URBAN DYNAMICS

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To My Father M. M. F.

Foreword

Much has been written of the crisis of the cities, the greatest domestic crisis to challenge America in a century. The National League of Cities and the United States Conference of Mayors in July 1968 issued a joint statement on the urban situation, which said in part:

The crisis of the City is in reality a national domestic erisis. It affects every segment of our society: urban jobless require welfare paid for by Federal dollars nationally collected, inadequate urban schools cast upon the nation another generation of people unprepared to make their own way, urban traffic congestion adds millions of dollars to the cost of items on neighborhood store shelves around the country. The crisis of the cities belongs to the nation.

"The nation cannot dissolve the urban dilemma by ignoring it or by suppressing its manifestations. The nation must face it, as it has faced crises in the past, by: acknowledging its basic causes; recognizing the nation's will and ability to resolve them; accepting that objective as its obligation to current and future generations; and reordering national priorities to assure the commitment of the kind and magnitude of resources required.

In this important and provocative book, Professor Forrester asks whether the measures we have adopted to alleviate urban problems have not in fact intensified them. If he is right in contending that some solutions in the past have been less successful than their proponents anticipated—and in a few cases even counter- productive in the long run—we must re-examine the problems of our cities, abandon a number of old approaches, and adopt or invent new modes of attack.

Whether Professor Forrester's conclusions are right will be a matter of con- siderable and spirited debate. He offers them as tentative proposals and invites challenge, comment, or amendment. The very debate this book will provoke—no matter what the outcome—will constitute an important and helpful event in the battle to save our cities.

The plight of urban America is so grave and complex that it clearly defies simple remedies. Professor Forrester makes the point that long experience with simple systems has shaped our intuitive short-term responses and that, however well motivated, they may be ineffective or even detrimental when applied to such a complex system as an urban area. viii Foreword

His book presents a new analysis of our urban dilemma based on the methods of "industrial dynamics" as applied to a simulation-computer model, or "system," of an urban area. Using a digital computer to simulate the behavior of the sys- tem, Professor Forrester attempts to isolate the dynamic characteristics of the sys- tem and to show how the behavior of the actual system might be modified.

Joun F. Coiiins Former Mayor of Boston, 1960-1967 Past President of National League of Cities Former Executive Committee Member of United States Conference of Mayors Massachusetts Institute of Technology Cambridge, Massachusetts November 1968

Preface

The problems of our aging urban areas are examined here by using recently developed methods for understanding complex social systems. The plight of our older cities is today the social problem of greatest domestic visibility and public concern, In this book the nature of the urban problem, its causes, and possible corrections are examined in terms of interactions between components of the urban system.

This book emerged when my work in "industrial dynamics" converged with the efforts of Professor John F. Collins to focus attention of the academic com- munity on the troubles of our cities. This examination of the urban system began in discussions with Professor Collins, who had taken the next office as a visiting professor at M.LT. after leaving bis position as mayor of Boston. His enthusiasm and his-desire to continue to analyze and improve urban processes ied to a joint endeavor to structure and model the dynamics of urban decay and revival.

Expecting the most valuable source of information to be, not documents, but people with practical experience in urban affairs, I suggested that Professor Collins organize informal discussions with

such men. He invited Daniel J. Finn, Joseph S. Slavet, and others to attend a series of lengthy meetings with us and a changing group of M.LT. students.

J approached these discussions knowing the conceptual nature of the structure being sought, but not the specific details of the structure or the institutional components of behavior to be fitted into it. The others brought the knowledge of the pressures, motivations, relationships, reactions, and historical incidents needed to shape the theory and structure of the specific social system. Discussions between the others, focused by me at the desired degree of aggregation to main- tain balance between detail and generality, gradually revealed a system structure that related system components to system behavior, When a system theory takes shape as a simulation model, its behavior precipitates more discussion and brings out additional supporting and contradictory information that helps refine the theory. The results of this process of discussion, crystallization, and re-examination are presented here.

The history of this effort explains why there are no references to the urban literature in this book. Several reviewers of the manuscript criticized the absence of ties to the literature on the assumption that such ties must exist but had not been revealed. Actually the book comes from a different body of knowledge, from the insights of those who know the urban scene firsthand, from my own reading in the public and business press, and from the literature on the dynamics of social systems for which references are given. There are indeed relevant studies on urban behavior and urban dynamics, but to identify these is a large and separate task.

'This study has depended heavily on having a time-shared computer facility available. Without the immediate accessibility provided by a personal computer terminal in my study at home, with day, evening, and week-end service, this exploration of urban dynamics would probably not have been undertaken. About four thousand pages have been processed through the computer terminal to establish the model, the computer runs, the definitions, and the organization of printed information. Part of the background studies of social systems were facili- tated by time-shared computer service made available by Project MAC at MLLT. Computer time for the publication of this book has been supported by the Ford Foundation through the Urban Systems Laboratory at M.LT.

Alexander L. Pugh Ili has been especially helpful in expediting this work with his skill and patience in accelerating the schedule of the DYNAMO II compiler to handle this large simulation model. His willingness, even at night and on week ends, to solve programing difficulties has substantially shortened the time required for this investigation.

'The encouragement of Gordon S. Brown and Charles L. Miller gave impetus for the additional effort needed to convert into a book what started as an informal series of discussions aimed at mutual enlightenment. Particularly helpful have been the criticisms of the first draft of the manuscript by O. B. Dial, Albert G. H. Dietz, Ithiel de Sola Pool, and Alien E. Pritchard, Jr. I am also grateful for the comments of Billy E. Goetz, Jack I. Hope, Edward J. Logue, Edward B. Roberts, Richard L. Schmalensee, and Paul N. Ylvisaker.

In developing the model and in preparing the manuscript and organizing related seminars and lectures, I have benefited from the enthusiastic assistance of Bruce A. Enders, Randall J. Hekman, and Phillip P. Weidner, all students at M.LT. The willingness of Miss Isabella S, Evans to retype the manuscript many times, under time pressure and often beyond normal office hours, has sustained the schedule of the book.

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1 Orientation

This book is about the growth processes of urban areas. An urban area is a system of interacting industries, housing, and people. Under favorable condi- tions the interplay between the parts of a new area cause it to develop. But as the area develops and its land area fills, the processes of aging cause stagnation. As the urban area moves from the growth phase to the equilibrium phase, the population mix and the economic activity change. Unless there is continuing renewal, the filling of the land converts the area from one marked by innovation and growth to one characterized by aging housing and declining industry.

If renewal is to succeed and a healthy economic mix is to continue, the natural processes of stagnation must not run their normal course. But the interactions between economic and social activity are so complex that intuition alone can not devise policies that prevent decay.

This book examines the life cycle of an urban area using the methods of industrial dynamics that have been developed at the M.LT. Alfred P. Sloan School of Management since 1956.* The term "industrial dynamics" has become too restrictive because the methods are applicable in many fields other than industrial management. The concepts of structure and dynamic behavior apply to all systems that change through time. Such dynamic systems include the processes of engineering systems, biology, social systems, psychology, ecology, and all those where positive- and negative-feedback processes manifest themselves in growth and regulatory action.

From the standpoint of industrial dynamics, systems are seen as feedback processes having a specific and orderly structure. From the structure of the particular system arises its dynamic behavior. The industrial-dynamics approach to a social system organizes the growth and goal-seeking processes of the system into a computer model. A digital computer is then used to simulate the behavior of the system. The computer simulation reveals the dynamic characteristics of the system that was described in the structure-formulating stage. By changing the guiding policies within the system, one can see how the behavior of the actual system might be modified.

*See Reference 1.

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In this book a particular simulation model of an urban area is examined. Such a model is a theory of urban structure and internal relationships. The model is a selection, from numerous alternatives, of factors that are believed pertinent to questions about urban growth, aging, and revival.

The growth model starts with a nearly empty land area and generates the life cycle of development leading to full land occupancy and equilibrium. A variation on the model is started with the equilibrium conditions that are reached at the

end of the growth life cycle. This equilibrium model is used to explore how various changes in policy would cause the condition of the urban area to be altered over the following fifty years.

Various common urban-management programs are examined. This model of an urban system suggests that many past and present urban programs may actually worsen the conditions they are intended to improve. Promising alternative pro- gtams, addressed to the underlying causes of urban decay rather than to symptoms, suggest different approaches.

The theory (model) of urban behavior presented in this book has so far been subjected to the scrutiny of only a few people who are professionally competent in the urban field. Interest and enthusiasm have been great enough to suggest that the results should at this time be more widely available than through informal seminars. Only with wider comment and criticism can the methods, the assumptions, and the results be adequately evaluated.

Although this book is presented as a method of analysis rather than as policy recommendations, it is probably unavoidable that many will take these results and act on them without further examination of the underlying assumptions. Doing so is unjustified unless the pertinence of the model itself is first evaluated against the requirements of the particular situation. The approach presented in this book is suggested as a method that can be used for evaluating urban policies once the proposed dynamic model or a modification of it has been accepted as adequate.

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The next six chapters contain the results from the simulation model and their implications for urban programs. The detailed description of the computer model itself is deferred to Appendix A on the assumption that most readers will want to see the uses to which the model can be put before devoting time to understand- ing the detailed internal structure.

Chapter 2 outlines the principles of structure found in any system and interprets how they apply to an urban area. The resulting model describes construction and population movement within a specific area. The area could be the political boundary of a city but usually will differ. The area treated here would be only a part of our larger cities. The appropriate area is small enough so that cultural, economic, and educational interchange is possible between its component popula~ tions. It could be a suburban area or the core area of a city but probably not an area containing both.

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The urban area is represented as a social system set in an environment with which it communicates. People in three categories—managerial-professional, labor, and underempioyed—can move into and out of the area. The flow to and from the area depends on the relative attractiveness of the area compared to its surrounding environment. Conditions in the surrounding environment are taken as a reference (which can be changing) and the attractiveness of the area rises and falls with respect to that moving reference. The attractiveness of the area, compared to its environment, depends on the conditions and activities within it. The environment is taken as a limitless source. It can supply people as long as the area is more attractive. It can absorb people who leave when the area is less attractive. These three concepts of specific land area, relative attractiveness, and the limitless environment are important in understanding this model of urban processes. (They are explained more fully in later sections.)

In Chapter 3 the life cycle of an urban area is generated by the simulation model and shows how growth gives way to maturity and then stagnation. The area is a complex, self-regulating system that creates internal pressures to modify economic activity and shift the uses of land, structures, and people. These changes are dominated by the construction, aging, and demolition of industry and housing combined with concurrent population movements.

As a preview of Chapter 3, Figure I-1 is a 250-year life cycle of an urban area generated by the computer in accordance with the urban theory described in the model. The figure shows the area starting with almost empty land and developing over a period of 100 years. By that time the land area has become filled, new construction decreases, and the urban system stagnates into a high level of underemployed housing and declining industry. The economic mix becomes unfavorable with too high a ratio of underempicyed to skilled labor. Too high a proportion of the housing is in the underemployed-housing class, and too high a proportion of industry is in the declining-industry category.

These changes, as the area emerges from growth and enters the stagnation phase, occur as a result of the aging of structures and the consequent change of activity occurring in them. In the growth phase industry has a high intensity and employment per unit of industrial land area is high. At the same time housing is constructed for those engaged in the expanding industry, the residential popula- tion is economically successful, and the population density is low per unit of residential land area, The type of construction determines and freezes the ratio of industrial to housing area. Then, as the structures age, the industrial vitality declines, new industries start elsewhere, and employment per unit of industrial jand declines. But the opposite happens to population as housing ages. Rental costs decline and the kind of occupancy shifts to those people whose economic circumstances force more crowded population density per unit of residential land. In short, starting from a balance between industry and people at the end of the growth phase, employment declines while population rises until an equilibrium is reached in which the economic condition of the area falls far enough to limit further growth in population. 0

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that often exist in a social system in equilibrium. Here a regenerative process has caused the labor population to fall, which makes the area less attractive to industry; hence there are fewer jobs, which further discourages labor. Because available jobs have decreased while the number of underemployed remains almost constant, the underemployed /job ratio (not shown until Chapter 4) has risen 30% by the end of 50 years. A program can have subtle ramifications when it disturbs the equilibrium within an urban system. Although the underem- ployed/housing ratio (not shown) fell from an initial satisfactory value of .8 to a final value of .5 (representing a very low population density for that economic class) there was an associated increase in the ratio of underemployed to available

"S.. Underentployed jobs. SS eed . cas . « "Worker hopsing The unfavorable change in employment opportunities accompanying an im-

provement in housing (as in Figure 1-2) is not accidental. As will be seen throughout this book, the urban area tends toward an attractiveness equilibrium with its surroundings. The area has a certain composite attractiveness to each

class of person. (At the lower end of the economic scale this might better be Matire bissincks' referred to as unattractiveness.) A mixture of many components (for example, ESTES EESS housing, jobs, public services, legal restrictions, prejudice, racial and ethnic

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Figure 1-1. Life cycle of an urban area—250 years of internal development, maturity, and stagnation.

Chapter 4 examines urban-revitalization programs of four common kinds, none of which yield substantial improvement. Some of the programs make conditions of the area worse (as in Figure 1-2). Here the urban area starts in equilibrium with the same stagnation conditions that existed at the 250th year in Figure 1-1. At time = 0 in Figure 1-2 a low-cost-housing program has been started. Low-cost housing is constructed each year for about 2.5% of the underemployed population. The result is a further unfavorable shift in the condition of the area.

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created by the housing, the underemployed population rises 10% in the first 10

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In Figure 1-2 housing for the underemployed rises 45%, most of the change Worker honing , occurring in the first 30 years. Because of the added attractiveness of the area . : : Seezzzzsdaregecceas

years but then falls back as the decrease of industry reduces the number of 7 Mature business

available jobs, diminishing the attractiveness of the area. The labor population ee 3 atin Gada di 22 3 (skilled labor) falls 30%, as does worker housing for labor. The additional low- oti ~ cost-housing construction slightly reduces the available land area and alters the a ;

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population mix. This pressure on available land, along with a 16% rise in tax rate (not shown in the figure), makes the area less attractive for business and

leads to a decline of 49% in new enterprise and 45% in mature business. This Figure 1-2 Changes in an urban area resulting from Iow-cost-housiag construction for 2.5% of the under- surprisingly large change results from shifts in the multiplicity of delicate balances employed each year. US yLSL PHP WHEN, UHH JHP=W,NE=E,MB=® 01 =D

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Figure 13 Changes caused by slum-housing demolition of 5% per year and new-enterprise construction of about M% per year started at time = 0. In I-3a note the rise in labor, mature business, and new enterprise: the decrease in underemployed housing; and the upward economic movement of underemployed into the labor class. In 1-36 see the decrease in the underomployed/underemployed-jobs ratio. The underemployed/ underemployed-housing ratio necessarily rises to more crowded conditions as the job ratio improves.

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groupings, and traditions) forms the attractiveness image of an area. Because

of freedom to migrate (tempered by all the forces contributing to attractiveness), attractiveness to any class of person tends to become the same for all tegions. If not, population flow continues until attractiveness equilibrium is reached.

However, a specific composite attractiveness can result from many different mixtures of attractiveness components. As one component rises, another can fall. The urban area may have no choice in the composite value of attractiveness because of the equalizing effect of population movement, yet it may have a wide choice in the trade-offs between components of that attractiveness, In Figure 1-2 the area, through its natural processes, raises unemployment to compensate for improved housing.

Chapter 5 examines a series of policies for reversing urban decline. These policies are directed, not at a frontal and expensive assault on the symptoms of trouble, but instead at the causes. An example is Figure 1-3 where, at time = 0, two program changes have been made which continue through the following 50 years.* One program is the demolition of 5% per year of underemployed housing (slum housing). The other program is the generation of between 1% and 2% per year of new enterprise.

Figure 1-3a shows a decrease of 44% in underemployed housing. The popula- tion in the underemployed category falls 8%. Skilled labor climbs 62%, while worker housing for that population class rises 33%. Mature business and new enterprise both increase 75%. The economic balance of the area has shifted substantially in the direction of more activity and a much more favorable ratio of skilled labor to underemployed. This shift from underemployed to labor population is accomplished by a higher upward economic mobility for the underemployed that accompanies the industrial revival. At the same time a corresponding shift from underemployed to worker housing delays an increase in the underemployed immigration rate so that economic rebalancing is not defeated.

Figure 1-35 shows other variables in the urban system during the same time interval as Figure 1-32. The underemployed/job ratio has improved from 1.8 to 1.0 by increasing employment opportunities to balance with the underemployed population. The underempioyed/housing ratio has risen from .8 to 1.3, or 63%, indicating a housing shortage. Tax assessments have fallen 19%.

Because of the demolition of slum housing and its replacement by industry, the new policies in Figure 1-3 might appear at first glance to favor the upper- income groups at the expense of the underemployed. But the number of underem- ployed living in a city is not a measure of the city's social value; quite the contrary. 'The city should not concentrate the less successful economic

classes into decaying areas that lack economic opportunity. If we think of the city as a socioeconomic converter, one measure of its effectiveness is the upward economic mobility from the underemployed to the labor class. In Figure 1-3 the net flow of people from underemployed to labor (not shown) has increased 114%. After reaching a better

"Figure 1-3 combines the conditions of Figures 5-6 and 5-10. Laks

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economic balance, the area is more effective in upgrading skills and carning ability.

"Although the policies of slum. demolition and new-enterprise construction in Figure 1-3 have reduced the underemployed population, this has not been done by driving underemployed from the city (more detailed information in Chapter 5 and Appendix B). At all times after the inauguration of the new policies, the underemployed-arrival rate into the city is higher and the departure rate is lower than before the policy changes. The reduction in underemployed population results from greater movement of underemployed into the labor class. At the same time underemployed-housing conditions have shifted to limit the inward population flow so that it does not rise faster than the revitalized area can absorb. Because the populations are constant in equilibrium, the greater intake of under- employed must be balanced by a higher outflow of trained labor and managers, representing greater economic contribution from the revived area to the surround- ing environment.

Figure 1-3 shows the converse of the behavior shown in Figure 1-2. Because of the reduced availability of underemployed housing, immigration does not rise excessively and the ratio of underemployed to jobs has an opportunity to improve. In both situations the city comes into an attractiveness equilibrium with its environment, but in the second situation this equilibrium is produced by a lower housing attractiveness (Jess availability but probably higher quality) coupled with much-improved job opportunitics.

In the stagnant city there is crowding and empty housing at the same time. The ratio of people to housing may be low, but for economic reasons many of the dwelling units are unoccupied. Scarce jobs and low income force people to share space and rental costs. To start the renewal process illustrated here, slum demolition begins to make room for industrial sites to provide employment. Employment begins the upgrading of skill and income to shift population to the labor status and into the new worker housing for which they create a demand. Continuing demolition of slum housing keeps the underemployed influx from rising faster than the increase in employment opportunities.

Chapter 6 comments on simulation and the modeling of social systems.

Chapter 7 illustrates how model studies can be interpreted in terms of urban policies and programs. The city emerges as a social system that creates its own problems. If the internal city system remains structured to generate blight, external help will probably fail. If the internal system is changed in the proper way, little outside help will be needed, Recovery through changed internal incentives seems more promising than recovery by direct-action government programs. But to generate this recovery, trends in tax laws and land-use zoning will need to be reversed.

