25 20 20 20 0 0
[23]  AV←1000× 12 9 8 7 6 5 4 0 0 0
[24]  NIM← 0.037 0.037 0.03 0.03 0.03 0.03 0.03 0.03
[25]  NOM← 0.034 0.034 0.026 0.026 0.023 0.023 0.023 0.023
[26]  NI← 0.035 0.03 0.03
[27]  NO← 0.015 0.027 0.027
[28]  PTF←0.6
[29]  CTF←1.33
[30]  MIF←300
[31]  EDF←0.15
    ∇
```

```
      ∇CITY[⎕]∇
    ∇ CITY
[1]  LP:I←I+1
[2]   II←I+1
[3]   EXOG
[4]   HSNG
[5]   HSHD
[6]   JOBS
[7]   GOVT
[8]   'YEAR ';I
[9]   →T×ι(~∨/I= 1 5 10 15 20 25 30 35 39)
[10]  REPT
[11] T:→LP×ι(I<39)
    ∇


      ∇EXOG[⎕]∇
    ∇ EXOG
[1]   INC←INZ×(1.015 1.015 1.015
      1.015 1.01 1.01 1.005 1.005)*I
[2]   CRN←900+100×I
    ∇


      ∇HSNG[⎕]∇
    ∇ HSNG
[1]   HCST
[2]   PPOL
[3]   UPPR
[4]   MARK
[5]   WELH
[6]   PGEN
[7]   DBLD
[8]   DABD
[9]   HSG[II;]←⌊HSG[I;]+CHS+NUB+CHA
[10]  HSG[II;8]←2000+(2000×(I>8))+3000×(I>13)
    ∇


      ∇HCST[⎕]∇
    ∇ HCST
[1]   DEM← 2 8 ρ(INC×0.0191),,HSD[I;]
    ∇


      ∇PPOL[⎕]∇
    ∇ PPOL
[1]   CST← 2 10 ρPR,,HSG[I;]
    ∇
```

```
        ∇MARK[⎕]∇
      ∇ MARK;DD;ND;DS;NS;J;K;A
[1]     DD←,DEM[1;]
[2]     ND←,DEM[2;]
[3]     DS←,CST[1;]
[4]     NS←,CST[2;]
[5]     J←0
[6]    L1:J←J+1
[7]     K←0
[8]    L2:K←K+1
[9]     →T1×ι((((0.5×DD[J])<DS[K])∧DS[K]<(
        1.3×DD[J]))=0)
[10]    A←ND[J]-NS[K]
[11]    →G×ι(A>0)
[12]    NS[K]←-A
[13]    ND[J]←0
[14]    →T1
[15]   G:NS[K]←0
[16]    ND[J]←A
[17]   T1:→L2×ι(K<10)
[18]    →L1×ι(J<8)
[19]    UD←ND
[20]    US←NS
      ∇


        ∇WELH[⎕]∇
      ∇ WELH;A;B;C;D
[1]     A←+/UD[7 8]
[2]     B←+/D←US[4 5 6 7]
[3]     C←A-B
[4]     →P×ι(C≥0)
[5]     UD[7 8]←0
[6]     US[4 5 6 7]←US[4 5 6 7]×(-C)÷B
[7]     →T
[8]    P:US[4 5 6 7]←0
[9]     UD[7 8]←UD[7 8]×C÷A
[10]   T:WFH[II]←A⌊B
[11]    CRI[II;]←⌊100×UD÷,DEM[2;]
      ∇


        ∇UPPR[⎕]∇
      ∇ UPPR;X;FS;NS;NU
[1]     BF←(+/,HSD[I; 2 4 6 8])÷+/,HSD[I;]
[2]     FS← 0 0.11 0 0 TABL 0 0.3 0.6
        1 ,BF
[3]     NS←FS× 0 0 0.9 0.95 1 1.05 1.1
        0 0 0 ×HSG[I;]
[4]     NU←NS[1+ι9],0
[5]     CHS←NU-NS
      ∇
```

```
      ∇PGEN[⎕]∇
    ∇ PGEN;BCM;TM;TCM;EHM
[1]   BCM←BC÷MIF
[2]   TM←AV×TR[I]÷1200
[3]   TCM←BCM+TM+MAM
[4]   PL←(,CST[1;])-TCM
[5]   TCM[10 9]←1
[6]   PLN←PL÷TCM
[7]   EHM←TM+MAM
[8]   PLE←(,CST[1;])-EHM
[9]   EHM[9 10]←1
[10]  PLE←PLE÷EHM
    ∇


      ∇DBLD[⎕]∇
    ∇ DBLD;FUO;FUB;J
[1]   FUB←10⍴0
[2]   J←0
[3]  L:J←J+1
[4]   FUB[J]←(0 0 0 0.05 0.1 0.1 TABL(-1),
      0 0.01 0.1 0.22 0.5 ,PLN[J])×US[J]=0
[5]   →L×⍳(J<7)
[6]   NUB←(,CST[2;])×FUB
    ∇


      ∇DABD[⎕]∇
    ∇ DABD;FAY;J;NAY;FUA;FAD
[1]   FAY←10⍴0
[2]   J←0
[3]  L:J←J+1
[4]   FAY[J]← 0.2 0.05 0.028 0.006
      0.002 0 0 TABL(-1),(-0.2),(-
      0.1), 0 0.05 1 3 ,PLE[J]
[5]   →L×⍳(J<7)
[6]   FAY←FAY×(1 1.7 1.8 1 TABL 0
      0.5 0.75 1 ,BF)
[7]   NAY←FAY×,CST[2;]
[8]   CHA←(-NAY[⍳8]),0,+/NAY[⍳8]
[9]   FUA←CST[2;10]÷+/,CST[2;]
[10]  FAD← 0 0 0.3 0.5 TABL 0 0.02
      0.06 0.4 ,FUA
[11]  CHA[10]←CHA[10]-FAD×CST[2;10]
    ∇
```

```
      ∇HSHD[⎕]∇
    ∇ HSHD
[1]   HMEC
[2]   JMEC
[3]   CMEC
[4]   GMEC
[5]   NMIC
[6]   HDRC
[7]   EDUC
[8]   HSD[II;]←⌊HSD[I;]+WCH[I;]+NHD+HDR+NMI+NMO
    ∇


      ∇HMEC[⎕]∇
    ∇ HMEC;THD;NWF
[1]   THD←+/,HSD[I;]
[2]   NWF←(+/,HSD[I; 2 4 6 8])÷THD
[3]   HME←16ρ1
[4]   HME[1 5 7]← 1 1 0.6 0.1 TABL
      0 0.2 0.6 1 ,NWF
[5]   HME[3]← 1 0.8 0.4 0.1 0.1 TABL
      0 0.2 0.5 0.7 1 ,NWF
[6]   HME[9 11 13 15]←1÷HME[1 3 5 7]
[7]   HME[2 4 6 8]← 1 3 3 1.5 1.2 TABL
      0 0.1 0.3 0.5 1 ,NWF
[8]   HME[10 12 14 16]←1÷HME[2 4 6 8]
    ∇