In complex systems long-term improvement often inherently conflicts with short-term advantage. The greatest uncertainty for the city is whether or not education and urban leadership can succeed in shifting stress to the long-term actions necessary for internal revitalization and away from efforts for quick results

that eventually make conditions worse. Political pressure from the outside to help

the city emphasize long-term, self-sustaining recovery may be fat more important than financial assistance.

1.2 Background

This study of urban dynamics was undertaken principally because of discoveries made in modeling the growth process of corporations. It has become clear that complex systems are counterintuitive. That is, they give indications that suggest corrective action which will often be ineffective or even adverse in its results. Very often one finds that the policies that have been adopted for correcting a difficulty are actually intensifying it rather than producing a solution.

Choosing an ineffective or detrimental policy for coping with a complex system is not a matter of random chance. The intuitive processes will select the wrong solution much more often than not. A complex system—a class to which a corporation, a city, an economy, or a government belong—behaves in many ways quite the opposite of the simple systems from which we have gained our experi- ence.

Most of our intuitive responses have been developed in the context of what are technically called first-order, negative-feedback loops. Such a simple loop is goal-seeking and has only one important state variable. For example, warming one's hands beside a stove can be approximated as a first-order, negative-feedback loop in which the purpose of the process is to obtain warmth without buming one's hands. The principal state variable of the loop is the distance from the stove. If one is too close he burns his hands, if too far away he receives little heat. The intuitive lesson is that cause and effect are closely related in time and space. Temperature depends on the distance from the stove. Too much ot too little heat is clearly related to the position of the hands. The relation of cause and effect is immediate and clear. Similarly, the simple feedback loops that govern walking, driving a car, or picking things up all train us to find cause and effect occurring at approximately the same moment and location.

But in complex systems cause and effect are often not closely related in either time or space. The structure of a complex system is not a simple feedback loop where one system state dominates the behavior. The complex system has a multiplicity of interacting feedback loops. Its internal rates of flow are controlled by nonlinear relationships. The complex system is of high order, meaning that there are many system states (or levels). It usually contains positive-feedback loops describing growth processes as well as negative, goal-seeking loops. In the complex system the cause of a difficulty may lie far back in time from the symptoms, or in a completely different and remote part of the system. In fact, causes are usually found, not in prior events, but in the structure and policies of the system.

'To make matters still worse, the complex system is even more deceptive than merely hiding causes. In the complex system, when we look for a cause near in time and space to a symptom, we usually find what appears to be a plausible '

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cause, But it is usually not the cause. The complex system presents apparent causes that are in fact coincident symptoms. The high degree of time correlation between variables in complex systems can lead us to make cause-and-effect associations between variables that are simply moving together as

part of the total dynamic behavior of the system. Conditioned by our training in simple systems, we apply the same intuition to complex systems and are led into error. As a result we treat symptoms, not causes. The outcome lies between ineffective and detrimental.

This failure of intuition has often been found in the corporate setting by the process of building a simulation model of the policy structure of the organization.* Often it is possible to show that those policies and practices of which the organiza- tion is most aware are by themselves sufficient to create the difficulties that plague the 'organization. In fact, often the very things being done to correct the difficulty make it worse. If the attempted solution intensifies the problem, wrongly attrib- uted to another source, the organization likely will redouble its "corrective" action, producing more difficulty and pressure for still more remedial action. A

destructive spiral becomes established.

The likelihood that these same counterintuitive processes might be at work in a system as complex as a city provided the major incentive for undertaking this study.

The pervasive sense of failure and frustration among men concerned with management of urban affairs points to the likelihood that the inherent behavior of complex systems defies the intuitively "obvious" solutions of the past. Among political leaders, managers of redevelopment activity, and political scientists interviewed in connection with this study, there was the overwhelming opinion that the problems of the urban area remain severe in spite of the variety of programs that have been tried over the last three decades.

Contributing to the selection of ineffective programs is the nature of the conflict between short-term and long-term considerations in complex systems. Very often the actions that scom easiest and most promising in the immediate future can produce even greater problems at a later time. Humanitarian impulses coupled with short-term political pressures lead to programs whose benefits, if any, evaporate quickly, leaving behind a system that is unimproved or in worse condition. Job-training programs, low-cost-housing programs, and even financial aid, when used alone without improvements in the economic climate of a city, can fall into this category of short-term promise followed by detrimental long-term. change.

Another purpose of this study is to focus attention on the entire life cycle of an urban area. A few of those interested in urban areas have shown a tendency to turn away from the old, decaying inner city and to concentrate on new cities as a solution to the urban problem. But a new city becomes old. If the normai processes of stagnation and decay are allowed to continue in young cities that

Reference 2, where suppression of growth in a product caused by the capital-investment policy can easily be attributed to assumed shortcomings in the sales department,

are still in good health, they too will falter. Furthermore, the processes of stagna- tion and decay that one sees in today's urban areas will, unless preventive measures are taken, overwhelm the present healthy suburban areas. Urban difficulties are not a matter of location so much as a phase in the normal life eycle of occupied land.

For all these reasons it seems urgent that we begin to understand the growth and aging process of a city. This book is intended as a contribution to that understanding. It is preliminary. It suggests a method of attack. It is not presented as a set of final answers to guide urban policy-making. Before implementing the kinds of policy changes that are explored in this book, there should be much more

examination of the theory of urban growth herein proposed. 4 i i I : fa 4 : \ ' i ;

2 Structure of an Urban Area

2.1. General Structure of Systems

Before discussing the specific structure chosen here to represent an urban area, the general nature of structure as found in all dynamic systems will be sum- marized.* To model the dynamic behavior of a system, four hierarchies of structure should be recognized:

Closed boundary around the system Feedback loops as the basic structural elements within the boundary Level (state) variables representing accumulations within the feedback

loops

Rate (flow) variables representing activity within the feedback loops Goal Observed condition as components of Detection of discrepancy a rate variable

Action based on discrepancy.

Closed-System Boundary. To develop a complete concept of a system, the bound- ary must be established within which the system interactions take place that give the system its characteristic behavior. Figure 2-1 symbolizes the closed-boundary concept. The boundary is chosen to include those interacting components neces- sary to generate the modes of behavior of interest. If a particular difficulty in a system is being investigated, the system described within the boundary should be capable of generating that difficulty. The closed-boundary concept implies that the system behavior of interest is not imposed from the outside but created within the boundary.

The closed boundary does not mean that the system is unaffected by outside occurrences. But it does say that those outside occurrences can be viewed as random happenings that impinge on the system and do not themselves give the system its intrinsic growth and stability characteristics.

*For additionat discussion of the general theory of structure, see References 4 and 6,

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Dynamic bebavior generated within the boundary. Characteristic modes of behavior created bby internctions within the boundary.

Figure 21 Closed boundary defining a dynamic system.

To build a computer simulation mode! of a system, one must first estimate what components are interacting to produce the behavior being investigated. The choice selects those components which lie within the dynamic boundary for the particular study and excludes all other potential components as being irrelevant to the study and therefore outside the dynamic boundary.

Feedback-Loop Structure. The dynamic behavior of systems is generated within feedback loops. Feedback loops are the fundamental building blocks of systems. Figure 2-2 shows the simplest possible feedback-loop structure. A feedback loop is composed of two kinds of variables, called here rate and level variables. These two kinds of variables are necessary and sufficient. The simplest

possible feedback loop must contain one of each. A feedback loop is a structure within which a decision point—the rate equation—controls a flow or action stream. The action is accumulated (integrated) to generate a system level. Information about the level is the basis on which the flow rate is controlled.

The distinction between rates and levels—often with other terminclogy-—is recognized in many fields. In economics flows and stocks are often used to mean the same as rates and levels mean here. In accounting the two kinds of variables are sharply distinguished. The balance sheet of a corporation lists the values of level variables. The profit-and-loss statement represents rates of flow and corresponds to the rate variables (except for a small technicality arising because

Controfled { flow

~-q Level

Figure 2-2 Simplest possible feedback loop having one rate and one level.

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profit-and-loss variables are averaged over a time period rather than being instantancous values). In psychology Lewin* describes psychological field theory in such terms that it is clear his "life space" is a set of level variables subject to being changed by various rates. In engineering the "state-variable" approach to engineering systems refers to the same concept here called levels.

In a feedback loop the level variables are accumulations or integrations. A bank balance, the number of people in a city, the number of new enterprises, or the amount of slum housing are all level variables. Each results from accumulat- ing or integrating the inward and outward flows. The rates of flow cause the levels to change. The levels provide the information inputs to the rate equations which control the flows. Levels are changed only by rates of flow. The rate variables depend only on information about the ievels. No rate can directly affect any other rate and no level directly affects any other level. One level can affect another only through an intervening rate. Any path through the structure of a system will encounter alternating levels and rates, never two variables of the same type in succession.

The rate equations are the statements of system policy. They determine how the available information is converted to an action stream. Within each rate equation there is explicitly or implicitly a goal toward or away from which that decision point in the system is striving. There is also a process whereby the observed condition of a system is detected. It is the observed condition, not the true condition, that determines action. Very often in systems the perceived condition of the system is distorted and lags with respect to the true condition. A rate equation states the discrepancy between the goal and the observed condi- tion. And finally, the rate equation states the action that will result from the discrepancy. an

Using these concepts of structure, we now proceed to represent an urban area.

2.2 Structure of the Urban Mode!

When first modeling a social system it is usually best to model the general class of system rather than a specific system. Here, this means a model to represent the central processes common to all urban areas rather than to represent those of a specific area. The general model will be simpler and more basic because it omits the peripheral considerations that may be special to a particular place. It focuses on those system components that are always to be found interacting in urban growth and stagnation. The model should include only those processes necessary to the creation and correction of urban decay.

Boundary of the Urban System. The first step in modeling the urban interactions is to choose a system boundary that defines the concepts that interact to produce the behavior of interest. Interest here is in the broad sweep of how an area evolves.

The model should show how an area develops from empty land and eventually

*Reference 3.

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Figure 23. The urban area in its limitless environment.

filis that land with decaying housing and declining industry to produce economic stagnation. For an urban area in its stagnation phase, we are interested in the policy changes that can produce revival and a return to economic health.

Urban growth and stagnation do not appear to require changes in the world environment as a cause. The urban problem is not limited to any single couniry, society, or historical era. The behavior of a city is much more directly dependent on its own economic merit and its changing internal mix of industry, housing, and population. Most urban areas seem to evolve through a similar pattern. It can be assumed that any one area is small enough in the world setting not to affect the outside environment. For our purposes the urban area can therefore be taken as a living system that communicates with an environment it does not substantially influence.

Figure 2-3 suggests an urban area in a limitless environment. The area com- municates with the environment but does not alter it, People from the outside come into the area and leave it without affecting the outside.

'The specific system boundary is most easily defined in terms of the interacting components that are to be included within the system. Figure 2-4 shows the principal level variables and rate variables chosen as the central framework of an urban system. The nine rectangles represent the system levels. They are accumulations generated by the net rates which flow in and out of each level. 'The 22 principal rates are shown by the valve symbols controlling the flow streams. Not shown is the network of information connections from the levels to the rates.

In Figure 2-4 are three subsystems: business, housing, and population. These a7

DID SHD UA

Né 95 16

UB

'Underemployed 3

Declining industry

Underemployed housing

Dr UH

UD

14 30 7

WHO LTU

UTL

49

LB 31 29 LD

Labor

Matore business 'Worker housing

MB WH 4b

WHC LA

3a

NED mM

PHO

LTM

100 B

52 Figure 2-4 Tne major levels (rectangles) and rates (valve symbols) for the model of an urban area

MPB

New enterprise MA

Premium housing

Managerial-professional

NE PH MP

101

NEC PHC MD

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three subsystems are chosen because they appear to be the dynamic framework of urban structure. The changes in housing, population, and industry are the central processes involved in growth and stagnation. They are more fundamental than city government, social culture, or fiscal policy. Observation of the city suggests that the important changes involve shifting populations as housing structures age and industry falls behind the outside economy.

The aging of a city is here conceived as an internal process, like the aging of a person. Aging is not a series of changes generated and imposed primarily by the outside environment, although changes from the outside might hasten or retard the process. In Figure 2-4 the levels (rectangles) and rates (valves), along with the information connections from levels to rates (not shown), represent the system components within the dynamic boundary. The "cloud" symbols are the sources or destinations of flows going from or to the outside environment. The flows from or to the outside are controlled only by conditions within the system.

sais

The Environment as a Point of Reference. If flows from and to the outside are controlled only by the levels within the system boundary, the outside environment is implicitly taken as a reference. If conditions in the urban area are more favorable than those outside, people and industry will move in, and of course the reverse is true.

There is no need to assume that the reference environment is fixed and unchanging. Of course it does change over a period of several hundred years in the life of a city. We do assume that the "normal" condition of a city changes along with the outside reference. Our attention is focused on how the particular city differs from the normai as it evolves.

This concept of the closed boundary within which lie the components that create the behavior of interest is apparently hard to explain. The closed boundary and the limitless environment are two sides of the same coin. Certain components interact to create the kinds of responses being studied. These, by definition, lie within the boundary. Anything that is not essential to creating the behavior of interest is, by that lack of essentiality, on the outside in the unspecified environment.

Elements outside the boundary are related to those inside very differently than the inside elements are related to one another. The cause-and-effect relationships between environment and system are unidirectional, whereas the internal ele- ments are structured into feedback loops that cause the internal clements to interact. The environment can affect the system, but the system does not sig- nificantly affect the environment, In terms of loop structure, there are no loops essential to this study that run from the system to the environment and back to the system.

Let us illustrate these comments about system. versus environment. Critics of the concept of an urban area as a closed dynamic system might argue that mechanization of agriculture in rural areas has accelerated migration to American cities. Or, in some countries, famine in rural areas has increased migration to

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the city. These comments are of course true. But these influences are not the primary causes of aging and stagnation in cities. If slum areas can be generated without such external changes, then internal interactions must be more essential.

The open-loop test of independence between system and environment can be stated as follows: Mechanization of agriculture in the environment can increase pressure on a city, but does the development ofa city slum affect the mechanization of agriculture in any direct way? Probably not. Similarly, weather may affect mi- gration, but migration does not affect weather. This break in reverse causality dy- namically separates the environment from the urban system discussed in this book.

The closed dynamic boundary does not mean that the urban area is isolated. People come and go.-Commerce exists. But it does mean that cause-and-effect loops do not reach outside the boundary and return. For example, migration to the area has its effect by filling and thereby altering the area, not by emptying the outside world.

These assumptions will be satisfactory as long as a city does not dominate the social system within which it lies. The assumption of a city existing in a limitless environment might need revision for analysis of a large city in a small country with strong barriers against immigation.

All other urban areas, even those that are part of the same city, are part of the outside environment. The area being modeled communicates with the sur- sounding countryside and other urban areas in the environmental setting.

So the urban area is represented as a living, self-controlling system that regu- lates its own flows of people to and from the outside environment. This approach does not assume that either the area or the outside world is static. It assumes that the technology, the living standards, and the nature of economic activity in the area change to keep pace with the outside. The changing outside environment is not pertinent to this book.* We are here concerned only with how the urban area performs relative to that outside. If the area is more attractive to a particular class of person, inward migration of that class occurs. If the area is less attractive, outward migration occurs.

Relative Attractiveness. Using the environment as a reference point means that conditions within the urban model are being generated relative to the environ- ment, The model shows how the area becomes more or less attractive than the surrounding country and other cities and thereby causes the movement of industry and population to and from the area. Only differences in attractiveness between the area and environment are significant. The model does not, and need not, deal with changing technology and a rising national standard of living. We are interested in urban improvement relative to the absolute reference set by the outside environment.

* Appendix B shows how the choice between alternative policies is independent of outside environmental

changes. The better policy remains better as the outside changes, even though the absolute desirability of the city does change with external conditions.

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The Internal System. The top subsystem in Figure 2-4 contains three levels and four rates representing business activity. At the upper left new-enterprise units are created. An enterprise unit is here taken as a standard land and building area. Principally as a function of time and aging, the new enterprise shifts to the category of mature business. After the further passage of years mature business ages into the category of declining industry and still later is demolished and disappears. The flow from one category of business activity to the next depends not only on time but on the condition of the entire urban system.

The middle subsystem in Figure 2-4, containing three levels and six rates, represents the construction, aging, and demolition of housing. Premium housing, associated with the managerial-professional population, is constructed on the left. After an aging time and depending on the need for premium housing, the pre- mium housing declines into the worker-housing category. In addition worker housing is constructed directly without passing through the premium-housing category. Worker housing ages and declines into the underemployed-housing category. The rate of

obsolescence from worker housing to underemployed hous- ing again depends on time and on the demand for worker housing. If a low-cost- housing program exists, it creates underemployed housing directly. The under- employed housing disappears through the slum-housing-demolition rate, which depends on the age of the underemployed housing and on the occupancy ratio.

The lower subsystem in Figure 2-4, with three levels and twelve rates, repre- sents the population. Three categories of people are shown—managerial-profes- sional, labor, and underemployed. The labor is skilled labor fully participating in the urban economy. Underemployed workers include, in addition to the unemployed and unemployable, people in unskilled jobs, those in marginal economic activity, and those not seeking employment who might work in a period of intense economic activity. People can enter each category from the outside environment and leave to the outside. Each category has an internal birth rate. There is also an upward economic mobility from the underemployed to the labor class and from the labor class to the managerial-professional group. In addition there is a downward economic mobility from labor to underemployed. The flow rates depend on the population mix, available housing, and jobs provided by industry.

In the system a direct correspondence exists between the three housing cate- gories and the three population categories. This defines what is meant by the housing categories. The managerial-professional group live only in premium housing; the labor group, in worker housing; and the underemployed, in underem- ployed housing. This relates the housing to its cost and to the economic classifica- tions of the population.

However, there is no direct correspondence between the business units and the population. Each category of business employs each population category. A new-enterprise unit of business employs more people than a mature-business unit; the latter employs more than a declining-industry unit. Furthermore, the person- nel mix changes with a higher ratio of managers to skilled labor in the new-enter~ 20° Chapter Two

prise category and with the managers proportionately declining as the new-enter- prise unit ages into mature business and further decays into the declining-industry category. The table below defines a productive unit in terms of the employment mix under normal economic circumstances.* For example, a new-enterprise unit under normal conditions is defined as employing 4 managers, 20 labor men, and 10 underemployed workers. The important characteristics assumed for a business unit are the declining employment and the shifting personnel mix as the business

unit ages.

	Managerial- Professional	Labor	Underemployed
New Enterprise NEM =	4		10
Mature Business	15	5	
Declining Industry DIM =			

A corresponding shift in population density defines the principal distinction between categories of housing units as a unit ages and passes through the three categories of housing, as shown in the table below:

Premium-Housing Population Density (PHPD) = 3 persons/housing unit Worker-Housing Population Density (CWHPD) = 6 persons/housing unit Underemployed-Housing Population Density (UHPD) = 12 persons/housing unit

These housing densities represent the normal if housing and population are in economic balance. The actual densities of people per housing unit may run higher or lower depending on the population and available housing.