      ∇JMEC[⎕]∇
    ∇ JMEC;RWC;RBC;EI
[1]   JME←16ρ1
[2]   RWC←JOB[I;1]÷+/,HSD[I; 1 2]
[3]   JME[1 2]← 0.5 1.5 1.5 TABL 0 4 10 ,RWC
[4]   RBC←JOB[I;2]÷+/,HSD[I; 3 4]
[5]   JME[3 4]← 0.5 1.5 1.5 TABL 0 3 10 ,RBC
[6]   RBC←JOB[I;3]÷+/,HSD[I; 5 6]
[7]   JME[5 6]← 0.5 0.5 1.5 1.5 TABL
      0 1 2.6 10 ,RBC
    ∇
```

```
      ∇CMEC[⎕]∇
    ∇ CMEC;J
[1]   CME←16ρ1
[2]   J←0
[3]  L:J←J+1
[4]   CME[J]← 1 0.1 0.1 TABL 0 10 100 ,CRI[I;J]
[5]   →L×ι(J<4)
[6]   CME[5]← 1 0.1 0.1 TABL 0 20 100 ,CRI[I;5]
[7]   CME[7]← 1 0.1 0.1 TABL 0 20 100 ,CRI[I;7]
[8]   CME[6]← 1 0.1 0.1 TABL 0 40 100 ,CRI[I;6]
[9]   CME[8]← 1 0.1 0.1 TABL 0 40 100 ,CRI[I;8]
    ∇


      ∇GMEC[⎕]∇
    ∇ GMEC
[1]   GME←16ρ1
[2]   GME[ι8]← 1.2 1 1 0.9 0.7 0.1 TABL 0 1 2 3
      5 15 ,CR[I]÷CRN
[3]   GME[8+ι8]←1÷GME[1]
[4]   GME[ι4]←GME[ι4]×(1.1 1 0.1 TABL 0 5 50 ,TR[I])
[5]   GME[8+ι4]←1÷GME[1]
    ∇


      ∇NMIC[⎕]∇
    ∇ NMIC;NME
[1]   NME←HME×JME×CME×GME
[2]   NMI←NME[ι8]×NIM×,HSD[I;]
[3]   NMO←-1×NME[8+ι8]×NOM×,HSD[I;]
    ∇


      ∇HDRC[⎕]∇
    ∇ HDRC
[1]   HDR←-1× 0.033 0.025 0.033 0.025
      0.033 0.03 0.033 0.03 ×,HSD[I;]
    ∇


      ∇EDUC[⎕]∇
    ∇ EDUC
[1]   NHD← 0.015 0.027 0.019 0.03
      0.023 0.035 0.023 0.035 ×,HSD[I;]
[2]   NHD←NHD+(0.1 0.1 0.1 0.1 0.5
      0.5 ,(-0.7),(-0.7))×(8ρNHD[7 8])
[3]   NHE←((EDF×NHD[2+ι6]), 0 0)-(0 0 ,EDF×NHD[2+ι
      6])
[4]   NHI← 0 0 0 0 0 0 0 ,0.2×+/NHD[6 8]
[5]   NHD←NHD+NHE+NHI
    ∇
```

```
      ∇JOBS[⎕]∇
    ∇ JOBS
[1]   WEBJ
[2]   GEBJ
[3]   BASJ
[4]   WCHG
    ∇


      ∇WEBJ[⎕]∇
    ∇ WEBJ;J
[1]   WJF←3ρ1
[2]   WHD←(+/,HSD[I; 1 2]),(+/,HSD[I; 3 4]),(+/,HSD[I;
      5 6])
[3]   HJR←WHD÷,JOB[I;]
[4]   WJF[1]←1+0.5×(HJR[1]-0.5)
[5]   WJF[2]←1+0.75×(HJR[2]-0.67)
[6]   WJF[3]←1+(HJR[3]-0.56)
    ∇


      ∇GEBJ[⎕]∇
    ∇ GEBJ
[1]   GF← 1 0.9 0.8 0.5 0.3 0.1 TABL 0 5 10 15 25
      50 ,TR[I]
[2]   GF←GF×(1 1 1 0.9 0.7 0.1 TABL 0 1 2 3 5 15 ,CR[I]÷
      CRN)
    ∇


      ∇BASJ[⎕]∇
    ∇ BASJ;AF;NFI;NFO
[1]   AF←GF×WJF
[2]   NFI←NI×AF
[3]   NFO←NO÷AF
[4]   BJC←JOB[I;]×(NFI-NFO)
[5]   JOB[II;]←⌊JOB[I;]+BJC
    ∇
```

```
      ∇WCHG[⎕]∇
    ∇ WCHG;J;FLO;JHR;NLO
[1]   FLO←3⍴0
[2]   JHR←1÷HJR
[3]   FLO[1]← 0.15  0  0  TABL  0  2  10  ,JHR[1]
[4]   FLO[2]← 0.15  0  0  TABL  0  1.5
      10  ,JHR[2]
[5]   FLO[3]← 0.15  0  0  TABL  0  1.8
      10  ,JHR[3]
[6]   NLO←(FLO[1],FLO[1],FLO[2],FLO[2],(
      0.4×FLO[3]),(1.7×FLO[3]),  0  0)×,HSD[I;]
[7]   WCH[II;]←⌊(-0.8×NLO[⍳4]),(-1×NLO[5  6]),
      0.8×NLO[5  6]
    ∇


      ∇GOVT[⎕]∇
    ∇ GOVT
[1]   DEMC
[2]   PROP
[3]   PRTX
[4]   CRIM
    ∇


      ∇DEMC[⎕]∇
    ∇ DEMC
[1]   TEX←TEZ×1.038*I
    ∇


      ∇PROP[⎕]∇
    ∇ PROP
[1]   AVR←+/AV×,HSG[I;]
[2]   AVC←1300×+/,JOB[I;]
[3]   TAV←AVR+AVC
    ∇


      ∇PRTX[⎕]∇
    ∇ PRTX
[1]   TPT←CTF×PTF×TEX
[2]   TR[II]←100×TPT÷TAV
    ∇


      ∇CRIM[⎕]∇
    ∇ CRIM
[1]   CR[II]←1393-(0.01216×3.3×+/,HSD[I;])-(
      0.02858×3.3×+/,HSD[I;  2  4  6  8])+102×500×(+/,HSD[I;
      7  8])÷+/,HSD[I;]
    ∇
```

```
      ∇TABL[⎕]∇
    ∇ R←Y TABL XA;X;Z;I
[1]   X←XA[⍳⍴Y]
[2]   Z←XA[1+⍴Y]
[3]   →(+/(Z<X[1]),Z>X[⍴Y])/ER
[4]   I←+/Z≥X
[5]   I←I-(Z=X[⍴Y])
[6]   R←Y[I]+(Z-X[I])×(Y[I+1]-Y[I])÷(X[I+1]-X[I])
[7]   →0
[8]  ER:Z;'EXCEEDS RANGE OF X ';X[1];' TO ';X[⍴Y]
    ∇