Figure 2-4 shows the principal system levels and the related rates of flow, but it does not show the connections from the system levels to the rates. Each rate of flow is determined at any given moment by the values of several system levels. The network of connections from the level variables to the rates would be too complex and confusing to superimpose in its entirety on Figure 2-4, but in the next section one information network, that connecting the system levels to the underemployed-arrival rate, will be examined as a typical illustration of how all system rates are related to levels, (The detailed development of the computer model representing the dynamics of an urban area is given in Appendix A.)

2.3 Example of a Flow Rate

Connections between system levels and one rate are shown in Figure 2-5. Here

the nine principal system levels, carried over from the preceding figure, appear in the background. The dash lines carry the system levels through various inter- mediate concepts shown in the circles to generate the attractiveness-for-migration

"As will be seen later, the jobs open (o the underemployed depend on the ratio of skilled labor to labor jobs, If labor is in short supply, the underemployed fill 2 proportionately larger fraction of the jobs. If labor is in oversupply, labor tends to fll the jobs that would otherwise be available to the underemployed. In the table above the lelter groups are the symbols used in the model equations in Appendixes A, C, D, and F.

NE PH MP

ema levels determine the underemployed-artival rate UA. (Letter groups are the symbols in

Syst lentify the system equations, as in Appendix A.)

the equations and numbers ide

Figure 2-5 A typical set of influences controlling a flow rate. Shows how the

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multiplier AMM. The present actual urban attractiveness is not perceived im- mediately by those in distant places who might migrate to the area. A perception- time delay is shown in the rectangle marked "2," for Equation 2, which generates the attractiveness-for-migration multiplier perceived AMMP. The iatter in turn modulates the flow of underemployed population into the area.

In Figure 2-5 the attractiveness-for-migration multiplier AMM is based on five influences. These are the underemployed-arrivals-mobility multiplier UAMM, the underemployed/housing multiplier UHM, the public-expenditure multiplier PEM, the underemployed /job multiplier UJM, and the underemployed-housing- program multiplier UHPM. These five variables combine to influence the under- employed arrivals UA entering the area. Figure 2-6 summarizes these five in- fluences on the underemployed-arrival rate. Upward economic mobility expressed by UAMM makes the area more attractive. Available housing as generated by

| Graphic | Name of | Situation Evaluated | Symbol Multiplier | by Multiplier | Response to Evaluation |

Graphic Name of Situation Evaluated . Symbol Multiplier by Multiplier Response to Evaluation UNDEREMPLOYED- How readily are the The larger the percent: ARRIVALS-MOBILITY underemployed moving age that moves from the MULTIPLIER into the skilled-labor underemployed to the class? labor class per year, the more attractive is the city to outsiders. UNDEREMPLOYED/ Are there underemployed- The more _underem- HOUSING housing vacancies in the _ployed-housing vacancies MULTIPLIER city? in the city, the greater the attractiveness of the city. PUBLIC- How much tax money The more spent per EXPENDITURE, is being spent per capita capita, the greater is the MULTIPLIER in the city? public service offered by the city and the greater its attractiveness fo out- siders. UNDEREMPLOYED/ How many jobs are — The more jobs available, JOB available for under- the more attractive is MULTIPLIER employed people? the city to outsiders. UNDEREMPLOYED- Is there a construction The more houses con-

HOUSING- program for low-cost structed per year in the PROGRAM housing in operation? _—_program, the greater the MULTIPLIER attractiveness of the city.

Figure 26 Influences on underemployed-arrival cate

sesame

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UHM attracts underemployed to the area. Public expenditure PEM for schools, services, and welfare makes the area attractive. The measure of available jobs UIM is a strong influence on attracting those looking for economic opportunity. And a low-cost-housing program as manifested in UHPM is favorable to the underemployed and produces attractiveness beyond and in addition to housing availability.

Although a full discussion of the model equations will be left until Appendix A, details of the first several equations will be discussed here as examples of how the model represents urban interactions.

Figure 2-7 shows the detailed relationships between some of the concepts that appeared in Figure 2-5, It also illustrates how the influences that were outlined in Figure 2-6 are combined to generate the flow of undezemployed arrivals into the area.

In this model all rates of flow are stated in terms of a "normal" set of conditions. This normal rate of flow is then modified by a multiplier that represents the deviation of the actual urban-area conditions from the normal.

As given in the following equation, the normal value of the underemployed- arrival rate is expressed as a fraction of the population already in the area, Here the population is taken as the sum of the underemployed plus the labor groups. The multiplier UAN with a value of .05 states the concept that under normal conditions the underemployed-inflow rate wili be 5% per year of the under- employed plus labor populations.

UAKLECUK+L.K> CUAND CAMMP.K> 1,R UANT.05 161, uA - UNDEREMPLOYED ARRIVALS CMEN/YEARD u = UNDEREMPLOYED (MEN) L ~ LASBR CHEN) VAN = UNDEREMPLOYED ARREVALS NORMAL CFRACTEBN/ Yi

AWMP - ATTRACTIVENESS-FOR-MI GRATION MULTIPLIER PERCEIVED (0D! MENSIZNLESS)

The last term in Equation I is the attractiveness multiplier as perceived AMMP. The perceived multiplier is a delayed value of the actual multiplier. The actual multiplier AMM is the true present

state of the system. The attractiveness multi- plier as perceived modifies what would otherwise be the normal migration into the area. When the attractiveness of the area is normal, the multiplier has a value of 1; its actual value can range from zero to several.

The following equation introduces the perception-time lag between the true present attractiveness-for-migration multiplier AMM and the perceived value AMMP (this is a first-order exponential delay*):

+See Reference 1, Chapter 9. U 'Underemployed 16

a N. Ce eee Labor 1 a, ib ~ AMMP UAN Attractiveness for Underemployed migration multiplier, arrivals, normal perceived i / \ 7 I oo 4 AMMPT Attractiveness for Attractiveness migration moultiptier for migration, perception time multiplier

UM. uIMT

'Underemployed/ job multiplier

UAMM UAMMT Underemployed arrivals mobility

t t RC, 121, AD, i 'Tax collections SI

S. ~~. (UH, 95, LO~_ 'Underemployed 'housing - " UHPD ! i \ I 'Underemployed housing —s— Forres, 147.4) Underemployed population density UFS i "Tax per capita v Underemployed + subsidy program DUS, 136, A) family size TPCN Underemployed jobs

Tox per capita, normal Figure 27 Underemployed-arrival rate,

Undecemployed housing program

N. 7 "OU, 16, LO (LCHP, 149, ROY

"UHM URPMT

Low cost housing program

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AMPK =AMMP, J+ CDT/AMMPT? CANM J "AMMP. J) Bayt AMPS 2o15N AMMPT=20 242,C

AMHP = ATTRACTIVENESS=FOR-MIGRATIGN MULTIPLIER PERCEIVED COIMENSIGNLESS)

AMMPT = ATTRACTIVENESS FOR MI GRATION-MULTI PLIER PERCEPTIGN TIME CYEARS)

AMM = ATTRACT! VENESS@FOR"Mi GRATIGN MULTIPLIER CDE MENS IBNLESS)

In the preceding equation the perception delay has been taken as 20 years. This means that a 20-year time lag occurs between the true condition of the area and the perception of that condition by remote members of the underemployed population. This is about one generation and seems to be approximately the time required to become aware of changing conditions in our social institutions. Of course this time delay is a function of communications and would have been longer a hundred years ago than it is today with television and with more rapid transportation. However, the perception-time delays are not very important in this study because they do not have any influence on the equilibrium conditions but only influence the duration of transients as the area changes from one stage to another. Because the numerous other time constants in the system are equal or longer in duration, the perception-time delays will have only secondary in- fluence even on the transient changes.

All the processes within the urban area are conceived here as having certain normal values associated with the size of the area. These norms are then modu- lated over a wide range by the internal condition of the area. The equation below describes this modulating variable for the underemployed arrivals. The attrac- tiveness-for-migration multiplier AMM is the input to the perception delay in Equation 2 which after the delay directly affects the underemployed-arrival rate through term AMMP in Equation 1. The following equation combines six terms into a product that represents the attractiveness of the area to the underemployed population. The terms combined are those that were summarized in Figure 2-6. They are the underempioyed-mobility multiplier, the underemployed/housing multiplier, the public-expenditure multiplier, the underemployed/job multiplier, and the underemployed-housing-program multiplier. In addition a term AMF called the attractiveness-for-migration factor has been added. This factor does not represent any actual urban process but is a coefficient that can be changed as a part of model experimentation to test the sensitivity of the system to modifica- tions in the attractiveness-for-migration multiplier AMM.

In Equation 3 the components of attractiveness are combined by multiplication tather than by addition. Multiplication produces two intended effects. First, the changes in the multipliers are mutually enhancing. Were ali multipliers to increase slightly, the effect would be greater than the sum of the separate influences. Second, it is possible to have one multiplier sufficiently powerful when it becomes

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AMM.K=CUAMMeK) CUHMGK? CPEMSK) CUJMoK) CUHPM eK) CAME) 3A AMP=1 3.156

(AMM = ATTRACTIVENESS-FOR-MI GRATION MULTIPLIER COIMENSIONLESS?

UAMM = UNDEREMPLOYED-ARRI VALS=MBBILI TY MULTIPLIER CDEMENSINLESS?

UHM == UNDEREMPLOYED/HOUSING MULTIPLIER COI MENSI@NLESS)

PEM «= PUBLIC~EXPENDI TURE MULTIPLIER (D{ MENS IONLESS)

WM =~ UNDEREMPLAYED/88 MULTIPLIER COEMENS KONLESS)

UHPM = UNDEREMPLOYED-HOUSING~PROGRAM MULTIPLIER

CDI MENS HBNL ESS) AMF = ATTRACTIVENESS =FOR-ME GRATION FAC TAR DIMENSIONLESS?

0 to dominate the entire group. Such domination is particularly important if one multiplier could become strong enough to shut off the inflow of people. For example, a great enough excess of people over available housing ot jobs might suppress inward migration. If any one of the multipliers becomes 0, the entire product in Equation 3 becomes 0.

Each of the five multiplier inputs to Equation 3 is represented in the model by a nonlinear table function that permits any choice of interdependence between two variables. Equation 4 illustrates how these table functions are introduced. The underemployed-arrivals-mobility multiplier UAMM is stated in terms of underemployed mobility UM. Underemployed mobility UM is generated else- where in the system. It gives the fraction per year of the underemployed that move into the labor category. Equation 4 describes a table function that is illustrated in Figure 2-8.

LUAMM.K STABL EC UAMMT, UMAK 40,015, 6025) 44a UAMBT= 63/4 1/1/4.2/1.3/108/1.65 elyT

UAMM - UNDEREMPLBY ED-ARRi VALS~MABILI TY MULTIPLIER

COIMENSI@NLESS) UAHMT = UNDEREMPLOY ED-ARRI VALS=M@BI LE TY-MULTIPLIER Tat

BLE UM UNDEREMPLOYED MBBILITY CFRACTIGN/V EAR?

Equation 4 is not the normal algebraic equation. The word "TABLE," because it appears without either parentheses or the multiply sign "+." is recognized as an operating function. Here the function is a table look-up in @ table known as UAMMT, the input of which is the variable UM. The range of UM is from 0 to 15 in steps of 025. Equation 4.1 gives the table itself with the values of the equally spaced points (as shown in Figure 2-8). The table-function operation enters with the value of UM, does linear interpolation, and determines UAMM.

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imme im UAMMT Eq. 4d

UAMM-Underemployed arrivals 'mobility multiplier {

al

° ms 05 ns a a8 as UM- Underemployed mobility

Figure 2-8 Influence of underemployed upward economic mobility on underemployed-arrival rate.

Figure 2-8 shows that a normal upward mobility of 5% per year from the underemployed into the labor category is taken as the value that will give a multiplier value of I for UAMM. Should there be no escape from the under- employed group, as represented by a 0 value of UM, the mobility multiplier would fall only to .3. In other words, the complete absence of upward mobility would not give the city a sufficiently unfavorable image to prevent inward migration. At the right-hand extreme of Figure 2-8 upward mobility would cause a rise in the underemployed-arrival rate but with a decreasing slope, indicating the belief that increasing mobility above normal is less influential in increasing artivals than is decreasing mobility influential in suppressing the rate (an argument could easily be made in favor of curvature in the upward direction).

Figure 2-9 shows the relation in the urban model between housing and under- employed migration into the area. The underemployed /housing ratio is the ratio of the underemployed population to the population that could normally occupy the underemployed-housing units. As the ratio decreases, there are fewer people

8 2° an 2&8 UHMT

8 Eq. 5.1

a 3 ' ps 3 z Ky 5 6 =

0 3 Hi is 2 UER-Underemployed/housing ratio

Figure 2-9 Influence of underemployed-housing availability on underemployed-arrival rate.

inrelation to available housing. As the ratio increases, it indicates a higher degree of crowding, An underemployed /housing ratio of 1 produces the neutral multi- plier value of 1. When there are fewer people in relation to available housing, the ratio is lower and the multiplier rises, indicating that available housing makes the area more attractive. The figure shows a fairly steep dependence of attractive- ness on housing in the normal region. However, for low values of the ratio as excess housing becomes available, more housing produces little additional effect as shown by the flattening of the curve. At the right-hand extreme, where conges- tion rises to twice normal for this economic category of person, the unavailability of housing becomes a strong depressant on inward mobility. The shape and positioning of such a curve suggests statements about the society being described. Furthermore, the definition of underemployed housing will vary greatly depend- ing on the country and its economic circumstances. South America and India would have a curve of similar shape but perhaps of quite different numerical values and slopes to describe the influence of housing on migration toward a city. Some persons allege that there is little interdependence between under-employed migration and housing. However, as we will see in later chapters, an old city normally tends to have an excess of underemployed housing and a deficiency of jobs. Even though there is a strong housing relationship at some

parts of the curve shown in Figure 2-9, its effect may be obscured if the city system operates near the upper horizontal section of the curve where housing exerts little influence. However, for studies of new urban-management policies, one must establish a hypothesis about the entire shape of such a curve because new policies may well entail internal readjustments and a system that operates in portions of the interdependency relationships that have not historically been experienced. Figure 2-9 says that a maximum availability of underemployed housing can raise the inward-migration rate by a factor of 2.5. When the overcrowding is 2 times normal crowding, the inward migration is driven down to .05 of normal.

'The per capita tax expenditure* in the area is taken as one measure of attrac- tiveness. Figure 2-10 shows the relationship in the model. The tax per capita ratio js the ratio of taxes per capita in the area to the tax per capita in the outside environment from which people come. A ratio of I produces a multiplier of 1, indicating that if the tax per capita in the area is the same as in the outside environment there is no incentive from this source to move into the area. The expenditure of taxes is here used as an indication of public services, schools, welfare, and other public-supported activities. The curve states that inward migra- tion would fall to .2 of the value it would otherwise have if expenditures declined to zero. At the other extreme an expenditure rate of 3 times normal would make the city 4 times as attractive as the outside environment. One could argue that the curves should drop more steeply and reach zero before the tax per capita

Tax revenue and public expenditure are here taken as equal except for certain simulation runs where a subsidy from the outside is given to the city.

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*

multiplier Y

MN ay

PEM — Public expenditure

i

2

is 2 2 3 TPCR-Tax per capita ratio 'Figure 2-10 Influence of tax expenditures per capita on underemployed-arrival rate.

ratio reaches zero, but as we will see later such small variations in the functional relationships will make negligible difference in the results.

An important factor in determining migration into an urban area appears to be availability of economic opportunity as indicated by jobs. Assertions by people in the underemployed category support this view, as do social scientists. The model results in later chapters suggest that unfavorable conditions in the job multiplier have usually carried the major burden of limiting migration into cities. Fig. 2-11 shows the relation used here between available jobs and inward migra- tion. The underemployed /job ratio UR is the ratio of underemployed to available jobs. The underemployed/job multiplier UJM gives the influence on migration. For a man/job ratio of 1, the multiplier is taken as neutral with a value of 1. As more jobs become available, the UR ratio falls and the multiplier rises but eventually levels off in the left-hand section when jobs are in excess and still more jobs would have no effect on the attractiveness of the area. In the right-hand section of the curve, inward migration falls off to a very low value as the excess of men increases. In examining such a curve one must remember that in the real-life situation there is a great deal of flexibility in defining what constitutes

a job as well as what constitutes an underemployed person. The long sloping

TTT UIMT Bq. 101

So

'UIM-Underemployed/job multiplier VA

$ 1 1s 2 25 3 UR-Underemployed/job ratio.

Figure 211 Influence of availability of jobs for the underemployed on underemployed-arrival rate, I

30. Chapter Two

UHPM-Underemployed housing program multiplier \

ol

° or 'ot oF ot 05 UHPR—Underemployed housing program cate

Figure 2-12. Influence of underemployed-housing program on underemployed-arrival rate.

section from a UR ratio of .5 to 1.5 indicates a region in which marginal workers and marginal jobs appear in response fo economic pressures. One would not expect such a curve to show extreme steepness in the region of UR = 1 because of the broad distribution in desire to work and the broad distribution in how insistently employers will attempt to fill potential job openings. ou. The remaining influence on inward migration of the underemployed in this model is generated by a low-cost-housing program. Figure 2- 12 shows the assumed effect. The normal condition is taken as no low-cost-housing construction. As housing rises to a rate of 5% per year of the underemployed population, the attrac- tiveness of the city is assumed to rise by a factor of 3. The influence of a

housing program is in addition to the availability of housing as given in Figure 2-9. The re- jationship in Figure 2-12 results from the demonstrated interest and activity of the city in behalf of the underemployed as well as the higher quality of housing that

sults. a ; nis section has discussed, as a typical example, the relationships influencing the underemployed-arrival rate into the city. The preceding graphic relationships showing influences on underemployed arrivals are all part of the rate equation for UA. The auxiliary equations (indicated by an A after the equation number) are subdivisions of the rate equation they affect. As such, their presence Is com- patible with the statement made in Section 2.1 that a model consists of only rate

equations and level equations.

2,4 Example of a Level : . The level variables describe the state of a system. A level is the accumulation resulting from the flows in and out of the level. Mathematically the levels are integrations. Figure 2-4 illustrates by rectangles the nine principal system levels used here to represent a city, . The following equation for the underemployed workers in the city is a level

equation:

Structure of an Urban Area 31

SHCDT) CUA SKE UB KEL TUs JK "Ue JK "UTLAUKY 16,4 16. 15N u ~ UNDEREMPLAYED (MEN) w ~ UNDEREMPLAYED ARREVALS CMEN/YEAR) w ~ ONDEREMPLOYED BIRTHS CMEN/YEAR) LTU = LABOR 1 UNDEREMPLOYED CMEN/YEAR) UD == _~UNDEREMPLOYED DEPARTURES CMEN/Y EARD UTL = UNDEREMPLOYED T2 LABBR CMEN/YEARD

The ievel equation above is a simple bookkeeping statement that says the underemployed at the present time K is equal to the underemployed at the previous time of computation J plus the change that occurred in the interval DT between successive computations. During the interval from time J to time K the underemployed-arrival rate is given as UA, the underemployed birth rate as UB, the labor-to-underemployed flow as LTU, the underemployed departures as UD, and the underemployed-to-labor flow as UTL. These are the five flow rates affecting the level of underemployed. An initial value must be given to each level equation; here 1,200 underemployed is given as the initial condition of the area.

All level equations are of the same form. A new value is computed by taking the old value and adding the change during the preceding time interval. This is the process of integration or accumulation. It is the process by which systems. change through time.

2.5 Summary of Flow Rates

This section identifies the major influences affecting each rate of flow. Such a summary of the system structure should be sufficient background for reading the remaining chapters. (The exact details of the structure and relationships used to represent an urban area are given in Appendix A.)

Fignre 2-4 showed the 22 flow rates that affect the 9 principal system levels. One of these flow rates, the underemployed arrivals UA, has been discussed in detail in Section 2.3. The other 21 flow rates and the factors affecting them are summarized here,

The underemployed U in the area are increased by the underemployed arrivals UA, the underemployed birth rate UB, and the labor-to-underemployed down- ward mobility LTU. The

underemployed are reduced by the underemployed-to- labor upward mobility UTL and the underemployed departures UD. All of these rates are illustrated in Figure 2-4.

Underemployed Birth Rate UB. This is the net difference of births minus deaths and is taken as .015 of the underemployed population per year.

Labor to Underemployed LTU. The downward mobility or economic dropout from labor to underemployed in the model depends on the ratio of labor to available labor jobs. A dropout rate of 3% per year exists when labor and labor jobs are 32. Chapter Two

in bafance. The rate drops slowly when labor is insufficient for available jobs and rises rapidly as labor exceeds jobs.

Underemployed to Labor UTL. This is the upward economic mobility representing the flow of the underemployed into the labor category. When conditions are normal, it is 10% per year. However, it is modified by a number of influences. It depends on the fraction of underemployed working, rising as the fraction increases. It depends on the ratio of labor to iabor jobs; a shortage of labor makes the upward mobility larger, while an excess of labor makes it smaller. Upward mobility also depends on the ratio of the labor population to the underemployed population, with the upward mobility being greater when the underemployed are small in number compared to the labor group. This means that a small number of underemployed mixed with and having good access to a more successful economic group can make the transition more easily than a large number of underemployed in an area where there is little opportunity for contact with those they might emulate. Upward mobility also depends on the tax per capita ratio, which suggests that better schooling and social services can increase the upward economic flow.

Underemployed Departures UD. The normal underemployed-departure rate is assumed to be 2% of the underemployed population. The departure rate is affected inversely to the arrival rate; that is conditions that increase the arrival rate reduce the departure rate and vice versa.

The labor level L, in addition to the UTL and LTU rates already described, is affected by the labor birth rate LB, the labor-arrival rate LA, the labor-to- manager rate LTM, and the labor departures LD.

Labor Birth Rate LB. This is the net of birth rate minus death rate and is taken as 01 per year of the labor population.

Labor Arrivals LA. Arrivals of skilled labor are influenced by factors similar to those affecting arrivals of underemployed workers. Normal arrival rate is .03 per year of the labor group. Arrival rate increases as the labor/job ratio decreases, indicating the availability of excess jobs. The labor-arrival rate depends on the ratio of the labor population to the underemployed population, with the labor-arrival rate falling as the labor population decreases in comparison to the under- employed population. This indicates that an unfavorable social climate will depress the inward movement of skilled labor. Labor arrival depends on the tax ratio, being reduced somewhat as taxes rise. Labor arrival depends on the ratio of labor population to worker housing, with a housing shortage reducing the tendency to move into the area.

Labor Departures LD. Labor departures are given a normal value of 2% per year with a multiplier that is inverse to the arrival multiplier. Factors that encourage arrival will reduce departure and vice versa.

Structure of an Urban Area 33

Labor to Manager LTM. The upward economic mobility from labor to the managerial-professional class is taken as normaily .02 per year of the labor group and depends on three influences. The flow LTM increases if there is a shortage of managers for managerial jobs. The flow increases if the managerial population is above 10% of the labor population and decreases when the manager/labor ratio is lower. This is based on the assumption that the availability of a substantial managerial group to act as an example and to be accessible to the Jabor population increases opportunities for transition into the managerial-professional class. An increase in taxes per capita, implying better educational opportunities, increases the flow from labor to management.

The managerial-professional population MP is increased by the labor-to- manager flow LTM already described, the managerial-professional birth rate MPB, and the manager arrivals MA. The managerial-professional level is decreased by managerial departures MD. No downward mobility from the managerial class to the labor class has been included because it is probably too small to be significant.

Managerial-Professional Birth Rate MPB. The birth rate minus death rate is taken as .0075 of the managerial-professional population per year.

Manager Arrivals MA. Arrivals into the managerial-professional class follow the same pattern as for the labor class. A shortage of managers compared to available managerial jobs increases the arrival rate. A higher ratio of managers to total

population implies a more favorable social climate and increases the arrival-rate multiplier. Increasing taxes depresses the arrival rate. Housing affects the man- ager-arrival rate, encouraging arrivals when it is adequate and discouraging arrivals as housing congestion increases.

Manager Departures MD. A managet-departure rate of 2% per year of the man- agerial-professional population is considered normal. This is modulated by a multiplier that is generated as the inverse of the arrival multiplier. Conditions favoring managerial arrival decrease managerial departure. Conversely, an en- vironment discouraging arrival hastens departure.

Premium housing PH is the housing associated with the manageriai-professional population. It is increased by premium-housing construction PHC and is de- teased by premium-housing obsolescence PHO. Premium housing declines in value and condition to become worker housing.

Premium-Housing Construction PHC. Normal premium-housing construction is considered to be 3% per year of existing premium housing. This normal growth rate is then modified by a multiplier representing a combination of six influences. The ratio of managers to premium housing indicates whether or not there is a housing shortage, with a greater shortage causing an increase in the premium- housing-construction rate. All of the housing- and business-construction rates in the model are influenced by land multipliers having shapes similar to Figure 2-13. I I i i

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I t T ry 6 * 10 LFO= Land fraction occupied

PHLM—Premium housing,

CY

Figure 2-13 Influence of land occupancy on premium-housing construction.

When zero land is occupied, the area has not yet developed economically and the incentive for building is low. As activity in the area increases, all components of a city begin to develop and to enhance each other. Figure 2-13 asserts that the maximum influence from land occupancy occurs when the land is about 50% filled, As the iand area approaches full occupancy, the more attractive and useful sections have already been built up and the economic incentive for additional construction declines. When the land is fully occupied, additional construction is physically impossible. New building can take place only as demolition makes empty land available. A third influence on premium-housing construction is the ratio of the managerial-professional class to the total population. An increase in the ratio implies a community attractive to the managerial group and encourages premium-housing construction. The tax rate affects premium-housing construc: tion, with high taxes having an adverse influence on construction. Premium ons ing construction is affected by two multipliers that indicate the degree of enthu- siasm for new building, The enterprise multiplier increases premium-housing construction if the recent history of new-enterprise construction has been high. Similarly, the history of premium-housing construction itself produces a specula- tive incentive, with recent construction encouraging more construction.

ium-Housing Obsolescence PHO. A normal life of about 30 years for pre- cen housing is assumed. This means that normaily .03 of premium Rousing per year ages into worker housing. But this normal obsolescence rate is int hence by pressures for premium housing. If premium housing is in great demand, the obsolescence rate would decline, implying a longer average life for Premium housing. If premium housing is in excess supply, the obsolescence rate will be

mal. I

Oe a bousing WH (as shown in Figure 2-4) is increased both by Premian housing obsolescence PHO and by worker-housing construction WHC. It is

depleted by worker-housing obsolescence WHO.

i? i ing is built directly in addition Worker-Housing Construction WHC. Worker housing is € to becoming available through the obsolescence of premium housing. The worker-

Structure of an Urban Area 35

housing-construction rate depends on six factors representing the same concepts as in premium-housing construction. These are the adequacy of housing, a land multiplier, the ratio of labor to underemployed as a measure of community desirability, the tax ratio, the recent trend in new-enterprise construction, and the recent trend in worker-housing construction.

Worker-Housing Obsolescence WHO. The normal average life of worker housing has been taken as 50 years, representing 2% per year transfer of worker housing into the underemployed-housing category. This normal obsolescence rate is then modified upward or downward depending on the demand for worker housing.

The underemployed housing UH is increased by worker-housing obsolescence

WHO and any low-cost-housing program LCHP. It is decreased by slum-housing demolition SHD.

Low-Cost-Housing Program LCHP. This flow rate is not a normal city process. It is an externally generated program which can be activated in the model to

observe the response of the urban system to the construction of housing directly for the underemployed.

Slum-Housing Demolition SHD. A 50-year life has been assumed as normal in the underemployed-housing category, implying a normal demolition rate of 2% per year. This rate is modified to increase as the occupancy ratio of the housing decreases. The multiplier also increases as the fraction of total land occupied increases. This implies that if construction in the area continues once the land teaches almost full occupancy, demolition must be taking place.

New enterprise NE is increased by new-enterprise construction NEC and reduced by new-enterprise decline NED into mature business.

New-Enterprise Construction NEC. New enterprise is assumed to be constructed under normal circumstances at a rate equal to separate fractions of each of the three business categories. This normal rate is then influenced by a multiplier that combines five influences on new-enterprise construction. The ratio of managers to managerial jobs influences new construction; the greater the supply of man- agers, the greater the tendency to construct new business. The land fraction occupied influences new-enterprise construction (as shown in Figure 2-13). The availability of labor encourages new construction. A high tax rate reduces con- struction. A speculative factor increases construction over the normal amount if there has been a recent history of high construction.

New-Enterprise Decline NED. A new enterprise is assumed to have an average life of about 12 years before becoming a mature business. The decline rate is taken as .08 of the new enterprise each year, with a multiplier that falls as the demand for new enterprise increases and vice versa. This implies that aging is ses

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less rapid in a period of high economic demand than in one of economic stagna- tion.

The model assumes that mature business MB is simply the older, stabilized condition reached in time by new enterprise. In turn, time is the principal deter- minant in the aging rate of mature business MBD into declining industry DL

Mature-Business Decline MBD. A normal life of 20 years is used in the model for mature business. The decline rate of 5% per year is modified by the new- enterprise multiplier in such a way that mature business declines more slowly in periods of economic activity and a high demand for business.

Declining industry DI is business activity that has passed its prime. Ailing economically, it employs fewer people per productive unit than more healthy business units. In time declining industry disappears by demolition DID.

Declining-Industry Demolition DID. A 30-year life is assumed as normal for the declining-industry phase of a business unit. The average age shortens in periods of economic demand and rises in periods of economic stagnation. As with slum- housing demolition, the demolition rate of declining industry depends on the land fraction occupied in such a way that the demolition rate increases as new construc- tion forces land occupancy to nearly 100%.

'Taxes influence a number of activities within the urban model. An assessed value is asctibed to each class of business and housing, and a total assessed value is computed. "Taxes needed" are computed on the basis of population, with the assumption that public expenditures are greater per person in the underemployed category than in the labor category and greater in the labor category than in the managerial-professional class. Political power is included as the ratio of labor to underemployed. As the percentage of the population in the underemployed category rises, tax assessments increase, because the underemployed group has the political power as well as the need for tax expenditure, although it pays little tax.

2.6 Parameters in the Simulation Model

Any reasonably consistent set of coefficients could be used as the basis for this model representing urban growth and stagnation. Most of the values chosen are not critical in determining the behavior of the system." However, the time plots and computed resuits are perhaps more easily understood in terms of the actual figuces taken in the model. The following have been used:

MAJOR PARAMETERS

Land area (AREA) = 100,000 acres Land per house (LPH) = I acre Land per productive unit (LPP) = .2 acre

* Appendix B discusses sensitivity of parameters.

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Housine Densiiies Premium-housing population density (PHPD) Worker-housing population density (WHPD) Underemployed-housing population density (UHPD) FaMILy SIZES

Managerial-professional family size (MPFS) = 5 people LFS)

3 persons/housing unit 6 persons/housing unit 12 persons/housing unit

Waa

Labor family size 6 people Underemployed family size (UFS) = 8 people PERSONNEL NEEDED IN Business UNiTs

Managerial- Under-

Professional Labor employed New Enterprise NEM = 4 NEL = 20 10 Mature Business NBM =2 MBI 15 1S Declining industry DIM =1 DIL = 10 5

Taxes Levigp

Premium-housing assessed value (PHAY) = $30 thousand/housing unit Worker-housing assessed value (WHAV) = $15 thousand/housing unit

Underemployed-housing assessed value (UHAV) = $ 5 thousand/housing unit

New-enterprise assessed value © (NEAV) = $500 thousand/productive unit

Mature-business assessed value (MBAV) = $300 thousand/productive unit

Declining-industry assessed value (DIAV) = $100 thousand/productive unit Taxes NEEDED

'Tax per management person (TMP) = 3150/year

Tax per labor person (LLP) = $200/year

Tax per underemployed person (TUP) = $300/year

'Tax assessment normal (TAN) = $50/year/thousand doliars

At the start of a simulation computation initial values must be specified for all level variables in the system. These state the starting conditions of the system. The nine principal levels shown in Figure 2-4 have values given below. The system also contains certain perceived values and average growth rates that are level variables and have initial values specified in Appendix A. Generally, the initial values are not important except in determining behavior in the very early part of the simulation run. Any initial imbalance between the selected initial values is worked out within the system as new values are computed for the level varia- bles. For most systems the ultimate equilibrium values are independent of the starting point.

New enterprise (NE) = 200 productive units Maire business (MB) = 1,000 productive units Declining industry OD 100 productive units Premium housing (PH) = 5,000 housing units

Worker housing (WH) Underemployed housing (UH) Managerial-Professional (MP) Labor (L)

Underemployed (U) = 1,200 men

1,000 housing units 1,100 housing units 3,900 men

3 Growth and Stagnation

This chapter discusses the dynamics of the urban life cycle as created by the simulation model outlined in Chapter 2. Chapters 4 and 5 will start with an urban area already in the stagnant condition and explore the effects of various changes in urban-management policies. But here, first, the broad sweep of urban growth and maturity are investigated to show how an area begins to decline.

The stages of an urban life cycle within a period of 250 years occur starting with empty land, growing to full land occupancy, maturing through a rapid realignment of internal urban balance, and emerging into an equilibrium charac- terized by stagnation with its unemployment, faltering industry, and increased faxes.

The serious reader who wishes to understand Chapters 3, 4, and 5 thoroughly should read them twice—first in the order in which they appear and again after reading Appendix A, which contains the full details of the model representing the urban arca.

The warning given earlier should be repeated here. The results in these three chapters depend in various ways on the concepts of urban interaction that are built into the simulation model. It is possible that substantial changes in structure might affect the conclusions implied by these computed results. Before accepting the implications as a basis for action, the reader should satisfy himself that the structure adequately represents the urban system and the particular problems with which he is dealing. However (as shown in Appendix B), the system is not highly sensitive to the values chosen for system parameters. Changes as great as factors of 2, 3, or 5 can be made in many of the parameters with only slight effect on the equilibrium conditions of the urban system. Even where the

parameters do affect the equilibrium condition of the system, changes in those parameters usually do not affect the direction of policy modifications that lead to improvement.

A specific land area becomes a city because its physical characteristics encour- age construction and concentration of business and housing. These economic characteristics causing an urban area to develop are represented in the simulation model by the "normal" coefficients in the flow rates, by the psychological and

mobility multipliers which connect the internal structure of the urban system, and by the land multipliers which relate available land to construction of business and housing.

Figure 3-1 shows the changing urban conditions during growth and aging. At the start, when time = 0, the land area is 3% occupied and a normal balance exists between the various activities. In the first stage of its life cycle, the area described in this model develops for 100 years. Between 100 and 200 years there is a period of maturing and internal readjustment. After 200 years there is continu- ing equilibrium.

READING THE COMPUTER PLOTS AND PRINTED VALUES

Plotted Curves

The curves (as in Figures 3-12, 6, and c) are computer plots showing the behavior of the system variables as generated through time by the simulation model. The horizontal axis is a time scale in years. At the left margin is a line giving the plotting symbols. For example, in Figure 3-la, U = U means that the number of underemployed U is plotted on the graph with the symbol U, WH = W means that worker housing WH is plotted on the graph with the symbol W. The vertical scales at the left of the plot are marked at the top end with the plotting symbols to which they apply. For example, the first scale running from 0 to 600,000 is the scale for the variables plotted with the symbols U, L, P, W, and H. The letter T following the numerical-scale value means thousands. Along the top of the graph the letter groups indicate where curves overlap. For example, in Figure 3-1a at time 145, the letters WH, PB mean that the curves for W and H cross and the first symbol W is the one plotted. The curves for P and B cross too and are represented by the first symbol P.

Printed Tabulation

Printed values (as in Figures 3-1d and 3-1e) give numerical values for the same variables that are plotted and for selected variables not plotted. The printed values appear in blocks. The left column indicates the time associated with the values. The letter groupings at the head of the table give the symbol identifications of the variables in the same grouping pattern as for the numerical values. The fifth column gives line numbers as an aid to matching a letter group in the heading with its numerical value in the table. The variables to the ieft of the line number column are all measured in thou- sands. The variables to the right are all measured in units.

In Appendix C is an alphabetical list of definitions with units of measure for each of the symbol groups. In Appendix D is an alphabetical list of variables and constanis giving the equation numbers where they are defined. The equation numbers refer to the model equations in Appendix E and the equation descriptions in Appendix A.

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Growth and Stagnation 41

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Figure 31 Urban development, maturity, and stagnation. Pigure 3-la shows the major levels, Figure 3-16 the important ratios, and Figure 3-Le selected flow rates.

Figure 3-12 plots the nine major system levels: the three categories of, personnel, the three economic groups of housing, and the three ages of industry. The first 100 years is a period of internal development and growth in population. A social system contains numerous positive-feedback loops which can generate exponential growth behavior, One of these can be seen in Equation 1 in Section 2.3. The underemployed arrivals UA flow into and increase the number of underemployed U. But the number of underemployed U is one of the variables attracting the arrivals UA. In other words, the arrival rate increases the underemployed, which increases the arrival rate by increasing the size, visibility, activity, and communica- tion channels of the city. This inherent feedback process is present in the arrival Tates of other population classes and in the construction rates for housing and industry.

But the positive-feedback loops do not forever remain positive feedback in character. Continued exponential growth is impossible. Size itself changes the conditions of the system and suppresses the positive-feedback behavior. As the particular land area becomes full, the construction land multipliers decline toward zero and suppress new construction. As the economic and housing conditions of 42. Chapter Three

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(a) Figure 3-1 (cont)

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Figure 3.1 (cont)

the system change, the arrival rates of people into the area are reduced and the departure rates increased until the numbers of people stabilize.

In Figure 3-ia the growth period ends at 100 years. New enterprise and pre- mium housing have reached a peak, and the managerial-professional population, worker housing, and labor are nearly at a maximum. Figure 3-1¢ shows several important flow rates. By year 100 the worker-housing-construction boom has ended. The premium-housing-construction rate has declined substantially from its peak. At year 100 the urban area is at the end of its first construction phase. As shown in Figure 3-16, land area has been almost fully utilized. (Remember that the model system is dealing with a fixed land area. The area is best thought of as a section of one of our older cities, not as the entire area within the political boundary.)