      ∇REPT[⎕]∇
    ∇ REPT
[1]   'HOUSING ';,HSG[I;];' TOTAL ';+/,HSG[I;]
[2]   'UNUSED SUPPLY ';⌊US
[3]   'UNMET DEMAND ';⌊UD
[4]   'CHS ';⌊CHS
[5]   'CHA ';⌊CHA
[6]   'NUB ';⌊NUB
[7]   'WFH ';⌊WFH[I]
[8]   'HOUSEHOLDS ';,HSD[I;];' TOTAL ';+/,HSD[I;]
[9]   'HME ';HME[⍳8]
[10]  'JME ';JME[⍳8]
[11]  'CME ';CME[⍳8]
[12]  'GME ';GME[⍳8]
[13]  'NMI ';⌊NMI
[14]  'NMO ';⌊NMO
[15]  'INC ';⌊INC;' AVERAGE ';(+/INC×,HSD[I;])÷+/,HSD[I;]
[16]  'HDR ';⌊HDR
[17]  'NHD ';⌊NHD
[18]  'WCH ';⌊WCH[I;]
[19]  'JOBS ';,JOB[I;];' TOTAL ';+/,JOB[I;]
[20]  'WJF ';WJF
[21]  'GF ';GF
[22]  'BJC ';⌊BJC
[23]  'GOVERNMENT   TAV ';TAV;'  TEX ';TEX
[24]  'TAX RATE ';TR[I]
[25]  'CRIME RATE ';CR[I];' NORMAL ';CRN
[26]  ' '
    ∇
```

```
      ∇PLOT[⎕]∇
    ∇ PLOT A;OUT;ALPH;NR;J;S;T;K;X;SC;FACT
[1]   OUT← 23 42 ρ' '
[2]   OUT[1;]←'∘⎕****⎕****⎕****⎕****⎕****⎕****⎕****⎕***⎕∘'

[3]   OUT[23;]←OUT[1;]
[4]   OUT[;1]←'∘⎕****⎕****⎕****⎕****⎕∘'
[5]   OUT[;42]←OUT[;1]
[6]   ALPH←'∘∆∇○αωερ⊥⊤'
[7]   NR←+/ 0 1 ×ρA
[8]   SC← 1 2 4 5 10 20 40 50 100 200 400 500 1000
      2000 4000 5000 10000 20000 40000 50000
[9]   SC←SC,100000× 1 2 4 5 10 20 40 50 100 200
      400 500 1000 2000 4000 5000 10000
[10]  FACT←20÷SC
[11]  J←0
[12] L1:J←J+1
[13]  S←+/((⌈/T←,A[;J])>SC)
[14]  A[;J]←⌊0.5+T×FACT[1+S]
[15]  'THE SCALE FOR INDICATOR ';ALPH[J];' IS ';SC[1+S]
[16]  →L1×ι(J<NR)
[17]  ' '
[18]  J←0
[19] L2:J←J+1
[20]  K←0
[21] L3:K←K+1
[22]  X←A[J;K]
[23]  OUT[(22-X);1+J]←ALPH[K]
[24]  →L3×ι(K<NR)
[25]  →L2×ι(J<40)
[26]  OUT
[27]  ' 1950       1960       1970       1980       1989'
[28]  '  YEAR'
    ∇
```

```
      ∇PLTS[⎕]∇
    ∇ PLTS
[1]   3 1 ρ' '
[2]   'HIGH COST HOUSING'
[3]   ' '
[4]   '∘ = OWNER OCCUPIED HOUSING'
[5]   'Δ = RENT >120/MONTH'
[6]   '∇ = RENT 100-120/MONTH'
[7]   '○ = RENT 80-100/MONTH'
[8]   ' '
[9]   PLOT HSG[; 1 2 3 4]
[10]  3 1 ρ' '
[11]  'LOW COST HOUSING'
[12]  ' '
[13]  '∘ = RENT 60-80/MONTH'
[14]  'Δ = RENT 40-60/MONTH'
[15]  '∇ = RENT <40/MONTH'
[16]  '○ = STANDING ABANDONED UNITS'
[17]  ' '
[18]  PLOT HSG[; 5 6 7 10]
[19]  3 1 ρ' '
[20]  'BLACK HOUSEHOLDS'
[21]  ' '
[22]  '∘ = WHITE COLLAR'
[23]  'Δ = BLUE COLLAR'
[24]  '∇ = UNSKILLED'
[25]  '○ = UNEMPLOYED'
[26]  ' '
[27]  PLOT HSD[; 2 4 6 8]
[28]  3 1 ρ' '
[29]  'WHITE HOUSEHOLDS'
[30]  ' '
[31]  '∘ = WHITE COLLAR'
[32]  'Δ = BLUE COLLAR'
[33]  '∇ = UNSKILLED'
[34]  '○ = UNEMPLOYED'
[35]  ' '
[36]  PLOT HSD[; 1 3 5 7]
[37]  3 1 ρ' '
[38]  'JOBS'
[39]  ' '
[40]  '∘ = WHITE COLLAR'
[41]  'Δ = BLUE COLLAR'
[42]  '∇ = UNSKILLED'
[43]  ' '
[44]  PLOT JOB
[45]  3 1 ρ' '
[46]  'TAX RATE AND CRIME RATE'
[47]  ' '
[48]  '∘ = TAX RATE IN DOLLARS/100'
[49]  'Δ = CRIME RATE IN CRIMES/100,000 PEOPLE'
[50]  ' '
[51]  PLOT⍉(2 40 ρTR,CR)
    ∇
```

B. State Variables (alphabetical)

Variable Name	Computer Name	Dimension	Generated By:
Crime Rate	CR	40	CRIM
Crowding Index	CRI	40,8	WELH
Households	HSD	40,8	HSHD
Housing	HSG	40,10	HSNG
Jobs	JOB	40,3	BASJ
Tax Rate	TR	40	PRTX
Worker Changes	WCH	40,8	WCHG

C. Exogenous Variables (alphabetical)

Variable Name	Computer Name	Dimension	Fixed or Varying	Used By
Assessed Value	AV	10	F	PGEN,PROP
Building Cost	BC	10	F	PGEN
Crime Rate, Normal	CRN	1	V	GMEC,GEBJ
Initial Crime Rate, Normal	CRZ	1	F	EXOG
County Tax Factor	CTF	1	F	PRTX
Eduction Factor	EDF	1	F	EDUC
Current Year	I	1	V	several
Following Year	II	1	V	several
Income	INC	8	V	HCST
Initial Income	INZ	8	F	EXOG
Maintenance per month	MAM	10	F	PGEN
Mortgage and Interest Factor	MIF	1	F	PGEN
Job Normal In Migration	NI	3	F	BASJ
Household Normal In Migration	NIM	8	F	NMIC
Job Normal Out Migration	NO	3	F	BASJ
Household Normal Out Migration	NOM	8	F	NMIC

C. Exogenous Variables (continued)

Variable Name	Computer Name	Dimension	Fixed or Varying	Used By
Housing Cost	PR	10	F	PPOL
Property Tax Factor	PTF	1	F	PRTX
Initial City Budget	TEZ	1	F	DEMC

D. Intermediate Variables (alphabetical)

Variable Name	Computer Name	Dimension	Generated By	Sector
Black Fraction	BF	1	UPPR	HSNG
Change in Housing from Abandonment	CHA	10	DABD	HSNG
Change in Housing Supply	CHS	10	UPPR	HSNG
Crowding Migration Effects	CME	16	CMEC	HSHD
Housing Supply & Cost	CST	2,10	PPOL	HSNG
Housing Demand & Cost	DEM	2,8	HCST	HSNG
Government Effects on Jobs	GF	1	GEBJ	JOBS
Government Migration Effects	GME	16	GMEC	HSHD
Household Dissolutions	HDR	8	HDRC	HSHD
Household to Job Ratio	HJR	3	WEBJ	JOBS
Household Migration Effects	HME	16	HMEC	HSHD
Job Migration Effects	HME	16	JMEC	HSHD
New Households	NHD	8	EDUC	HSHD
Household In Migration	NMI	8	NMIC	HSHD
Household Out Migration	NMO	8	NMIC	HSHD

D. Intermediate Variables (continued)

Variable Name	Computer Name	Dimension	Generated By	Sector
New Units Built	NUB	10	DBLD	HSNG
Profit-Loss Existing	PLE	10	PGEN	HSNG
Profit-Loss New	PLN	10	PGEN	HSNG
Total Assessed Value	TAV	1	PROP	GOVT
Total Municipal Expenditures	TEX	1	DEMC	GOVT
Unmet Housing Demand	UD	8	MARK	HSNG
Unused Housing Supply	US	10	MARK	HSNG
Worker Effects on Jobs	WJF	3	WEBJ	JOBS

E. Local Variables (by Algorithm)

Algorithm	Local Variable Names						
UPPR	X	FS	NS	NU			
MARK	DD	ND	DS	NS	J	K	A
WELH	A	B	C	D			
PGEN	PL	BCM	TM	TCM	EHM		
DBLD	FUO	FUB	J				
DABD	FAY	J	NAY	FUA	FAD		
HMEC	THD	NWF					
JMEC	RWC	RBC	EI				
CMEC	J						
NMIC	NME						
EDUC	NHE	NHI					
WEBJ	J	WHD					
BASJ	AF	NFI	NFO	BJC			
WCHG	J	FLO	JHR	NLO			
PROP	AVC	AVR					
PRTX	TPT						

F. State Variable Values for Standard Run

Years 1950 to 1985

Households (x100)

	WWC	BWC	WBC	BBC	WU	BU	WUN	BUN
1950	300	20	300	30	360	150	40	20
	296	22	294	33	358	162	39	22
	293	24	288	37	356	176	38	23
	289	27	281	41	352	189	37	25
	285	30	275	45	348	201	37	28
	281	34	268	50	343	214	38	31
	276	38	260	55	338	224	38	37
	271	42	253	61	331	234	39	42
	266	47	244	68	325	245	39	48
	261	52	236	74	317	255	40	54
1960	255	58	227	81	310	265	41	61
	248	64	218	88	302	272	41	68
	242	69	208	95	293	279	42	76
	234	75	198	102	285	284	42	83
	226	80	187	109	276	287	43	91
	217	86	176	115	267	290	43	98
	209	91	165	121	257	292	43	105
	199	95	154	126	248	292	42	112
	190	99	142	131	239	292	42	118
	180	103	130	135	230	291	41	125
1970	170	107	118	140	220	291	40	132
	161	111	106	144	211	291	39	139
	150	115	94	148	202	292	38	146
	140	118	82	152	193	292	37	153
	130	122	69	156	183	293	36	160
	119	125	56	160	173	293	34	166
	109	129	43	164	163	292	33	171
	98	132	30	167	153	291	31	174
	87	134	18	169	143	288	30	177
	75	136	11	171	132	283	28	181
1980	64	137	6	172	122	274	27	185
	53	137	3	173	111	261	25	190
	42	136	2	171	100	247	24	195
	30	132	1	165	90	234	22	199
	17	124	0	152	80	219	20	205

Housing Units (x100)

	Owner Occ	Private Rental						Pub.		Aban.
1950	281	47	60	157	325	268	55	20	0	20
	280	53	69	173	321	252	50	20	0	21
	280	60	79	187	317	237	46	20	0	23
	279	68	89	200	311	221	42	20	0	25
	279	77	100	212	303	205	38	20	0	27
	278	88	112	221	295	189	34	20	0	29
	278	99	124	229	285	173	30	20	0	31
	277	113	135	235	274	157	26	20	0	32
	277	127	146	240	261	142	23	20	0	34
	276	142	156	243	249	129	19	40	0	35
1960	275	155	164	245	237	117	17	40	0	36
	275	168	172	245	227	107	14	40	0	37
	274	180	178	244	217	98	13	40	0	39
	273	192	182	242	208	90	11	40	0	40
	273	202	186	240	200	83	9	70	0	42
	272	212	190	238	192	75	8	70	0	44
	271	220	192	235	186	69	7	70	0	46
	270	228	194	233	179	63	6	70	0	48
	269	234	195	230	173	57	5	70	0	50
	268	239	196	228	166	51	5	70	0	53
1970	266	243	196	226	159	46	4	70	0	57
	263	246	197	224	151	41	3	70	0	62
	257	247	196	223	142	37	3	70	0	68
	248	247	196	220	134	33	2	70	0	76
	236	246	194	215	124	29	2	70	0	86
	221	244	191	207	113	26	2	70	0	103
	203	238	184	195	102	22	1	70	0	126
	184	228	173	181	91	19	1	70	0	154
	163	213	159	163	79	16	1	70	0	183
	142	194	143	144	67	13	1	70	0	207
1980	120	171	125	124	56	10	0	70	0	222
	100	148	107	104	46	8	0	70	0	225
	82	124	89	86	37	6	0	70	0	216
	66	103	73	70	30	5	0	70	0	200
	52	83	59	56	23	4	0	70	0	178

Jobs

	White Col.	Blue Col.	Unsk.
1950	65000	50000	92000
	65952	49828	91694
	66877	49628	91417
	67792	49416	91197
	68696	49191	91022
	69589	48954	90882
	70469	48705	90766
	71336	48445	90658
	72189	48174	90554
	73028	47893	90454
1960	73851	47601	90350
	74644	47288	90215
	75364	46920	89979
	76008	46498	89635
	76573	46021	89178
	77059	45490	88607
	77465	44907	87923
	77791	44274	87129
	78038	43592	86229
	78204	42861	85223
1970	78288	42083	84117
	78273	41248	82896
	78084	40305	81467
	77701	39248	79817
	77096	38063	77923
	76231	36731	75747
	75049	35221	73230
	73454	33476	70264
	71435	31512	66866
	69166	29475	63302
1980	66536	27337	59439
	63340	25008	55028
	59380	22429	49876
	54897	19815	44412
	49405	16933	38219

Tax Rate and Crime Rate

	Tax Rate	Crime Rate
1950	5	1000
	5.3671	1080.5
	5.5062	1287.6
	5.6579	1442.4
	5.8151	1669.2
	5.9797	1945.4
	6.1534	2275.6
	6.3345	2691
	6.5241	3117.3
	6.724	3579.8
1960	6.9382	4070.4
	7.1693	4587.5
	7.4145	5125.5
	7.6757	5678.5
	7.9548	6237
	8.2529	6793.9
	8.5709	7342.7
	8.9096	7877
	9.2722	8409.9
	9.6605	8945.1
1970	10.08	9489
	10.543	10047
	11.058	10623
	11.655	11208
	12.351	11796
	13.182	12384
	14.203	12964
	15.506	13515
	17.201	14034
	19.426	14544
1980	22.353	15058
	26.198	15624
	31.214	16256
	37.849	16938
	46.588	17725

G. REPT Output for Standard Run