But immediately after year 100 the area begins to age. Its land is filled. New construction is suppressed by lack of land within the fixed and fully occupied area, New enterprise settles into mature business and deteriorates into declining industry. Premium housing and worker housing, which had reached a peak at 100 years, are aging, and as they decline in condition they feed the rising level of underemployed housing, which peaks at about 130 years.

The minimum in many of the curves in Figure 3-ia, occurring at about 150 £,MB 20,0120

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Growth and Stagnation 45

'Figure 3.2 Stagnation in urban activity occurring between years 80 and 180.

years, is partly caused by the growth multipliers in the model that represent speculative and historical influences. The rapid growth prior to year 100 caused some overshoot in the amount of construction. The depression and despondency occurring between years 100 and 140 suppressed building below the normal equilibrium values. By year 200 a stable and continuing equilibrium has been established.

This model contains no random influences, so equilibrium becomes a con- tinuing set of static values. In an actual system economic cycles external to the area, various technological innovations, and world events would cause a con- tinuing state of fluctuation around these equilibrium values.

Figure 3-2 shows a section of the same urban behavior as Figure 3-1 but on an expanded time scale for the period from year 80 to year 180. In Figure 3-2a are a succession of peaks occurring as the land area fills, growth falters, and the city settles into equilibrium. The growth phase is terminated by the filling of the land area, as seen in Figure 3-25 where the land fraction occupied rises from 4 in year 80 to .8 in year 100. In Figure 3-2a the peak in new enterprise occurs just before year 100. Time causes a shift of new enterprise into the mature- business category, which peaks at year 112. The aging and deterioration of mature business causes an increase in declining industry, which peaks at year 140.

A similar succession of peaks appears in the population mix of the area but

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TIME, Ay rs v4 AMM LAJH, LSM WSK SHLI UM thousands units of seo UA 2 ANMP: LAM (LUM NEGR TH UMMP r 1 = oD MD uo 3 BOM LAMP LOR) PEM TPCR wR WO. TOTO, 6.465 SH3e17 13895997350 1,000 0675 oop we UH & OOM LatH MARM 'PHAN TR WHAM 20.971 +490 (13.235 2 72 t NE WS DIEM LAUGH AIM PHEW RN WHEM ASH HGH 20.006 5 LA NEC we 6 OILM LOR vAM PHGM 'UAMM HGM 000 58.88 328.87 4 tcHP NECP OUTLET LOM MAM PHGR = UM wg 368066 2.235 183.89 5 to PUN 8 ECM LEM MPM PRL UMW 7.08 "(255 00 6 we 8 PHP ELM MAT PHM LEW HM 1000 000 12.2357 Lol Put W100 LM 'LHR 'HOM PHOM UHM WHOM B i PHEP WwHO17 EM uF MR PHPM UHPR: WAT 9 u™ PHS WHC 12 EMM LMM ae PRTM UHR WHOM 10 ug 'SHO WHEP 15 ETM LMP wR SHAK WM MA 'SHOP Wd 14 LAHH LR mR 'SHDM uM — thousands units 80, 5.735 108.59 1.238 10. +175 10.735 1.191 LMT 3.296 n0 45,36 55.61 Bee 6.052 15010 . ses eg 1.251 2000 10.526 2037 285143 44594 1,792 85.58 .000 2.367 5.005 88.56 2652 +000 230.38 1989 1-097 13.097 1.029 865.000 we +000 5.004 100. B40 180. 1 067 . 2 1.018 3 096 rf 1,038 5 4178 3 1022 7 44193 1e7e 3359 8 1.005 1.088 2708 9 1887 eS 42308 680014175 1392 114765 028 2989 120 1,567 ath e- 13.823 shee. 2000 72,380 we 825 978 120, 2.150 390-01 3 S18 320 155 (e) af 19,119 2 ot « . eee 25.720 3S 14864 res) 1.765 I Figure 3-2 (cont.) 85.57 301.09 8 9959 93T 4.708, 5.614 221.8 5 2122 38 38 6 Se =lo08 for different reasons. In Figure 3-2a the labor and managerial categories peak a 866-86 38 at year 105. They have ceased to increase because the business units which provide 8 38 41221 unt jobs have already peaked. However, at year 100 there are still ample lower-skill

Bo 88 pes Jobs available for the underemployed, underemployed housing is still rising, and Bt? 391 o~ the area appears to be attractive. There is a delay in perception by the under- 6779 1.054 employed of urban attractiveness, so the inward flow continues, with a peak in (a) the underemployed category occurring at year 120. Figure 3-2 (cont.} Housing follows a similar pattern. Premium housing

and worker housing

teach peaks at year 100. But the aging and decay of worker housing into underem- ployed housing delays the peak in underemployed housing until year 130.

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The underemployed/job ratio UR in Figure 3-25 rises rapidly between years 90 and 130. in the time interval from year 100 to year 120 the underemployed jobs UJ have declined from 225,000 to 221,000, while the number of underem- ployed has risen from 251,000 to 390,000. It is in this time interval that the economic pressure on the underemployed group becomes sufficiently high to reduce the inflow of underemployed to the city and stabilize the population. During this interval from 100 to 120 years, Figure 3-2b shows a reversal of the roles of housing and jobs for the underemployed. Jobs, as shown by the rising underemployed /job ratio, are becoming less available. At the same time, housing, as shown by the falling underemployed/housing ratio, is becoming more available. The increase in housing is generated by the deterioration of the older parts of the city into a housing category no longer acceptable to the managerial and labor classes. At the same time construction of new industry has slowed or declined, and there has been a rise in the labor/job ratio LR. As jobs for skilled labor become less available, jobs requiring less skill are taken by more skilled labor, leaving even fewer jobs for the underemployed. Shifting conditions within the urban area are summarized in Figure 3-3, giving the attractiveness-for-migration multiplier AMM and its components at year 80 and at year 140. In the last column, the values for the year 140 are given as a fraction of the values at year 80. The

attractiveness multiplier AMM is the product of the four components also given in the table. The multiplier AMM declines to about half during the time interval. Upward economic mobility from the underemployed into the labor class as given by UAMM has become somewhat less favorable. On the other hand, the underem- ployed/housing multiplier UHM has risen by a factor of 4.7. The urban area has shifted from a shortage to an excess of housing for the underemployed. Because the capacity of the area is limited in absorbing the underemployed, some of the multipliers must fall to low enough values to generate the low attractiveness required to stabilize the population. The underemployed/job multiplier UJM carries the main burden of reducing attractiveness. The value of UJM at year 140 is only .15 of its value at year 80. In other words, the underemployed flood into the area until their falling economic circumstances act as a brake on further inward migration.

At At Year Year

30 140 140/80 AMM, Attractiveness-for-migration multiplier 68 36 3 Components of AMM: UAMM, Underemployed-arrivats-mobility multiplier 1.16 88 16 UHM, Underemployed/housing multiplier 38 479 47 PEM, Public-expenditure multiplier 95 92 27 UIM, Underemployed/job multiplier 1.65 25 1S

Figure 3-3 Changes in multipliers that influence underemployed arrivals.

Growth and Stagnation 49

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Figure 34 Number of units in each age category is proportional to average lie,

Figure 3-3 shows the urban processes that limit inward migration and establish a population equilibrium. During the initial growth phase the area is attractive and can accept additional population. But if carried far enough, the influx of people overcrowds the area, reduces the attractiveness, reduces the population inflow, and increases the outflow until population growth stops. By this process population rises and falls to maintain the attractiveness of the area in balance with that of the surrounding environment.

'The change in economic circumstances that occurs while growth is giving way to stagnation is caused by the changing proportions of people, housing, and industry. During the growth stage new construction outruns the aging process so that the decaying part of a city is little noticed in relation to the ever rising

new construction. But as the land area becomes filled, new construction can take place only as the old is demolished. An equilibrium is established in which the demolition rates and construction rates must be the same.

In the equilibrium state the proportions of old and new depend on the average lifetime in each age category (as in Figure 3-4). Suppose houses are built at the rate of ten units per year to enter the new category. If the average life in the new category is 20 years, the total number of new units will, in equilibrium, be the product of the construction rate and the average life. Similarly, if the system is in equilibrium, the number of units per year passing from the new category to the old category must be the same as the construction rate. Note that the number leaving the category is the number in the category divided by the life, If the units in the old category remain an average of 60 years, the number of old units will be the average life multiplied by the flow rate, or 600 units. Because the system is in equilibrium, the discard rate from the old category must also be the flow rate of 10 units per year, which is 600 old units divided by 60 years. As shown in the figure, the number of units in each category is proportional to the average time the unit stays in the category.

In a city, if business units and housing stand in a declining condition for more years than they serve at high economic effectiveness, the old will dominate the landscape. Because the condition of buildings tends to determine the economic status of the occupants, an excess of old buildings causes a high proportion of marginal business and unskilled and unemployed people.

In Figure 3-1a the commercial activity is eventually dominated by the declin- ing-industry category. The cause is found in the average lifetime of a business unit in each of the three categories. In equilibrium at 250 years, the system of

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Figure 3-1a is operating with an average life of 10.5 years* in the new-enterprise category, 17 years in the mature-business category, and 36 years in the declin- ing-industry category. In equilibrium the numbers of units will be in the same proportion. If the less effective declining category persists for a greater number of years than was its life in the productive category, the declining units usurp the land area.

In a similar way worker housing at the 250th year in Figure 3-la is showing an average life of 37 years, while underemployed housing has an average life of 35 years. This accounts for their nearly equal proportions in the equilibrium. condition. The numbers of units being proportional to the lifetime

in each cate- Bory assumes, of course, that the same flow occurs through each category. Were there a direct construction of underemployed housing, as in a low-cost-housing program, this would increase the underemployed housing beyond that indicated by average lifetime.

Figures 3-1 and 3-2 may not be of great concern to one interested in solving the problems of an urban area that is already fully developed. The years over which the area developed are history. Today's problems extend from the present into the future. In later chapters model runs dealing with changes in urban programs will start from the equilibrium conditions finally reached in Figure 3-1.

But the dynamics of the entire life cycle in this chapter are important in clarifying the process of urban stagnation. Furthermore, the life cycle behavior permits one of the many tests of model validity we can use to establish confidence in the model. If the model operates satisfactorily, beginning with a nearly empty land area, growing, and stabilizing in a sequence of events characteristic of a real-life area, it has passed one of many available tests.

"Equation 111 in Appendix A gives the transfer rate from the new-enterprise catégory into mature business, 'The fraction pet year transferred is NEDN, having a value of 08, multiplied by the enterprise-decline multiplier EDM. The valué of the latter is given in Figure 3-Le as 1.19. The product of these two is 095, which is the teciprocal of the average life, giving a life of 10.5 years. Likewise, MBDN multiplied by BDM as in Equation 14 indicates a 17-year life for matare-business units. The reciprocal of DEDN times DIDM as in Equation 117 yields a 36-yeat life in the declining-industry category.

4 Failures in Urban Programs

The preceding chapter has shown the normal processes of aging that change the proportions of housing, industry, and people toward an economically un- healthy combination. The consequences appear as slum areas, high tax rates, flight of industry to the suburbs, and mounting welfare rolls.

During the past three decades many different urban-management programs have been inaugurated in an effort to ameliorate these conditions. Creation of jobs, job training, financial aid to the cities, and Jow-cost-housing construction all have been undertaken in an effort to improve the situation of the under- employed. Most of these programs appear to have failed; in fact, conditions in the cities seem to have worsened. As conditions became more critical, greater emphasis was placed on corrective action, but even so the situation continued to deteriorate. Is it possible that these Programs are neutral in effect or even detrimental?

The model of urban behavior has been equipped to simulate various classicai urban-management programs (see Equations 140 through 150 in Appendix A). With these a job program for the underemployed can be introduced, under- employed training can be provided, tax expenditures for welfare and education can be subsidized, and a low-cost-housing program can generate housing directly for the underemployed category of the population.

To explore these urban-management programs, the computer runs will start from the equilibrium conditions existing at the end of Figure 3-1. The conditions at year 250 in that figure are the ones used for the time interval from —5 to 0 years in the following simulation runs.* The new Management programs are introduced at time = 0 and their effects over the following 50 years are plotted.

41 Job Program

Figure 4-1] shows the effect of introducing at time = 0 an underemployed-job Program. At time = 0, jobs for 10% of the total underemployed population are

ame initial conditions for the simutation runs that stact in equilibrium are given in Appendix A, Section 4

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Failures in Urban Programs 53

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Figure 4-1 Jobs created for 10% of the underemployed.

suddenly created. This is done, not by changing the commercial and industrial conditions in the area, but by some artificial process such as transporting people to jobs elsewhere or creating public-service types of work. In the model jobs created by the underemployed-job program UJP are added directly to the under- employed jobs UJ that otherwise exist within the system (see Equation 136 in Appendix A). The effect is to decrease the undcremployed/job ratio UR and to increase the underemployed/job multiplier UJM (Equation 10), which is one of the attractiveness multipliers influencing underemployed migration into the city.

At first glance Figure 4-1 shows little change resulting from the under- employed-job program, but more careful examination discloses several unfavora- ble changes in the composition of the urban area. In Figure 4-1a the total number of underemployed has increased. Underemployed housing has increased while worker housing has decreased. In Figure 4-10 the sudden improvement (decrease) in the underemployed /job ratio resulting at time = 0 from newly available jobs is largely dissipated over the next 20 years, even thongh the job program for 10% of the underemployed is continued throughout the entire 50-year period. The

underemployed /housing ratio and the labor/housing ratio both become slightly higher, indicating more crowding. Figure 4-1c shows an increase over the first 10 years in the underemployed-arrival rate and a decrease in the underemployed- departure rate. The excess of arrivals over departures persists until conditions 54° Chapter Four

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(dy Figure 4-1 (cont)

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Failures in Urban Programs 55

in the area become sufficiently more unfavorable to counterbalance the attrac. tiveness of the underemployed-job program.

Figure 4-2 summarizes the principal changes. The underemployed have risen 10%. Jobs, including those created by the job program, have risen 17%, The underemployed/job ratio has improved by declining 5.5%. Even so, the excess of underemployed beyond the underemployed jobs (U — UJ) has increased 2%. Underempioyed housing has increased while worker housing has decreased. The number in the labor category has decreased and the ratio of labor to underem- ployed has fallen by 12%. Both underemployed housing and labor housing are more crowded. The taxes needed have risen 14% because of the increase in underemployed workers and the decrease in taxable property, as reflected in the 8% decrease in new enterprise and the 3% decrease in mature business. Although declining industry and underemployed housing have increased somewhat, they do not represent much contribution to tax revenue.

Although the changes created are relatively small, they are nearly ail ia an unfavorable direction. They occur primarily because the slightly improved under- employed/job ratio UR has attracted more underemployed people. This has put more pressure on underemployed housing and has reduced the slum-housing-

Time (years)

Variable Symbol =5 30 Change (%) a. Underemployed-job program UIP 0 41,700 — b. Underemployed jobs US 208,400 243,800 +17. « UUT 168,900 173,600 +2. 4. UJ-UIP 208,400 202,100 3 ¢. Underemployed mobility UM 1045 044 2 £ L/U 1.04 92 ~12. 1. New enterprise NE 4,900 4,500 -8. 2. Mature business MB 7,800 7,600 -3. 3. Declining industry Di 16,500 16,700 +h 4. Premium housing PH 110,900 106,900 4. 5. Worker housing WH — 335,600 323,300 ~4. 6. Underemployed housing UH 310,100 325,600 $5. 7. Managerial-professional MP 71,100 68,800 3 8. Labor L 392,600 384,400 2 9. Underempioyed U_ —-377;300- 416,800 +10. 10. Manager/housing ratio MHR 1.07 1.07 0 1. Labor/housing ratio LHR 117 Lis +2 12. Underemployed /housing ratio UBER Bi 85 +5. 13. Manager/job ratio MR 1.38 1.38 0 14, Labor/job ratio LR 37 98 +h iS. Underemployed/job ratio UR 181 eal -6 16, Tax ratio needed TRN 2.25 287 +14. 17. Underemployed to labor net UTLN 5,500 6,830 +24,

Figure 42 Changer caused by an underemployed-job program (UIPC = 1), £488.01 20

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Figure 43 An underemployed-training program that moves 5% of the underemployed per year into the labor category.

abandoned multiplier SHAM, thereby increasing the average life of under- employed housing. A larger number of underemployed increase the tax require~ ments, which slightly discourages the construction of new enterprise.

42 Training Program

Another possible remedy for urban decay is a training program to upgrade the skills of the underemployed. Figure 4-3 shows the effect of an underem- ployed-training program that transforms 5% per year of the underemployed into the labor category. This transformation is done in the model system by an outside

influence that simply takes people from the underemployed category and puts them into the labor category. The feasibility and mechanics of doing this are not part of the model. Nor are the costs of doing so levied against the tax system in the model. Conditions are therefore taken as highly idealized: the educational process works, and it costs nothing. Even under these favorable circumstances the improvement is far from dramatic. Figure 4-3¢ shows that the number of underemployed declines for ten years and then rises again to about its original value. Men in the labor category increase. Housing remains nearly constant, and there are some increases in new enterprise and mature business,

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146059 (a) Figure 4-3 (cont)

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Figure 4-36 shows an underemployed/job ratio that improves slightly for the first three years and then returns to about the same ratio of underemployed to available jobs. The labor/job ratio increases, indicating a greater excess of labor over available jobs than at the beginning.

Figure 4-3c shows the major consequence of the training program. As people move from the underemployed group into the labor group, the population, housing, and job pressures in the underemployed sector tend to be reduced. This, along with the greater upward economic mobility represented by the training program, makes the area more attractive and the underemployed-arrival rate has increased. Conversely, the underemployed-departure rate has decreased, with a substantially larger netinward flow resulting. The underemployed-to-labor upward mobility rate is much increased by the training program, But, because an excess labor group is being created by the training program and jobs for them have not been influenced except by the secondary reactions of the system, the outflow from the labor category must increase. Because of higher labor unemployment, the dropout rate of labor to underemployed has increased, partly compensating for the training program. In addition there has been a substantial increase in the outflow of labor from the area, which is not shown in Figure 4-3c but which is indicated in the tabulation of Figure 4-4.

In the tabulation of changes occurring because of the underemployed-training program (created by UTR = .05 in Equation 140.1 of Appendix A), we see that the upward mobility UTL has increased by 110%. But at the same time the counterflow LTU has increased 63%. Underemployed arrivals have risen 43% while underemployed departures have fallen 20%. The total number of under- employed has risen slightly, by 1%, while at the same time underemployed housing has fallen by a like amount. Worker housing has risen 8% while the labor living in that housing has risen 23%. Because of the excess Jabor in the area, the labor-arrival rate has fallen 15% and the labor-departure rate has risen 81%.

'The training program has created a flow through the area with a much increased underemployed-arrival rate and a much increased labor-departure 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 iotal of underemployed has risen very slightly, and the ratio of labor to jobs is higher, indicating a higher degree of unemployment.