```
YEAR 1
HOUSING 28100  4700  6000  15700  32500  26800
      5500  2000  0  2000 TOTAL 123300
UNUSED SUPPLY 0  0  0  0  0  0  0  0  0  2000
UNMET DEMAND 0  0  0  0  0  0  0  700
CHS 0  357  629  1162  ¯289  ¯1461  ¯401  0
      0  0
CHA ¯38  ¯3  ¯5  ¯15  ¯52  ¯55  ¯14  0  0  177
NUB 0  278  300  517  0  0  0  0  0  0
WFH 0
HOUSEHOLDS 30000  2000  30000  3000  36000  15000
      4000  2000 TOTAL 122000
HME 1  3  0.81967  3  1  3  1  3
JME 1.0078  1.0078  1.0051  1.0051  1.0025  1.0025
      1  1
CME 1  1  1  1  1  1  1  1
GME 1  1  1  1  1  1  1  1
HMI 1118  223  741  271  1082  1353  120  180
HMO ¯1020  ¯23  ¯952  ¯26  ¯828  ¯115  ¯92  ¯16
INC 8120  7105  6090  6090  4040  4040  2010
      2010 AVERAGE 5548.2
HDR ¯990  ¯50  ¯990  ¯75  ¯1188  ¯450  ¯132
      ¯60
NHD 546  75  623  166  747  479  23  134
WCH 0  0  0  0  0  0  0  0
JOBS 65000  50000  92000 TOTAL 207000
WJF 0.99615  0.9925  0.99435
GF 0.9
BJC 952  ¯172  ¯306
GOVERNMENT  TAV 1157500000  TEX 7.785E7
TAX RATE 5
CRIME RATE 1000 NORMAL 1000
```

```
YEAR 5
HOUSING 27929  7753  10088  21200  30399  20535
      3845  2000  0  2785 TOTAL 126534
UNUSED SUPPLY 0  0  0  0  0  0  0  0  0  2785
UNMET DEMAND 0  0  0  0  0  870  0  777
CHS 0  813  991  919  ¯793  ¯1554  ¯380  0  0
      0
CHA ¯49  ¯8  ¯12  ¯29  ¯61  ¯51  ¯25  0  0  189
NUB 0  241  186  25  0  0  0  0  0  0
WFH 0
HOUSEHOLDS 28555  3076  27517  4563  34880  20183
      3791  2831 TOTAL 125396
HME 0.95555  3  0.74073  3  0.95555  3  0.95555
      3
JME 1.0429  1.0429  1.0111  1.0111  0.90816  0.90816
      1  1
CME 1  1  1  1  1  1  1  0.1
GME 0.9837  0.9837  0.9837  0.9837  1  1  1  1
NMI 1035  350  608  408  908  1649  108  25
NMO ¯1033  ¯36  ¯982  ¯41  ¯840  ¯155  ¯92  ¯22
INC 8618  7540  6463  6463  4204  4204  2050
      2050 AVERAGE 5755.5
HDR ¯943  ¯77  ¯909  ¯115  ¯1152  ¯606  ¯126
      ¯85
NHD 516  114  578  238  722  647  22  182
WCH 0  0  0  0  ¯139  ¯316  110  252
JOBS 68696  49191  91022 TOTAL 208909
WJF 0.98022  0.98661  1.0449
GF 0.8837
BJC 893  ¯237  ¯140
GOVERNMENT  TAV 1206059700  TEX 9.0375E7
TAX RATE 5.8151
CRIME RATE 1669.2 NORMAL 1400
```

```
YEAR 10
HOUSING 27659  14205  15645  24377  24952  12907
      1988  4000  0  3543 TOTAL 129276
UNUSED SUPPLY 0  0  0  0  0  0  0  0  0  3543
UNMET DEMAND 0  0  0  0  0  184  0  3500
CHS 0  1350  870  171  ¯1094  ¯1090  ¯210  0
      0  0
CHA ¯62  ¯22  ¯26  ¯46  ¯63  ¯52  ¯55  0  0
      125
NUB 0  0  0  0  0  0  0  0  0  0
WFH 0
HOUSEHOLDS 26118  5285  23648  7496  31786  25596
      4057  5431 TOTAL 129417
HME 0.8615  2.7112  0.61533  2.7112  0.8615  2.7112
      0.8615  2.7112
JME 1.0814  1.0814  1.0126  1.0126  0.86022  0.86022
      1  1
CME 1  1  1  1  1  1  1  0.1
GME 0.96552  0.96552  0.96552  0.96552  1  1  1
      1
NMI 869  553  426  596  706  1790  104  44
NMO ¯1068  ¯69  ¯1035  ¯75  ¯849  ¯218  ¯109
      ¯47
INC 9284  8123  6963  6963  4418  4418  2102
      2102 AVERAGE 5994.4
HDR ¯862  ¯133  ¯781  ¯188  ¯1049  ¯768  ¯134
      ¯163
NHD 469  198  506  355  665  850  23  258
WCH 0  0  0  0  ¯231  ¯741  184  592
JOBS 73028  47893  90454 TOTAL 211375
WJF 0.96501  0.98521  1.0744
GF 0.86552
BJC 823  ¯292  ¯104
GOVERNMENT   TAV 1252538500  TEX 1.089E8
TAX RATE 6.724
CRIME RATE 3579.8 NORMAL 1900
```

```
YEAR 15
HOUSING 27316  20263  18698  24035  20009  8310
      996  7000  0  4258 TOTAL 130885
UNUSED SUPPLY 0  0  0  0  0  0  0  0  0  4258
UNMET DEMAND 0  0  0  0  0  0  0  3687
CHS 0  1006  359  ¯169  ¯675  ¯457  ¯66  0  0
      0
CHA ¯79  ¯44  ¯43  ¯61  ¯63  ¯255  ¯60  0  0
      200
NUB 0  0  0  0  0  0  0  0  0  0
WFH 0
HOUSEHOLDS 22647  8097  18781  10920  27632
      28795  4322  9120 TOTAL 130314
HME 0.76312  1.9734  0.48416  1.9734  0.76312
      1.9734  0.76312  1.9734
JME 1.1227  1.1227  1.0165  1.0165  0.86276  0.86276
      1  1
CME 1  1  1  1  1  1  1  0.1
GME 0.88457  0.88457  0.88457  0.88457  0.94012
      0.94012  0.94012  0.94012
NMI 635  587  245  581  513  1382  93  50
NMO ¯1141  ¯158  ¯1141  ¯163  ¯886  ¯357  ¯139
      ¯114
INC 10001  8751  7501  7501  4643  4643  2155
      2155 AVERAGE 6224.9
HDR ¯748  ¯203  ¯620  ¯273  ¯912  ¯864  ¯143
      ¯274
NHD 404  304  414  480  586  1006  25  334
WCH 0  0  0  0  ¯216  ¯911  172  728
JOBS 76573  46021  89178 TOTAL 211772
WJF 0.95075  0.98153  1.0727
GF 0.79055
BJC 486  ¯531  ¯571
GOVERNMENT   TAV 1268879600  TEX 1.3123E8
TAX RATE 7.9548
CRIME RATE 6237 NORMAL 2400
```

```
YEAR 20
HOUSING 26888  23966  19655  22870  16694  5167
      508  7000  0  5337 TOTAL 128085
UNUSED SUPPLY 0  0  0  0  0  0  0  0  0  5337
UNMET DEMAND 0  0  0  0  0  0  0  1234
CHS 0  456  104  ¯130  ¯291  ¯126  ¯15  0  0
      0
CHA ¯191  ¯69  ¯60  ¯74  ¯455  ¯385  ¯49  0
      0  412
NUB 0  0  0  0  0  0  0  0  0  0
WFH 909
HOUSEHOLDS 18078  10370  13061  13589  23005
      29159  4170  12550 TOTAL 123982
HME 0.67034  1.4822  0.35551  1.4822  0.67034
      1.4822  0.67034  1.4822
JME 1.1873  1.1873  1.0361  1.0361  0.89609  0.89609
      1  1
CME 1  1  1  1  1  1  1  0.64
GME 0.80845  0.80845  0.80845  0.80845  0.89155
      0.89155  0.89155  0.89155
NMI 430  545  116  506  369  1035  74  318
NMO ¯1135  ¯295  ¯1182  ¯295  ¯886  ¯508  ¯161
      ¯219
INC 10774  9427  8081  8081  4880  4880  2209
      2209 AVERAGE 6448.2
HDR ¯597  ¯260  ¯432  ¯340  ¯760  ¯875  ¯138
      ¯377
NHD 319  391  305  569  494  1073  24  386
WCH 0  0  0  0  ¯142  ¯735  113  587
JOBS 78204  42861  85223 TOTAL 206288
WJF 0.93188  0.96383  1.0521
GF 0.71929
BJC 84  ¯778  ¯1106
GOVERNMENT  TAV 1251885400  TEX 1.5813E8
TAX RATE 9.6605
CRIME RATE 8945.1 NORMAL 2900
```

```
YEAR 25
HOUSING 23619  24620  19478  21567  12452  2993
      261  7000  0  8636 TOTAL 120626
UNUSED SUPPLY 0  314  0  0  0  0  0  0  0  8636
UNMET DEMAND 0  0  0  0  0  0  0  3609
CHS 0  0  0  0  0  0  0  0  0  0
CHA ¯1484  ¯195  ¯362  ¯832  ¯1060  ¯362  ¯36
      0  0  1677
NUB 0  0  0  0  0  0  0  0  0  0
WFH 6511
HOUSEHOLDS 13035  12252  6949  15689  18360
      29333  3605  16062 TOTAL 115285
HME 0.55484  1.4183  0.19581  1.4183  0.55484
      1.4183  0.55484  1.4183
JME 1.2622  1.2622  1.0605  1.0605  0.89615  0.89615
      1  1
CME 1  1  1  1  1  1  1  0.73
GME 0.72764  0.72764  0.72764  0.72764  0.85305
      0.85305  0.85305  0.85305
NMI 245  590  31  515  233  954  51  425
NMO ¯1098  ¯404  ¯1269  ¯396  ¯893  ¯558  ¯176
      ¯306
INC 11607  10156  8705  8705  5129  5129  2265
      2265 AVERAGE 6610
HDR ¯431  ¯307  ¯230  ¯393  ¯606  ¯880  ¯119
      ¯482
NHD 224  466  188  644  397  1136  21  438
WCH 0  0  0  0  ¯102  ¯655  81  523
JOBS 77096  38063  77923 TOTAL 193082
WJF 0.914  0.94356  1.0521
GF 0.56213
BJC ¯865  ¯1332  ¯2176
GOVERNMENT   TAV 1153528600  TEX 1.9054E8
TAX RATE 12.351
CRIME RATE 11796 NORMAL 3400
```

```
YEAR 30
HOUSING 14234  19400  14345  14445  6782  1353
      108  7000  0  20756 TOTAL 98423
UNUSED SUPPLY 0  0  0  0  0  0  0  0  0  20756
UNMET DEMAND 0  0  0  0  0  12012  0  12521
CHS 0  0  0  0  0  0  0  0  0  0
CHA ¯2148  ¯2246  ¯1803  ¯2004  ¯1116  ¯258
      ¯22  0  0  1524
NUB 0  0  0  0  0  0  0  0  0  0
WFH 0
HOUSEHOLDS 7583  13659  1122  17178  13277  28399
      2860  18122 TOTAL 102200
HME 0.40384  1.3458  0.1  1.3458  0.40384  1.3458
      0.40384  1.3458
JME 1.314  1.314  1.0369  1.0369  0.82432  0.82432
      1  1
CME 1  1  1  1  1  0.5275  1  0.1
GME 0.58846  0.58846  0.58846  0.58846  0.82708
      0.82708  0.82708  0.82708
NMI 87  525  2  423  109  412  28  60
NMO ¯1085  ¯587  ¯496  ¯564  ¯915  ¯587  ¯197
      ¯375
INC 12504  10941  9378  9378  5391  5391  2322
      2322 AVERAGE 6744.9
HDR ¯251  ¯342  ¯38  ¯430  ¯439  ¯852  ¯95  ¯544
NHD 124  519  74  688  290  1142  16  462
WCH 0  0  0  0  ¯121  ¯1032  96  825
JOBS 69166  29475  63302 TOTAL 161943
WJF 0.90356  0.96315  1.0984
GF 0.34033
BJC ¯2630  ¯2138  ¯3863
GOVERNMENT  TAV 819697900  TEX 2.2961E8
TAX RATE 19.426
CRIME RATE 14544 NORMAL 3900
```