Figure 4-5 gives an over-all view of the population levels and flow rates result- ing from the training program. The upper figure in each pair is for the original condition of the area and the lower figure is after the new equilibrium has been established with the 5% per year underemployed-training program. A change in one part of the system causes a realignment and rebalancing throughout the system. After the rebalancing the normal flow rates and levels have all changed,

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Time (years)

Variable symbol —5 50 Change (%) a. Underemployed-training program UTP 0 19,100 = b. Underemployed to labor UTL~— 16800355300 +110 . Labor to underemployed LTU 11,300 18,400 +8. d. Underemployed arrivals UA 17,300 24,700 +8. €. Underemployed departures UD 17300 -13,900 =2. f. Labor acrivals LA 7,400 6,300 ~15. g. Labor departures LD 13,200 23,900 481. i. L/U 1.04 1.26 +21, 1. New enterprise NE 4900 «5,800 +18. 2. Mature business MB 7,800 «49,700 424 3. Declining industry DI 16500 16,700 +h 4, Premium housing PH 110,900 119,200 + 5. Worker housing WH — 335,600 361,500 +8 6, Underemployed housing UIE 310100 395900 oh ial ional » E . & Labo Prosesion L 392,600 482,400 +23 9. Underemployed 377300 382,000 +h 10. Manager/housing ratio MBER 1.07 if Ak 11. Labor/housing ratio ; LHR Li 33 le 12. Underemployed/housing ratio UHR '81 38 2 13. Manager/job ratio MR 138 138 a 14, Labor/job ratio LR 97 1.06 + 15. Underemployed/job ratio UR 181 18 2 16, Tax ratio needed TRN 2382.06 xe 17. Underemployed to labor met. =; UTLN 5,500 16 +205.

Figure 4-4 Changes caused by a training PoE oN 5% per year from underemptoyed to labor

and the consequences may be far different from those expected when the original inge was introduced. _ one principal advantages accruing from the training program ave the net increase in upward mobility UTLN, the social-service function create y the outflow of labor, and the increase in new enterprise and mature business. The underemployed-training program is converting 19,100 underemployed pe year to labor, as a consequence of which the increase in UTLN is only 11,300. . discrepancy between the output of the training program and the net upward increase in flow from underemployed to labor is accounted for by the increase i dropout rate LTU from labor to underemployed and a reduction in the normal upward mobility that would have occurred in the absence of a training Program. Conditions have become somewhat more unfavorable for normal escape from the underemployed group and the natural processes have declined as the training icks up the task. ;

OE aanine program is moving 19,100 people per year, but the net jnorease in upward mobility is 11,300. The number of people that would normally mo

Failures in Urban Programs 61

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Figure 45 Flows and levels of men before and after starting a 5% per year training program to move under-

employed to labor.

upward by internal processes has decreased by 7,800 per year. This failure to achieve the full effect of the training program illustrates a general characteristic of complex systems. An action program changes the system balance, causing the system to relax its internal pressures, As the outside effort picks up the burden, more and more is left to the outside effort.

The numerical values from these computer runs, of course, do not indicate exactly what would happen in any particular city. They do, however, indicate the ways in which a complex, interconnected social system can react. If we have reasonable confidence in the relationships assumed in the model, we can expect

that the model! will indicate the direction of reactions that would occur in response to changes in urban policies.

43 Financial Aid

A third type of program often proposed for alleviating the difficulties of the city would bring financial aid to the city from state or national government. The effect of an external tax subsidy on the model area is shown in Figure 4-6. In the model system the tax subsidy* bas three direct effects. It increases the tax per capita ratio TPCR which, implying additional welfare and public services, increases the public-expenditure multiplier PEM, which is one of the coefficients influencing the inward and outward migration of the underemployed. The tax per capita ratio also influences the underemployed educational multiplier UEM and the labor educational multiplier LEM 'to increase the upward economic mobility from underemployed to labor and from labor to the managerial-profes- sional category. The money for the tax subsidy is assumed to come from outside the city, to be in addition to previous expenditures, and not to affect directly the local tax assessments.

In Figure 4-6a the only significant changes resulting from the tax subsidy are slight increases in underemployed people and underemployed housing. In Figure 4-6b the most obvious change is an increase in unemployment in the underemployed category as shown by the increased underemployed/job ratio UR.

The subsidy is generated in the model by setting TPCS = 100 in Equation 147.1 in Appendix

I A. The effect is introduced by way of Equation 147 into Equation 8 where it influences Equations 7, 27, and 40, -E_MO=B 0120

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Figure 46 Tax subsidy of 3100 per capita per year.

In Figure 4-6c the underemployed-arrival rate UA increases, while the under- employed-departure rate UD first decreases and then returns approximately to its initial value.

Figure 4-7 summarizes some of the more significant changes taken from the tabulation in Figure 4-6d. The flow from underemployed to labor UTL has risen 15%. The counterfiow from labor to underemployed has risen too, but by a lesser amount. The underemployed-arrival rate has gone up 10% and the total number of underemployed has risen 8%.

The increased attractiveness of the area created by the tax subsidy has not resulted in appreciable changes in the amount of business activity and available jobs so that the underemployed/job ratio UR has risen 9%, indicating a corre- sponding increase in underemployed workers beyond available work opportunities.

One of the more unexpected changes in Figure 4-7 is the 8% increase in the tax ratio needed TRN from internal sources within the city. This is caused by the increased tax demands generated by the

greater number of underemployed under circumstances that have produced no appreciable change in the assessed value of property within the city.

The changes discussed above suggest that financial support from the outside may do nothing to improve fundamental conditions within the city and may even

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Figure 46 (cout.)

Failures in Urban Programs 65

Time (years) Variable Symbol =3 50 Change (%) a, Tax per capita subsidy TPCS 0 100 =- b. Underemployed to labor UTL — 16,800 19,300 +15. ¢, Labor to underemployed LTU #1300 11,600 +3. d. Underemployed arrivals UA 17,300 19,100 +10. e. Underemployed departures UD —-17300-—«17;500 +h £ Labor arrivals : LA 7,400 6,800 ~8 g Labor departures LD 13,200 14,400 +9. h L/U 1.04 98 ~6 i. New enterprise NE. 4,900 4,900 0 2. Mature. business MB 7,800 7,900 +L 3. Declining industry DI 16,500 16,300 =1. 4, Premium housing PH: = 110,900 112,300 +1. 5. Worker housing WH 335,600 330,600 =i 6. Underemployed housing UH — 310,100 319,500 +3. 7. Managerial-professional MP 71,100 72.700 42. 8. Labor L 392,600 396,800 +1 9. Underemployed U_ «377300 407,000 +8 10. Manager/housing ratio MHR 1.07 1.08 +1 HL, Labor/housing ratio LHR Li7

1.20 +3. 12. Underempioyed/housing ratio UHR '81 85 +5. 13. Manager/job ratio MR 138 14i +2. 14. Labor/job ratio LR 7 38 +h 15. Underémployed/job ratio UR 181 197 49. 16. Tax ratio needed TRN 2.25 2.42 +8. 17, Underemployed to labor net UTLN 5,500 7,700 +40.

Figure 47 Changes caused by a tax subsidy of $109 per capita pet year (TPCS = 100.).

worsen conditions in the long run by causing an unfavorable shift in the propor- tions of population, housing, and business. In particular, in Figure 4-7 under- employed population rises, the ratio of labor to underemployed falls, and the internal tax demands rise.

4.4 Low-Cost-Housing Construction

As a fourth type of urban-management program, the effect of low-cost-housing construction will now be examined. Low-cost housing here means housing con- structed for the underemployed and not available to any other segment of the population. In the basic computer model the only housing available to the under- employed is the aging and declining housing that is dropping out of the worker- housing category. The low-cost-housing program considered here is not financed out of city tax revenues, It is a gift to the city from the outside, although its construction makes jobs for the labor and underemployed in the city. As will be shown in the following computer runs, a low-cost-housing program is much more detrimental to the long-run conditions of the urban area than the job program, training program, or tax subsidy previously examined. by UI EU

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Failures in Urban Programs 67

g ph ' 3 , i a5 ' : 7 = ' 4 BRS cet eee eet eee eee tt eens ere pres ie g gee, :. eet Premidm housing Mature business! ' 5 carer SaaS SUNEEE SEE ermrerererS memep serie ngs i en - re es aznsss2e lessees oeepeeeny : @ : Lace ee ee eet 5 ESS ene pee FECES S (Seen oman emg, vrrerees peesrs cess : 7 Ensssssiegrovonenee SEEKER aREEEEEEEEee ¢ - g Yeas 3 3 & zg New enterprise construction # rn +S Underemployed to labor ' 2 3 wy a chee t reed 3 2 fears 8 3 & 5 Figure 48 Construction of low-cost housing each year for about 2.5% of the underemployed. BSESSSS555555 we eens Bl cece eecenecetenee sta ee sees The low-cost-housing program is established with the intent to build housing . ' ' ' t for 5% of the underemployed each year. However (as will be seen in Equations ~~ Underenloyed/ob rato : : i H 149 and 150 of Appendix A), the intended construction is influenced by the land EE i Ler 2 ne multiplier, which reduces construction as the land area becomes full, and by = a seca tletee eee eel available labor. As a consequence the actual low-cost-housing construction LCHP

weeeeet provides for only 2.7% of the underemployed in the first year, 1.9% in the tenth : Liborfhousing-ratio ' year, and stabilizes at 3% in the fiftieth year. Annual low-cost-housing construction 1 posers rs ep re eg ee PPT ee et provides on the average for about 2.5% of the underemployed each year. If housing . = were coming only from the low-cost-housing program, this would mean a replace- ment of the housing units each 40 years,

Figure 4-84 shows the effect of introducing such a low-cost-housing program at year 0. The housing available for the underemployed begins to rise im- mediately. Because of the increased housing, more underemployed are attracted to the city and the underemployed population rises for the first 10 years. But the low-cost-housing program exerts continuous pressure on the available unfilled land, making the area less favorable for other types of construction. As a conse~ quence worker housing, premium housing, new enterprise, and mature business all gradually decline. As the business units decline in number, the available jobs decrease, thereby bringing economic pressure on all categories of the population and causing them to decrease.

'Underemployed housing ratio

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7.439 17,900 000 T3785 HAD 339910006523 HH BZD 82 career (a)

Figure 4.8 (cont.)

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Figure 4-8b shows changes in the significant system ratios. The underemployed/ job ratio drops slightly at first because of the jobs created by construction of low-cost housing, But as soon as the population begins to increase to fill the newly available housing, the underemployed /job ratio rises sharply from the initial value of 1.81 to become 2.14 at the tenth year and 2.35 at the fiftieth year.

Because underemployed housing increases while at the same time rising economic pres- sures cause the population to decline, the underemployed/housing ratio falls steadily over the 50-year period. Because of the rising ratio of underemployed to other classes of population, and the declining tax base, the tax ratio needed increases as a result of the low-cost-housing program,

Figure 4-8c shows some of the system rates. Slum-housing demolition increases to reach a new equilibrium consistent with' the rate of construction of low-cost housing coupled with the continued inflow of dwelling units from the aging process in the worker-housing category. Between year 0 and year 10 the under- employed-arrival rate into the area increases while the underemployed-departure rate temporarily decreases. This causes an increase in the underemployed popula- tion until the worsening economic conditions cause a reversal.

Figure 4-9 shows values of variables before and after 50 years of low-cost- housing-program construction and the percentage change occurring over the 50-year period. The slum-housing-demolition rate increases because, eventually in equilibrium, all of the new construction is matched by old units that are taken down. The underemployed population falls 1% while underemployed housing rises 45%. Worker housing declines 31% while the labor population falls 30%. The underemployed/job ratio worsens by rising 30%. The underemployed/ housing ratio, which was already below normal, falls another 32%. The tax tatio needed increases 36% while new enterprise falls 49%, mature business falls 45%, and declining industry falls 6%.

The low-cost-housing program brings additional pressure on the land area. It attracts people in the underemployed category, making the population proportions within the urban area even more unfavorable than in the normal stagnant condi- tion. The higher land occupancy, unfavorable population ratio, and rising tax tate all combine to reduce the kinds of new construction the city needs most. An examination of Figure 4-9 shows remarkably large changes in an unfavorable direction. In comparison to what sounds like an innocuous 2.5% housing-construc- tion rate for the underemployed, the results are unfavorable for all categories of population. The housing program, aimed at ameliorating conditions for the underemployed, has increased unemployment and has reduced upward economic mobility both in absolute numbers and as a percentage of population. Figure 4-9 shows that the net underemployed-to-labor flow rate UTLN has fallen 31%. Upward mobility as a percentage of the underemployed has decreased from 1.5% in the normal stagnant city to 1% after inauguration of the low-cost-housing program.

The preceding computer runs have examined programs that provide jobs, training, an external tax subsidy, and low-cost housing for the underemployed.

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Time (years) Variable Symbol 5 50 Change (%) . Low-cost-housin, am LCHP 0 11,100 = is Worker-housing e Bolescence WHO 9,100 6,500 28, ¢. Sium-housing demolition ed SHD 9,100 17,100 +88. d. UH/SHD = underemployed- housing life 34, 26. -24, e. Underemployed to labor UTL 16,800 11,200 -33. f. Labor to underentployed LTU 11,300 7,400 —35. g. Underemployed arrivals UA 17300-14300 me h. Underemployed departures uD 17300 '16,800 3. i. Labor artivais LA 7,400 4,600 -38. j. Labor departures LD 13,200 9.900 —25. k L/U 1.04 3 -30. 1. New enterprise NE 4,900 2,500 —49. 2. Mature ptsiness MB 7,800 4,300 —45, 3. Declining industry DI 16,500 15,500 -6. 4, Premium housing PH 110,900 73,300 —34, 5, Worker housing WH 335,600 231,200 —31. 6. Underemployed

housing UB 310,100 450,600 +6 7, Managerial-professional MP 71,100 46,900 "3 a 8. Labor L 392,600 272,900 30. 9. Underemployed U 377,300 372,600 "y 10. Manager/housing ratio MHR 1.07 1.07 0 11. Labor/housing ratio LHR 1.7 118 sy 12. Underemployed /housing ratio UHR. BE 3 - z 13. Manager/job ratio MR 138 138 0 14. Labor/job ratio LR 37 3 38 15. Underemployed/job ratio UR 181 23 +30. 16. Tax ratio needed TRN 2.25 3.06 +36. 17. Underemployed to labor net UTLN 5,500 3,800 —3h

' , Joye 49 Changes caused by Jow-cost-housing program that builds for about 2.5% of the underempl Figure 49 = 4 each year (LCHPC = .05).

The results range from neutral to detrimental. These computer runs disclose possible reasons for the futility and frustration that characterize urban-devel- opment programs. They demonstrate the counterintuitive nature of complex social systems by showing that intuitively sensible policies can affect adversely the very problems they are designed to alleviate. Commonly in complex systems a vicious cycle develops in which the action erroneously assumed to be corrective mal es the problem worse and the worsening calls forth still more of the presume: remedial action, which only further aggravates the situation.

5 Urban Revival

This chapter explores policies that might reverse urban decay. The preceding chapter showed the harmful effects of constructing low-cost housing, This chapter shows that constructing worker housing and premium housing can be detrimental too, but less so than constructing low-cost housing. The problem of the stagnant urban area is one of too much housing compared to employment opportunities and too much old industry and housing compared to new. This chapter, after exploring several policies, concludes that urban revival requires demolition of slum housing and replacement with new business enterprise. Only by this shift from slum housing to new business will the internal mix become healthy.

5.1 Worker-Housing Construction

Figure 4-8 showed how construction of low-cost housing can cause deteriora- tion. Figure 4-86 exhibits a higher-than-normal labor/housing ratio and raises the possibility that construction of worker housing might increase the attractive- ness to labor and lead to improving population balance and readjusting conditions in the area. The results are disappointing, as shown in Figure 5-1, where the changing conditions are caused by a worker-housing-construction program that builds for slightly more than 2% of labor families per year. The amount of desired construction is expressed as a fraction of total housing units and is influenced by the worker-housing land multiplier WHLM and the labor availability LCR (Equations 82, 86, and 138 in Appendix A). As a result the construction varies some from year to year. In Figure 5-la worker housing rises initially and then declines. The decline is caused by the reduction in the total number of labor families, the resulting increased vacancy rate, and the more rapid deterioration of worker housing into underemployed housing. Figure 5-1a illustrates the result of regenerative interactions caused by the housing program. Housing construction increases the land fraction occupied. Land crowding causes a slight reduction in the construction of new enterprise. Declining enterprise reduces the number of jobs, which in turn reduces skilled labor. The addition of worker housing has worsened a fundamental condition already

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than can find economic opportunity.

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Figure 5-1, Worker-housing-construction program for about 2.1% per year of the labor families

Figure 5-16 shows an initial small dip in the underemployed/job ratio caused by the work available from the housing-construction program. But as the new housing becomes available, the increasing worker housing reduces occupancy and causes a more rapid decline of worker housing into underemployed housing, which attracts underemployed. Because of reduced new-enterprise construction, industrial activity and available jobs decline in comparison to underemployed workers. As a natural accompaniment to the falling job opportunities, there is a relative increase in the amount of underemployed housing as seen in the declining underemployed/housing ratio. Because of relatively more housing and relatively fewer jobs, the city probably will show an even more accentuated condition of underemployed crowding into some dwellings and vacancy in others. Financial realities force crowding into a fraction of the housing, while the other housing becomes idle and deteriorates rapidly, though it may remain standing.

In Figure 5-1c, as 2 result of worsening conditions, the underemployed-depar- ture rate increases while the underemployed-arrival rate decreases, leading to the falling population seen in Figure 5-la

In Figure 5-1 the worker-housing-construction rate jumps when the program is inaugurated and then declines as the land fraction occupied increases and as normal construction, which was taking place before the special program began, decreases, As tabulated in Figure 5-2, the special worker-housing-construction program at year 50 is building 8,340 units per year, but the total worker-housing-

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(a) Figure 5-4 (cont)

Urban Revival 75

Time (years)

Variable Symbol =5 50 Change (%)

a. Worker-housing-construction program WHCP 0 8,340 — b. Worker-housing construction WHC 5,880 10,620 +81. c._Premium-housing construction PHC 3,140 2,660 =15. 1. New enterprise NE 4,900 4,030 ~18. 2. Mature business MB 7,800 6,070 —22. 3. Declining industry DI 16,500 14,260 -13. 4. Premium housing PH 110,900 88,900 =20. 5. Worker housing WH 335,600 354,600 +6. 6. Underemployed housing UH 310,100 341,600 +10. 7. Managerial-professional MP 71,100 58,500 =18. 8. Labor L 392,600 340,400 =13. 9. Underemployed U_ 377,300 333,800 -12. 10. Manager/housing ratio MHR 1.07 1.10 43. 11. Labor/housing ratio LHR Lay 96 ~18, 12, Underemployed/housing ratio UHR 81 65 ~20, 13, Managet/job ratio MR 1.38 138 0 14. Labor/job ratio LR 37 1.00 43. 15. Underémployed/job ratio UR 181 1.96 +8, 16. Tax ratio needed TRN 2.25 217 4 17. Underempioyed to labor net UTLN 5,500 3,020 —45,

Figure 52. Changes caused by a worker-hovsing-construction program (WHCR = .02).

construction rate has increased only 4,740 units per year. This means that the normal processes of worker-housing construction within the area have declined by 2,600 units per year. The decline in normal construction illustrates a rather general characteristic of systems. A positive program to generate some rate of flow will change the system balance and cause a depression in the normal proc- esses generating that same rate. The new program is only partly effective because much of it simply displaces normal processes.