```
YEAR 35
HOUSING 5282  8377  5926  5629  2367  418  31
      7000  0  17838 TOTAL 52868
UNUSED SUPPLY 0  0  0  0  0  0  0  0  0  17838
UNMET DEMAND 0  531  0  9397  33  21991  0  15151
CHS 0  0  0  0  0  0  0  0  0  0
CHA ¯1127  ¯1677  ¯1211  ¯1181  ¯518  ¯96  ¯8
      0  0  ¯2448
NUB 0  0  0  0  0  0  0  0  0  0
WFH 0
HOUSEHOLDS 1782  12408  40  15283  8029  21991
      2094  20506 TOTAL 82133
HME 0.28179  1.2873  0.1  1.2873  0.28179  1.2873
      0.28179  1.2873
JME 1.3704  1.3704  0.86836  0.86836  0.6707  0.6707
      1  1
CME 1  1  1  0.1  1  0.1  1  0.1
GME 0.13412  0.13412  0.13412  0.13412  0.79717
      0.79717  0.79717  0.79717
NMI 3  108  0  6  36  45  14  63
NMO ¯1604  ¯2444  ¯78  ¯2302  ¯823  ¯493  ¯215
      ¯460
INC 13471  11787  10103  10103  5666  5666  2381
      2381 AVERAGE 6684.3
HDR ¯59  ¯311  ¯2  ¯383  ¯265  ¯660  ¯70  ¯616
NHD 32  486  36  620  179  991  12  451
WCH 0  0  ¯3  ¯406  ¯131  ¯1436  104  1148
JOBS 49405  16933  38219 TOTAL 104557
WJF 0.89361  1.1762  1.2255
GF 0.10148
BJC ¯8016  ¯3770  ¯8156
GOVERNMENT  TAV 377928100  TEX 2.7667E8
TAX RATE 46.588
CRIME RATE 17725 NORMAL 4400
```

APPENDIX II

DATA REDUCTION

This Appendix discusses the sources for data used in the simulation, and the reduction of that data to the form required. Most of the data comes from United States Census publications for Housing and Population. A list of these sources used is included in the list of References. In order to simplify this discussion, those figures obtained directly from sources will be called raw data, and the source will be indicated. Manipulated data will have no source identification, but it will follow from the raw data.

Housing

Data on the 1950, 1960, and 1970 housing stock had to be reduced to the number of owner occupied units, the number of rental units in several rent categories (in constant dollars), the number of public housing units, and the number of standing abandoned units.

The following raw data were used: (Table A2.1-A2.3)

TABLE A2.1

1950 RAW DATA (CENSUS OF HOUSING)

Total occupied dwelling units	121285
Total owner occupied units	28085
Total rental units	93200

RENT AND NUMBER OF UNITS (THOUSANDS)

Rent/month	<10	10-15	15-20	20-25	25-30	30-35	35-40
Number of units	.1	1.8	6.7	10.9	13.2	10.0	8.9

Rent/month	40-50	50-60	60-70	75-100	>100	not reported
Number of units	17.2	10.5	6.6	2.8	.8	3.5

TABLE A2.2

1960 RAW DATA (CENSUS OF HOUSING)

Total dwelling units	134872
Total occupied units	127772
Total owner occupied units	28828
Total rental units	98944

RENT AND NUMBER OF UNITS (THOUSANDS)

Rent/month	<30	30-40	40-50	50-60	60-70
Number of units	2.2	3.6	6.9	10.9	14.5
Rent/month	70-80	80-100	100-120	>120	
Number of units	15.7	27.7	10.7	5.1	

TABLE A2.3

1970 RAW DATA (CENSUS OF HOUSING)

Total occupied dwelling units	120934
Total owner occupied units	24849
Total rental units	96085

RENT AND NUMBER OF UNITS (THOUSANDS)

Rent/month	<50	50-60	60-70	70-80	80-100
Number of units	3.8	3.3	4.7	4.3	15.3

Rent/month	100-120	120-150	150-200	>200
Number of units	21.6	28.1	11.7	3.2

These data were adjusted for use in the simulation by first correcting the rent levels to 1967 constant dollars, and then fitting the rental units to the rent categories used in the model. The corrected data follow: (Estimated values, where used, are so indicated.)

TABLE A2.4

ADJUSTED HOUSING DATA (THOUSANDS OF UNITS)

		1950	1960	1970
Total Dwelling Units		127 est.	135	131 est.
Total Occupied Units		121.3	128	121
Owner Occupied Units		28.1	29.1	24.9
Rental Units		93.2	98.9	96.1
Rent Levels in Real Dollars	>120	4.7	13.7	24.3
	100-120	6.0	17.8	18.7
	80-100	15.7	28.2	27.0
	60-80	32.5	22.3	13.8
	40-60	27.8	12.6	9.0
	<40	6.5	4.3	3.3

The data in Table A2.4, combined with estimated values of public housing, yield the following housing data which the simulation's housing state variable should replicate.

TABLE A2.5

HOUSING DATA FOR STATE VARIABLE COMPARISON

(DWELLING UNITS IN THOUSANDS)

		1950	1960	1970
Owner Occupied Units		28.1	29.1	24.9
	>120	4.7	13.7	24.3
Rent	100-120	6.0	17.8	13.7
Levels	80-100	15.7	28.2	27.0
in Real	60-80	32.5	22.3	13.8
Dollars	40-60	26.8	10.6	5.3
	<40	5.5	2.3	0.0
Public Housing Units		2.0	4.0	7.0
Standing Abandoned Units		2	3	6
Total Occupied and Abandoned		123.3	131.0	127.0

<u>Household</u>

The household state variable data results from a combination of employment statistics and household counts. Derivation of the required figures is complicated by the fact that the format for presenting census data has changed over the years. The following data from the census of population have been used.

TABLE A2.6

1950 HOUSEHOLDS RAW DATA

(ALL FIGURES IN THOUSANDS)

Total Households	122.4		
Total Married Men	109.4	Total Married Women	110.5
Total Widows	25.5	Total Families	115.3

Labor Force Living in Newark	Male	Female
Professional, Technical	7.8	4.5
Managerial	13.1	1.9
Clerical	10.1	17.0
Sales	8.2	3.9
Craftsmen, Foremen	23.8	1.4
Operatives	33.8	21.3
Private Household Workers	.2	5.4
Service Workers	11.4	5.1
Laborers	11.9	.5

Blacks: Employed Males	17.8	Unemployed Males	3.3
Employed Females	12.5	Unemployed Females	1.8
Total Black Males	36.3	Total Black Females	39.4

TABLE A2.7

1960 HOUSEHOLDS RAW DATA

(ALL FIGURES IN THOUSANDS)

Total Household Heads	127.8	Black Household Heads	39.0
Total Wife of Head	80.5	Black Wife of Head	22.0
Total Individual Head	26.0	Black Individual Head	8.0

Labor Force Living in Newark	Total Male	Total Female	Black Male	Black Female
Professional, Technical	6.6	4.3	.6	.9
Managerial	5.7	1.1	-	-
Clerical	8.7	14.8	1.7	1.9
Sales	5.5	3.4	.5	.5
Craftsmen, Foremen	17.1	.9	3.2	-
Operatives	29.5	16.0	10.5	6.5
Private Household Workers	-	3.8	-	3.3
Service Workers	9.5	5.7	2.9	2.6
Laborers	9.7	-	5.0	-
Not Reporting	11.2	7.2	5.3	3.8

TABLE A2.8

1970 HOUSEHOLDS RAW DATA

(ALL FIGURES IN THOUSANDS)

Household Members	Total	Black
Household Heads	121	60.4
Individual Heads	30	14