Although in Figure 5-2 worker-housing construction has risen 81%, total worker housing has risen only 6%. The small rise in worker housing is explained by a reduction in average housing life* (shown in Figure 5-3). Because of the lower

at — 5 years at 50 years Premium-housing life 35 years 36 years Worker-housing life 37 years 27 years Underemployed-housing life 34 Years 26 years

Figure 53 Avecage housing life before and afler the worker-housing-construction program.

"Housing fife is the reciprocal of normal-housing-obsolescence rate multiplied by the obsolescence multiplier. For example, premium-housing life is the teciprocal of (PHON) (PHOM), These are piven in Equations 79 and 80 of Appendix A, PHON = 03 and, from Figure 5-1d, PHOM = .948 at —5 years. The product is 0285, the reciprocal of which is 35 years. Similarly, worker-housing life comes from Equations 93 and 94 and underemployed-housing life from Equations 96 and 97. 30

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Figure 54 Premium-housing-construction program for about 4.7% per yeer of the managerial-professional families.

occupancy ratios, the housing is declining more rapidly. Although the rate of housing flow through the worker and underemployed categories is higher, the actual housing in existence has risen much less than the construction rate might suggest.

i Figure 5-2 all classes of population have declined. All classes of enterprise have declined even more. Housing has become more available, but the employ- ment situation for labor and the underemployed has worsened.

Before starting the worker-housing-construction Program, the stagnant city already had too high a level of housing and population in comparison to its industrial opportunities. The worker-housing construction has shifted this balance even further in the wrong direction. The results were not so serious as for the low-cost-housing program but still do not lead to urban improvement,

5.2. Premium-Housing Construction

To complete the examination of housing construction, Figure 5-4 shows the consequence of introducing a premium-housing-construction program. Very little

change is evident except for slight decreases in population and industry and some increase in the underemployed /job ratio, The changes are small but detrimental. Figure 5-5 summarizes the changes in the principal system variables,

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th «B78 #980 (a) Figure 54 (cont,)

Urban Revival 79

Time (years)

Variable Symbol 5 50 Change (%)

a. Premium-housing-construction program PHCP 0 3,320 _

b. Premium-housing construction total PHC 3,140 5,050 +61. 1. New enterprise NE 4,900 4,640 —5. 2, Mature business MB 7,800 7,300 -6. 3. Declining industry DI 16,500 15,610 —5. 4, Premium housing PH 110,900 112,100 +h 5. Worker housing WH 335,600 336,600 0 6. Underemployed housing UH 310,100 317,900 +3. 7. Managerial-professional MP 71,100 67,800 —5. 8. Labor L 392,600 377,800 4, 9. Underemployed U 377,300 367,800 3. 10. Manager/housing ratio MHR 1.07 1.01 -6. 1. Labor/housing ratio LHR Liv 112 4, 12. Underemployed/housing ratio UHR 3 a -5. 13. Manager/job ratio MR 138 139 +i. 14. Labor/job ratio LR 7 98 +h 15. Underemployed/job ratio UR ESL 1.86 +3. 16. Tax ratio needed TRN 2.25 2.22 +h 17. Underemployed to labor net UTLN 5,500 4,770 -13.

Figure $$ Changes produced by premium-housing program (PHCR = .05).

Construction of housing in any price class through externally imposed programs seems detrimental to the stagnant city. The reason is fairly clear if the funda- mental problem of the city is too much housing and too high a population, particularly in the lower economic groups. Additional housing fills land and makes new industry more difficult to initiate.

5.3 New-Enterprise Construction

Now that we have seen that the construction of housing moves the stagnant urban area in the wrong direction, we will examine the consequences of construct- ing new enterprise. The results are favorable but taken alone are not sufficient to overcome the difficulties.

Figure 5-6 shows the influence of a new-enterprise-construction program. It is here assumed that the new enterprise can be created directly as a result of a positive applied program. As a practical matter a city probably can not accom- plish this by any direct action; indirect action would be more realistic. However, we want to understand the influence new industry might have, and creating it by a direct-action program within the model system shows the consequences.

In Figure 5-6 the new industry being generated is equal to about 1.2% each year of the total productive units in the area. Figure 5-6a shows rises in all population classes and all business categories. Housing increases except for a slight 1 MPEM, NESE, B04 20

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Figure 56 New-enterprise-construction program that produces new each ductive units in the city.

year about 1.2% of the total pro- decline in worker housing. Figure 5-6b shows a modest decrease, representing improvement, in the underemployed /job ratio. Figure 5-6 shows that the area becomes more attractive to the underemployed, causing a rise in underemployed arrivals and a decline in underemployed departures. Figure 5-7 summarizes the changes caused by the new-enterprise-construction program. In the fiftieth year the direct-action-construction program is producing 418 new-enterprise units per year. Yet the total new-enterprise-construction rate has risen only 242 units per year. Nearly half of the direct-action Program is required to replace normal construction, which has been suppressed by the changed economic mix within the area.

The new-enterprise-construction program produces favorable changes. How- ever, these changes are not sufficient to correct the economic imbalance, Further- more, it is unlikely that new-enterprise construction can, be forced by any city- government program. It is more important therefore to look at direct-action programs that conceivably lie within the authority of a city and that will indirectly generate a rebalancing of those variables that can not be directly influenced.

5.4 Declining-Industry Demolition

if the mix within the city tends toward too high a proportion of old structures, the city might establish jand-clearing programs or a tax structure that provides

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W 28S 026 852 12 512 4512 2815, 13.803 .508 ue ans 4 2909 ~ - (4) Figure 5-6 (cont)

Urban Revival 83

Time (years) Variable Symbol -5 50 Change (%)

a. New-enterprise-construction program NECP 0 418 —

b. New-enterprise-construction tate total NEC 462 704 +52. 1. New enterprise NE 4,900 5,930 +21. 2. Mature business MB 7,800 9,930 +27. 3. Declining industry DI 16,500 23,730 +44. 4. Premium housing PH 110,900 126,500 +14. 5. Worker housing WH 335,600 331,200 -1. 6. Underemployed housing UH 310,100 320,400 +3. 7. Managerial-professional MP 71,100 90,400 +27. 8. Labor L 392,600 485,600 +24, 9. Underemployed U 377,300 451,600 +20, 10. Manager/housing ratio MEHR 1.07 1g +i 11. Labor/housing ratio LHR Li7 1.47 +26. 12. Underemployed/housing ratio UHR 81 94 +16. 13. Manager/job ratio MR 1.38 134 3. 14, Labor/job ratio LR 7 90 -7. 15, Underemployed/job ratio UR 181 151 -17. 16. Tax ratio needed TRN 2.25 2.36 +5. 17, Underemployed to labor net UTLN 5,500 13,010 +136.

Figure 5-7 Changes caused by the new-enterprise-construction program (NECR = .02).

incentive for removal of aging structures. Without exploring how the removal of old structures might be initiated, let us examine the influence of such removal within the simulation model.

Figure 5-8 shows the effect of demolishing 5% of declining industry each year. 'There are improvements in some variables. Figure 5-9 shows the changes caused by this program. Opening up land by demolition of decaying industry has reduced substantially the amount of such industry. Both new enterprise and mature business have increased. Housing has declined slightly, population has declined more, The increase in new enterprise and the reduction in population have reduced the tax load so that the tax rate needed has declined 9%.

In Figure 5-8d underemployed jobs UJ have fallen more than the number of underemployed U so that the underemployed/job ratio in Figure 5-8b is slightly higher than before the demolition program started. The changes are of mixed merit.

$5 Slum-Housing Demolition

To change the city toward having more industry and away from being an economically ineffective concentration of underemployed housing and under- employed population, one measure might be the demolition of slum housing. This could provide area for industrial expansion and might help to rebalance b

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Up teeters seerezreereart " ' XK ' ' : g wae RT i So ecm narnem n S ot ' 1 New emtepaise, : : ES "" i . if 3a! : : : (a : : Fa thesforesseese}ensanoszoesseesett ' 7 . 5 3 Je $ ¢ é 2 © Underemployed arrivils : : 3 2 ' estes teees a 3 R . 3 g Figure 58 Declining-industry-demolition program that removes 5% of declining industry each year. SF wed geey 5 the population proportions so that the city could escape from its stagnant condi- \Nunaeremese, hob ratio : tion. To determine whether slum-housing demolition results in favorable changes ' 71288 fection occupied ms for the city, the consequences for the original populations must be examined. " vie Figure 5-10 shows the extensive changes created by a slum-housing-demolition

program that removes 5% of the underemployed housing each year. Discussion of such a program does not imply that the demolition of slum housing should tesult from active intervention by the city. It might better be accomplished by eeeseersesrssy. changes in tax laws and land zoning.

Pabalel geaied al NY NNN In Figure 5-10 the slum-housing-demolition program reduces the under-employed housing to a new equilibrium after 50 years at about half its beginning value. As land becomes available, new industrial construction is induced and creates more jobs. Also there is an upsurge in the construction of worker housing which, along with the additional industry, supports a latger labor force. The underemployed-arrival rate UA in Figure 5-10c changes relatively little, meaning that the attractiveness of the city is about the same at the end of 50 years as it was before the beginning of the slum-housing-demolition program. However, Figure 5-10b shows a substantial compensating change in two of the components of city attractiveness for the underemployed. The underemployed/housing ratio UHR has increased, indicating less housing availability. At the same time the

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Time (years) Variable Symbol —5 30 Change (%)

a. Declining-industry-demolition program DIDP oO 324 _

b. Declining-industry demolition total DID 464 510 +10. 1. New enterprise NE 4,900 6,200 +26. 2. Mature business MB 7,800 9,700 +24. 3. Declining industry DI 16,500 6,500 61. 4, Premium housing PH 110,900 113,600 +2. 5. Worker housing WH 335,600 330,600 -2. 6. Underemployed housing UH 310,100 302,300 -3. 7. Managerial-professional MP 71,100 70,200 1 8. Labor L 392,600 355,300 —10, 9. Underemployed U 377,300 346,000 8. 10. Manager/housing ratio MHR 1.07 1,03 ~4. IL. Labor/housing ratio LHR 1.17 1.08 -8. 12, Underemployed/housing ratio UHR 8h 76 —6. 13. Manager/job ratio MR 1.38 139 +h 14. Labor/job ratio LR oF 39 +2. 15. Underémployed/job ratio UR 181 191 46. 16. Tax ratio needed TRN 2.25 2.04 -9. 17. Underempiloyed to labor net UTLN 5,500 4,200 ~24,

Figure 5.9 Changes caused by a dectining-industry-demolition program (DIDR = .05).

underemployed /job ratio UR has declined, indicating improved economic oppor- tunities for the underemployed that are present. Except for the rising under- employed/housing ratio UHR, with its implied shortage of housing, it would not be possible to maintain the more favorable employment conditions represented by the falling underemployed/job ratio UR. Were housing readily available, the improved economic conditions in the urban area would attract additional under- employed from the outside environment until economic conditions had fallen so far that no additional net inward flow would occur.

Figure 5-11 shows the changes produced by the slum-housing-demolition program. New enterprise and mature business increase 45%. Declining industry increases only 9% because the more favorable circumstances for new-enterprise construction encourage the abandonment and demolition of declining industry. Premium housing increases 30% and worker housing 34%, while underemployed housing is down 44%. The underemployed/housing ratio has risen 49%, a necessary crowding accompaniment to the improved underemployed/job ratio reduction of 33%. The tax ratio needed TRN has falien 33%.

Against these improvements in the city as a whole, one must ask what the slum-demolition program has done to the underemployed population. In the first 10 years, the underemployed population U has dropped from 377,310 to 345,420 (Figure 5-10d), or 8.5%. This has occurred because of the accumulated effects £48801 20

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Figure 510 Stura-housing demolition that removes 5% of underemployed housing each year,

of changed flow rates which are, in the tenth yeat, a decrease of 1,050 men per year arriving UA, an increase of 2,450 men per year leaving UD, and an increase of 1,840 men per year in upward mobility UTLN from underemployed to labor, The population adjustment of 8.5% can be estimated roughly in the same propor- tion—1.7% change owing to fewer arrivals, 3.9% change owing to more departures, and 2.9% change owing to greater transfer to the labor catagory. Only the value of the increased departure rate could be questioned. Other policies, discussed in Section 5.7, appear to revitalize a city without forcing a net outward migration of underemployed.

This slum-housing-demolition Program does not incorporate any rebuilding activity. The natural vitality of the city generates rebuilding once land area becomes available and various Processes start to move toward creating a healthier economic balance.

But even with the demolition program, the land fraction occupied at the end of 50 years has risen by 2%. Furthermore, worker housing has increased as well as premium housing. In Figure 5-10c the

worker-housing-construction rate WHCR tose steeply and remained high through the second decade as land area became available. This suggests that the city is still tending to generate housing more readily than industry and that some further suppression of housing in favor of industrial expansion should be explored.

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(a) Figure 5-10 (cont)

Time (years) Variable Symbol =5 50 Change (%) a, Slum-housing-demolition program SHDP i) 8,720 _ b. Slum-housing demolition total rate SHD 9,050 12,100 +34, c. Worker-housing construction WHC 5,880 7,860 +34, d, Land fraction occupied LEO 82 84 42. 1. New enterprise NE 4,900 7,100 445, 2, Mature business MB 7,800 11,300 +45. 3. Declining industry DI 16,500 18,000 +9. 4, Premium housing PH 1[0,900 144,700 +30. 5. Worker housing WH 335,600 450,300 +34, 6. Underemployed housing UH 310,100 174,300 ~44, 7. Managerial-professional MP 71,100 96,000 +35. 8. Labor L 392,600 530,800 +35, 9. Underemployed U 377,300 316,900 ~16. 10. Manager/housing ratio MHR 1.07 1 +4. 11. Labor/housing ratio LHR 117 1.18 +1. 12, Underemployed/housing ratio UHR Bi 121 +49. 13. Manager/job ratio MR 138 1,39 +1. 14, Labor/job ratio LR ST 101 +4. 15. Underemployed/job ratio UR 181 122 = 33. 16. Tax ratio needed TRN 2.25 f51 33, 17. Underemployed to labor net UTLN 3,500 5,580 +h

Figure 5-11 Changes caused by a slum-housing-demolition ptogram (SHDR = .05).

5.6 Discouraging Housing Construction

In Figure 5-1 the construction of worker housing depressed activity within the city. This suggests that less housing construction might be beneficial. Figure 5-12 shows results when a slum-housing-demolition program is pursued and in addition construction of new worker housing is restrained. The 5% slum-demolition pro- gram is the same as in Figure 5-10. In addition the worker-housing normal coefficient WHCN has been reduced from .03 to .015. This means, if all other conditions remained identical, that the worker-housing-construction rate would be reduced by a factor of 2. Of course, other conditions do not remain constant but shift to partly compensate for the restrictions on new construction. The reduced coefficient WHCN (see Equation 83 in Appendix A) implies less favor- able conditions for new construction. In practice these might mean zoning restrictions, increasing standards of building construction, a tax structure unfavorable to such construction, or other urban policies designed to shift the balance from housing to productive business activity.

A comparison of Figures 5-12 and 5-10 shows that the restriction on worker- housing construction has increased the labor force, decreased the underemployed, increased the managerial population, and increased business activity. Figure 5-13 shows the changes from the equilibrium city caused by the slum-demolition program and the restriction on worker-housing construction. New enterprise and ey

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Figure 5-12 Slum-housing demolition, of $% of the underemployed housing each year and restrictions that reduce to haif the normal worker-hovsing-construction rate.

mature business are up substantially more than declining industry. Premium

housing has increased 48% and worker housing 36%, while underemployed hous-

ing has declined 54%. In spite of the 23% decrease in the underemployed popula- tion, the net upward economic mobility UTLN has risen 29%, indicating that the city has become a more effective converter of the underemployed into people matched to modern business activity. Because of the changed internal mix in the city, the tax ratio needed TRN has fallen 4%.

Figure 5-14 shows the changes caused by restrictions on worker-housing con- struction only, when added to slum-housing demolition. The figure compares the fiftieth year from Figure $-10 with the fiftieth year from Figure 5-12. The difference between the two is caused by a halving of the worker-housing- construction rate for any particular set of urban conditions, Figure 5-14 contains some rather surprising results. Although there is half the tendency to construct worker housing, the amount of worker housing has risen by 1%. Premium housing has increased 13% and underemployed housing has decreased 18%. Ail of these changes are in comparison to the conditions caused by a slum-demolition program only. New enterprise and mature business have increased 14% each and declining industry is up 6%. The restriction on worker housing has increased the labor

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(a) Figure 5-12 (cont)

Time (years) Variable Symbol —5 50 Change (%) a, Slum-housing-demolition program SHDP 0 7,100 ~ b. Sium-housing demolition total rate SHD 9,100 9,500 +4 ¢. Worker-housing construction WHC 5,900 5,100 -i. 1. New enterprise NE 4,900 8,100 +65. 2. Mature business MB 7,800 12,900 +65. 3. Declining industry DI 16,500 19,000 +15. 4, Premium housing PH 110,900 163,800 +48. 5. Worker housing WH 335,600 456,900 +36. 6. Underemployed housing UH — 310,100 142,300 34, 7. Managerial-professional MP 71,100 108,100 +52. 8. Labor L 392,600 382,800 +48, 9. Underemployed U 377,300 290,300 23. 10, Manager/housing ratio MEHR 1.07 1.10 +3. 11. Labor/housing ratio LHR 117 1.28 +9. 12, Underemployed /housing ratio UBR Bl 136 +68. 13. Manager/job ratio MR 138 1.40 +1 14. Labor/job ratio IR 37 LOL +4. 15. Underemployed/job ratio UR 181 1.02 —4, 16. Tax ratio needed TRN 2.25 1,32 -4. 17. Underemployed to labor net UTLN 5,500 7,220 +29.

Figure 5-13 Changes caused by slum-housing-demolition (SHDR

08) and restriction of worker-housing construction (WHCN = 015).

occupying the housing by 10%. The restriction on housing construction has caused the underemployed /job ratio to decrease 16% and the tax ratio needed to decrease another 13% compared to what the slum-housing-demolition program alone produced. As a social converter from underemployed to labor, the new conditions with the worker-housing restriction have caused a 28% increase in underemployed~ to-labor net UTLN.

Figure 5-14 requires some explanation. The results of restricting worker-housing construction are spread widely through the urban system, many in unexpected directions. This internal rebalancing to readjust for a policy change is typical of complex systems. It is also common that the results may be opposite those expected, as here finding an increase in worker housing when the construction rate has been restrained. The biggest changes often occur in quite remote places. In Figure 5-14 the largest percentage change has occurred in the net upward mobility UTLN. The next largest change is downward, not in worker housing, which was directly affected, but in underemployed housing, which is indirectly influenced. The third largest change is a decline in the ratio of underemployed to available jobs, indicating more favorable economic opportunities. And the next largest changes are increases in new enterprise and mature business. Worker housing, which is directly influenced by worker-housing construction, is one of the four variables least affected.