Male Heads) Families	66	29
Female Heads) Families	24.6	17
Wives of Heads	61	27

Labor Force Living in Newark	Total	Total Female	Total Black	Female Black
Professional, Technical	11.6	5.2	4.1	2.5
Managerial	4.6	1.0	1.3	.4
Sales	5.2	2.2	1.8	.8
Clerical	25.6	18.1	11.3	8.2
Craftsmen, Foremen	15.1	1.1	6.5	.6
Operatives	43.7	17.1	23.4	8.7
Laborers	9.7	.6	5.0	.3
Service Workers	18.6	8.2	10.1	5.3
Private Household Workers	2.8	2.7	2.6	2.5

Reduction of the data in the preceding three tables yields two sets of figures; one dealing with numbers of households, the other with numbers of workers.

TABLE A2.9

ADJUSTED HOUSEHOLD DATA

(FIGURES IN THOUSANDS)

		1950	1960	1970
Black Households - Total		22	39	60.4
Black Individual Heads		3	8	14
Black Wives of Heads		12	22	27
Black Male Heads	Families	13	23	29
Black Female Heads	Families	6	8	17
White Households - Total		100	89	60.6
White Individual Heads		9	18	16
White Wives of Heads		73.3	58.5	34
White Male Heads	Families	78.8	61	37
White Female Heads	Families	11	10	7.6

TABLE A2.10

ADJUSTED EMPLOYMENT DATA

(FIGURES IN THOUSANDS)

	Year	White Male	White Female	Black Male	Black Female
White Collar	1950	29.6	21.4	.5	2.0
Blue Collar	1950	32.1	5.0	3.0	1.5
Unskilled	1950	39.9	20.6	14.3	10.5
White Collar	1960	20.2	19.0	2.6	3.3
Blue Collar	1960	22.2	4.4	7.1	3.1
Unskilled	1960	31.3	14.1	18.7	12.3
White Collar	1970	11.7	13.4	5.7	11.0
Blue Collar	1970	13.6	3.5	10.8	5.8
Unskilled	1970	18.3	10.4	20.5	12.3

By combining Tables A2.9 and A2.10 an estimate of black and white households can be achieved. These figures are shown in Table A2.11.

TABLE A2.11

HOUSEHOLD DATA FOR STATE VARIABLE COMPARISON

(HOUSEHOLDS IN THOUSANDS)

	1950	1960	1970
White White Collar	30	25	17
Black White Collar	2	4	9
White Blue Collar	30	22	13
Black Blue Collar	3	8	13
White Unskilled	36	36	22
Black Unskilled	15	22	25
White Unemployed	4	6	8
Black Unemployed	2	5	13

Jobs

The Job State Variable is derived from data obtained from the New Jersey unemployment insurance figures. These data are given in Table A2.12.

TABLE A2.12

NEWARK EMPLOYMENT RAW DATA (JOBS IN THOUSANDS. SOURCE: STATE OF NEW JERSEY, DEPARTMENT OF LABOR AND INDUSTRY, "NEW JERSEY COVERED EMPLOYMENT TRENDS")

Classification	1950	1960	1970
Manufacturing	88.6	79.5	64.3
Wholesale and Retail Trade	42.6	45.3	39.8
Transportation	10.4	12.6	16.6
Commerce and Utilities	8.9	10.0	11.5
Small Services and Amusements	14.9	20.6	25.9
Financial, Insurance and Real Estate	22.7	22.0	24.5
Construction and Contracting	5.0	5.1	6.0

To convert these data to categories by worker type, the conversion table shown in Table A2.13 was used. These figures represent estimates of the proportion of workers from each employment classification who are included in each skill category.

TABLE A2.13

FRACTION OF WORKERS IN SKILL CATEGORIES

Classification	White Collar	Blue Collar	Un-skilled
Manufacturing	.11	.40	.49
Wholesale and Retail Trade	.24	.12	.64
Transportation	.10	.10	.80
Commerce and Utilities	.78	.11	.11
Small Services and Amusements	.50	-	.50
Financial, Insurance and Real Estate	1.0	-	-
Construction and Contracting	-	.80	.20

Combining Tables A2.12 and A2.13, and adding a correction for jobs not covered by state unemployment insurance gives the values for comparison with the Job state variable. These are given in Table A2.14.

TABLE A2.14

JOB DATA FOR STATE VARIABLE COMPARISON

(VALUES IN THOUSANDS)

Category	1950	1960	1970
White Collar	65	70	75
Blue Collar	50	47	42
Unskilled	92	92	83

Municipal Expenditures

Newark's total municipal expenditures were obtained from the United States Census of Governments and City and County Data Books, for several years. These figures are given in Table A2.15 along with the values expressed in 1967 constant dollars.

TABLE A2.15

NEWARK'S TOTAL MUNICIPAL EXPENDITURES

(MILLIONS OF DOLLARS)

Year	Expenditure	Expenditure in 1967 Dollars
1950	53.6	74.5
1955	73.6	92.0
1957	80.8	95.8
1960	83.9	94.7
1962	93.5	103.3
1965	110.0	116.7
1967	143.1	143.1
1969	155.0	141.2
1971	198.0	160.5

Crime Rate Computation

The computation of crime rate presented in Chapter 7 is based on a formula derived from a multiple linear regression analysis of data from several northern industrial cities. These data are given in Table A2.16. The resulting equation is:

$$CR = 1393 - .012\ P + .028\ B + 1020\ U$$

where CR is crime rate in crimes per year per 100,000 population, P is total population, B is black population, and U is male unemployment percentage. The coefficient of determination for this equation was .88. This represents the best fit of all possible combinations of given data with the number of independent variables restricted to three or less.

TABLE A2.16

CRIME RATE DATA

City	Crime Rate CR	Population P (thousands)	Black Population B(thousands)	Male Unemployment U %	Median Family Income $ I	% Households Below Poverty Level PO
Cincinnati, O.	3850	452	125	4.2	8894	20.0
Buffalo, N.Y.	3960	463	94	5.9	8804	19.5
Rochester, N.Y.	4200	296	50	3.9	10002	13.9
Baltimore, Md.	6880	906	420	4.3	8815	18.4
East Orange,N.J.	4580	75	40	3.6	10125	12.5
Jersey City, N.J.	2960	261	55	3.8	9310	16.4
Newark, N.J.	8300	382	207	5.6	7735	23.2
Trenton, N.J.	7100	105	39	4.9	8726	18.3

CR = 1970 Crime Rate in Crimes per year per 100,000 persons
P = 1970 Total Population in Thousands
B = 1970 Black Population in Thousands
U = 1970 Male Unemployment Rate (percent)
I = 1970 Median Family Income (dollars)
PO = 1970 Percentage of Households below Poverty Level

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VITA

Education:

1967	B.S.E.E.	Newark College of Engineering
1968	S.M.E.E.	Massachusetts Institute of Technology

Work Experience:

1966	Summer Member Technical Staff, Bell Telephone Laboratories
1968-1971	Instructor in Electrical Engineering, Newark College of Engineering
Summer-1971, 1972	Instructor in N.S.F. High School Program for Inner City Students, Newark College of Engineering