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Year 50 Year 50

Variable Symbol Fig. 5-10 Fig. 5-12. Change (%) 1. New enterprise NE 7,100 8,100 +14, 2. Mature business MB 11,300 12,900 +14. 3. Declining industry DI 18,000 19,000 +6. 4. Premium housing PH 144,700 (163,800 +13. 5. Worker housing WH 450,300 «456,900 +1. 6. Underemployed housing UB -174300-———(142,300 ~ 18. 7. Managerial-professional MP 96,000 -——=108,100 +13. 8. Labor L 530,800 582,800 +10. 9, Underemployed U «316,900 290,300 -8. 10, Manager/housing ratio MHR an 1.10 aL 11. Labor/housing ratio LHR 118 1.28 48. 12, Underemployed/hovsing ratio UHR 121 1.36 432. 13. Manager/job ratio MR 139 1.40 +1. 14. Labor/job ratio LR 1.01 101 0 15. Underemployed/job ratio UR 1.22 1.02 -16. 16. Tax ratio needed TRN ist 132 =13. 17, Underemployed to labor net. = UTLN 5,580 7,120 +28.

Figure 5-14 Changes caused by restriction on workershousing construction only, wher added 10 @ slum- housing-demolition program.

Worker-housing construction is determined by Equation 82 and associated Equations 83 and 84 (discussed in Appendix A but reproduced here).

WHE KLE CWHCDAK) CLOR 4K) 82,8 WHC - WORKER-HBUSING CONSTRUCTION CHBUSING UNI TS/

YEAR)

WHCD - WORKER-H@USING CONSTRUCTION DESIRED CHBUSING UNI TS/Y EAR)

LCR = LABOR CANS TRUCTION RATIO CDI MENS BNLESS)

HCD .K 2CWHCN) OHH KD CHH Mo K)-4HHCP 2 &3,A WHCN=.03 83.1,C

WHCD = WORKER-HOUSING CONSTRUCTION DESERED HOUSING UNI TS/V EAR)

WHCR ~ WARKER-HOUSING CONSTRUCTION NORMAL CERACTIGN/Y EAR)

WH = WIRKER HOUSING CHBUSING UNITS)

WHM = WORKER-H@USING MULTIPLIER CD} MENS] BNLESS)

WHCP - WORKER-H@USING-CONS TRUCTION PROGRAM CHOUSING UNTTS/YEARD

WHMAK = CWHAMSK) CHHLMSK) CHHUMSK) CWH THK? CHHEMAKD CHHGHSK? 4A HHP

WHE=1 B4e1,0 WHM = WORKER-HOUSING MULTIPLIER CDLMENS 1 BNLESS

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WHAM + WORKER-HUSING-ADEQUACY MULTIPLIER COIMENSSONLESS)

WHLM = WORKER-HOUSING LAND MULTIPLIER CDI MENSE@NLESS)

WHUM WORKER-HBUSING UNDEREMPL@YED MULTIPLIER

CD MENS FBNLESS)

WHT = WARKER-HOUSING TAX MULTIPLIER CDEMENSTBNLESS>

WHEM = MORKER-HOUSING ENTERPRISE MULTIPLIER COLMENSINLESS).

WHGM = WORKER-HOUSING-GROWTH MULTIPLIER CDI MENSIGNLESS>

WHF «= WARKER-H@USING FACTOR COIMENSIGNLESS)

The dominant variables are given in Equation 83 determining the worker-housing construction desired as the product of WHCN, WH, and WHM. Worker-housing construction is proportional to the existing housing (representing the size of the urban area) and to the normal construction rate WHCN. This normal rate is then modified by the multiplier WHM, which combines the influences of the urban system on the housing-construction rate. These influences are given by the mul- tiple product in Equation 84.

Figure 5-15 shows several changes caused when the value of WHCN is reduced from .03 to .015. When a new equilibrium has been reached, the worker-housing multiplier WHM has increased 29% to compensate for nearly a third of the seduction in WHCN. The major changes affecting the multiplier are the worker- housing-adequacy multiplier WHAM, which has risen 18%, and the worker-hous- ing underemployed multiplier WHUM, which has increased 7%. The adequacy multiplier has risen because the ratio of labor to worker housing has increased, producing a higher demand for housing. The underemployed multiplier is derived from the ratio of labor to underemployed and indicates a more favorable city environment for the construction of worker housing. The net result of these changes is that worker-housing construction WHC has fallen 35% compared to

Year 50 Year 50

Variable Symbol Fig. 5-10 Fig. 5-12. Change (%) Worker-housing multiplier WHM 643 827 +29. Worker-housing-adequacy

multiplier WHAM 157 1.86 +18. Worker-housing underemployed

multiplier WHUM 935 1.00 47. Worker-housing construction WHC 7,360 5,130 35. Premium-housing obsolescence PHO 4,260 4,990 +417. Total rate entering worker

housing, 12,120 10,120 —17. Worker-housing-obsolescence

multiplier WHOM 1,382 1.164 —16. Worker-housing life 36 years 43 years +19.

Figure $15 Changes in the worker-housing variables caused by restricting construction. 020 4.5. {PHEW ,UH=H MPH NEE, HB ,D4=0

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Figure 5-16 Demolition of 5% of slum housing each year and business encouragement that increases new- enterprise construction 40% over what would have occurred under the same conditions without added incentive.

its rate under a policy of slum-housing demolition alone. However, the premium- housing obsolescence PHO has increased as a result of the higher rate of construc- tion of premium housing. This aging of premium housing represents a flow into the worker-housing category so that the total rate of flow into worker housing has declined only 17%. But Figure 5-14 showed an increase in the total worker housing in existence. The difference is explained by Figure 5-15, which shows a 19% increase in worker-housing life. The greater pressure to build worker housing caused by the restrictions on such construction has caused the housing to be maintained in the worker-housing category and used by the labor population for a longer period of time. As was seen in Figure 3-4, the total units in an age category are proportional to the rate of flow and to the length of time in the category. The smaller flow rate of worker housing multiplied by the longer life in the worker-housing category leads to a slight increase in total worker housing.

In Figure 5-126 the stum-housing demolition and the restriction on worker- housing construction lead initially during the first 10 years to a reduction in the land fraction occupied LFO. This encourages a rise in new-enterprise construction which is supported by the rising labor population, the latter generated by new industry, and by the changing ratio of labor to underemployed. The improving tax rate, which in Figure 5-13 falls 41%, encourages still more new-enterprise 100. Chapter Five

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Figure 5-16 (cont.)

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construction and more management and labor residing in the area. The individual influences are slight, but their multiple regeneration on each other can have a

substantial effect on the delicate equilibrium of a system poised between growth and decline.

5.7 Encouraging Industry

The natural tendency toward imbalance in which housing dominates industry might be corrected by urban policies that encourage industry as well as by policies that discourage construction of excess worker housing. Figure 5-16 shows the effect of policies that combine slum-housing demolition with active encouragement for new-enterprise construction. The slum-housing-demolition tate of 5% is the same as that in Figures 5-10 and 5-12. In the basic model the new-enterprise construction normal NECN is .05 per year (as described in Equation 102 in Appendix A). As with the other normal rates of flow, the actual rate is modulated by conditions within the urban area. In Figure 5-16 the coefficient NECN has been increased from .05 to .07 which means that, al! other circumstances being equal, the new-enterprise-construction rate would be increased 40%. Of course such a change in the propensity to build new enterprise will produce reactions throughout the system. A comparison of Figures 5-16 and 5-12 shows only a few

Time (years) Variable Symbol —5 30 Change (%) a. Slum-housing-demolition program I SHDP 0 8,770 _ b. Slum-housing demolition total rate SHD 9,100 12,360 +36. c. Worker-housing construction WHC 5,900 7,700 +31. d. New-enterprise construction NEC 462 830 +80. I, New enterprise NE 4,900 8,000 +63. 2. Mature business MB 7,800 12,000 +64. 3. Declining industry DI 16,500 22,200 +35. 4, Premium housing PH = 110,900 152,800 +38. 5. Worker housing WH 335,600 450,600 +34, 6. Underemployed housing UH = 310,100 175,300 ~43. 7. Managerial-professional MP 71,100 108,700

+53. 8. Labor L 392,600 600,000 +53. 9. Underemployed U 377,300 335,900 =I. 10. Manager/housing ratio MHR 1.07 1.19 +H. LL. Labor/housing ratio LHR 117 1.33 +14 12. Underemployed /housing ratio UHR 81 1.28 +58. 13. Manager/job ratio MR 1.38 136 -hL 14. Labor/job ratio LR OT 98 +h 15. Underemployed/job ratio UR 181 1.07 41. 16. Tax ratio needed TRN 2.25 1.50 ~33, 17, Underemployed to labor net UTLN 5,500 9,200. +67.

Figure 5-17 Changes caused by combined policies of slur-housing demolition (SHDR ment of new-enterorise construction (NECN = .07.

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Figure 5.18 Urban-arca development with continuous application from the beginning of policies for $% per 'Year slum demolition and discouragement of worker-housing consiniction.

substantial differences between the results obtained here from encouraging new enterprise and those obtained by discouraging worker-housing construction.

Figure 5-17, compared to Figure 5-13, shows a larger increase, 67%, in upward mobility UTLN. Underemployed population and underemployed housing have not declined so much.

In Figure 5-17 the number of underemployed has declined 11%. Figure 5-16d shows how this has been accomplished. During the first 10 years there is almost no change in either the underemployed-arrival rate UA or the underemployed- departure rate UD (arrivals have actually increased a little more than departures), The change in underemployed population is accounted for almost entirely by the increased net upward mobility UTLN, which in the first 10 years has risen from 5,497 men per year to 10,451. After the population stabilizes at 50 years, net arrivals (UA ~ UD) have increased by about 4,400 men per year, indicating that the city has become substantially more effective in accepting underemployed and providing an economic climate to generate upward economic mobility into the labor group.

References here to encouraging new enterprise must be considered in the context of the particular geographical area to be revived. New enterprise at a

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Figure 5-18 (cont)

remote point, for example in an industrial belt beyond the suburbs of a city, is not sufficiently related to the decaying areas to have substantial effect. New enterprise must compete in the specific aging area with the tendency for excess decaying housing. The policies discussed in this section must be exercised on a local basis, not on the basis of a metropolitan area as a whole. Otherwise some areas will be economically balanced while others will be isolated and decay. Balance should occur within an area smal] enough to have communication within the school system between different economic categories of population. It would be an area that can be crossed by available transportation during a rush period in 20 minutes. It appears that a larger area will tend to break up into isolated blocks of population and industry that are segregated by building age and eco- nomic effectiveness.

5.8 Preventing Urban Decline

Reviving blighted areas is a task forced on us by earlier failures in urban management. Preventing blight would of course be better than having to cure it. Many metropolitan areas that are not now conspicuously in trouble are never- theless following a pattern of full land occupancy with consequent aging and stagnation that will tura them into the slum areas of the future. More specifically,

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this is a future that can be anticipated for the low-cost subt i a urban housi - ments that sprang up after World War IL ne develop Policies used for reviving a decayed i i i c 'yed area should, if continuously aj lied, Prevent decay. With rare and very special exceptions, the ultimate equilitriven

equilibrium conditions as they do when appii i i pplied to a stagnant city. Figure 5-18 demonstrates how equilibrium is not dependent on history. In this figure the entire growth history of the urban area has occurred under the same

not been reached, Particularly in Figure 5-12. The new polici i not b , . policies during growth in Figure 5-18 have produced some effect on the growth pattern, (as seen by

Because of slum demolition and restrictions on worker-housing construction, the growth rate has been retarded slightly. But in Figure 5-18 the area enters directly into 2 more Fealthy state of equilibrium without going through the high under- employment conditions and the high ratio of underemployed t curred in Figure 3-1. Pioved Tabor that oc New and more satisfactory urban-development policies can be initiated at any point in the growth-maturity-stagnation cycle. Transient conditions will be

6 Notes on Complex Systems

This chapter is an interlude to comment on the general nature of complex systems. Chapter 7 will return to specific consideration of the city and interpret the material of Chapters 2 through 6 in terms of urban management.

6.1 Nature of Complex Systems

Complex systems have special responses which cause many of the failures and frustrations experienced in trying to improve their behavior. As used here the phrase "complex system" refers to a high-order, muitiple-loop, nonlinear feedback structure. All social systems belong to this class. The management structure of a corporation has all the characteristics of a compiex system. Similarly, an urban area, a national government, economic processes, and international trade all are complex systems. Complex systems have many unexpected and little understood characteristics.

Like all systems, the complex system is an interlocking structure of feedback loops. "Feedback loop" is the technical term describing the environment around any decision point in a system. The decision leads to a course of action that changes the state of the surrounding system and gives rise to new information on which future decisions are based. This loop structure surrounds all decisions public or private, conscious or unconscious. The processes of man and nature, of psychology and physics, of medicine and engineering all fall within this struc- ture. But the complex system has some special characteristics,

The compiex system is of high order. The "order" of a system is determined by the number of ievel equations (that is, integrations or states) in the system description. A company might have separate level variables representing the employees, the bank balance, the finished inventory, the in-process inventory, the physical machinery, various psychological attitudes, components of reputation, and elements of tradition. A system of greater than fourth or fifth order begins to enter the range here defined as a complex system. An adequate representation of a social system, even for a very limited purpose, can be tenth to hundredth order. The urban system in this book is twentieth order.

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A complex system is multiple loop. it will have upward of three or four interacting feedback loops. The interplay among these loops and the shifting dominance from one to the other gives the complex system much of its character.

The complex system has both positive- and negative-feedback loops. The negative-feedback loop is the one most commonly found in the literature of systems theory and is almost the only one discussed in engineering. But it is the positive-feedback loop that generates all growth processes, whether they be biological or economic. Negative-feedback loops are goal-seeking, tending to regulate the system toward some objective. Positive-feedback loops are goal- divergent, tending to depart exponentially from some point of unstable equilib- rium. But the positive-feedback character, which gives the positive loop its growth behavior, comes not only from structure but also from numerous variable factors around the loop. These factors are often set and controlled by other loops in the system. As these factors change, the positive-growth loop can be depressed in its regenerative characteristics and brought to a neutral point marking the boundary between positive- aud

negative-feedback behavior. If the loop is pushed into the negative-feedback region, the loop begins to generate exponential collapse toward the original reference point from which it was diverging. The behavior of social systems is intimately related to this interaction between positive- and negative-feedback processes. For example, the large changes seen in Figure 4-9 result from the shift of positive loops into a collapsing mode that finds a new and much lower equilibrium.

The complex system is nonlinear. Modern mathematics deals almost exclusively with linear processes. Life and society deal almost entirely with nonlinear proc- esses. Nonlinear coupling allows one feedback loop to dominate the system for a time and then can cause this dominance to shift to another part of the system where behavior is so different that the two seem unrelated. Multiple-loop realign- ment along various nonlinear functions makes the complex system highly insensi- tive to most system parameters. The same nonlinear behavior makes the system resistant to efforts to change its behavior. The nonlinearities, when understood, make it relatively easy to produce system models with realistic dynamic charac- teristics. Much of our knowledge about system components resides in the range of nonlinear relationships. Only by dealing forthrightly with the nonlinearities in systems will we begin to understand the dynamics of social behavior. Non- linearity is necessary to represent the behavior of complex systems. Nonlinearity is easy to handle once we stop demanding analytical solutions to systems of equations and accept the less elegant and more empirical approach of system simulation. Acceptance of the nonlinear nature of systems shifts our attention away from the futile effort to measure accurately the parameters of social systems and instead focuses attention on the far more important matter of system struc- ture.

Complex systems have characteristics that are commonly unknown. Complex systems behave far differently from the simple systems on which our intuitive responses have been sharpened. They are different from the behavior studied

in science and mathematics, where only simple systems have received orderly attention and analysis.

Complex social systems bring together many factors which, by quirks of history, have been compartmentalized into isolated intellectual fields, The barriers be- tween disciplines must melt away if we are successfully to cope with complex systems. Within the same system we must admit the interactions of the psy- chological, the economic, the technical, the cultural, and the political. The interac- tions among these are often more important than the internal content of any one alone. Yet, if these separate disciplines are isolated in our study and in our thinking, the interactions wil! never come into view.

Complex systems have many important behavior characteristics that we must understand if we expect to design systems with better behavior. Complex systems: (1) ate counterintuitive; (2) are remarkably insensitive to changes in many system parameters; (3) stabbornly resist policy changes; (4) contain influential pressure points, often in unexpected places, from which forces will radiate to alter system balance; (5) counteract and compensate for externally applied corrective efforts by

reducing the corresponding internally generated action (the corrective program is largely absorbed in replacing lost internal action); (6) often react toa policy change in the long run in a way opposite to how they react in the short run; (7) tend toward low Performance. Each of these seven characteristics will now be examined in more

etail.

6.2 Counterintuitive Behavior

_ The counterintuitive behavior to be expected from complex systems was men- tioned in Chapter 1 as a major reason for undertaking this study of urban dynam- ies. All complex systems—whether in engineering, biology, economics, manage- ment, or politics—can be expected to exhibit this devious behavior.

Chapter 3 has shown, perhaps as a surprise to some, that the rather obvious processes of growth, aging, and population movements create urban decay. Chap- ter 4 suggests the even more unexpected result that past programs designed to solve urban problems may well be making matters worse. Chapter 5 suggests that policy changes in exactly the opposite direction from present trends are needed if the decaying inner city is to be revived.

Intuition and judgment, generated by a lifetime of experience with the simple systems that surround one's every action, create a network of expectations and perceptions that could hardly be better designed to mislead the unwary when he moves into the realm of complex systems. One's life and mental processes have been conditioned almost exclusively by experience with first-order, negative-feedback loops. Such loops are goal-seeking and contain a single important system level variable. For example, one can pick up an object from the table because he senses the difference in position between hand and object and controls move- ment to close the gap. While many nervous and muscular responses are involved, pe system is dominated by the level variable representing the position of the

and.

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From all normal personal experience one learns that cause and effect are closely telated in time and space. A difficulty or failure of the simple system is observed at once. The cause is obvious and immediately precedes the consequence. But in complex systems all of these facts become fallacies. Cause and effect are not closely related either in time or in space. Causes of a symptom may actually lie in some far distant sector of a social system. Furthermore, symptoms may appear long after the primary causes.

But the complex system is far more devious and diabolical than merely being different from the simple systems with which we have experience. Although it is truly different, it appears to be the same. The complex system presents an apparent cause that is close in time and space to the observed symptoms. But the relationship is usually not one of cause and effect, Instead both are coincident symptoms arising from the dynamics of the system structure. Almost all variables in a complex system are highly correlated, but time correlation means little in distinguishing cause from effect. Much statistical and correlation analysis is fatilely pursuing this will-o'-the-wisp.

In a situation where coincident symptoms appear to be causes, a person acts to dispel the symptoms. But the underlying causes remain. The treatment is either ineffective or actually detrimental. 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 the problems of faltering companies, disappointments in developing nations, foreign-exchange crises, and troubles of urban areas.

6.3 Insensitivity to Parameter Changes

Complex systems are remarkably insensitive to changes in many of the system parameters (constants in the equations). Social science attempts to measure to a high degree of accuracy many of the characteristics of psychological and eco- nomic systems. Yet closed, nonlinear feedback models of those same systems show little change in behavior even from parameter changes of severalfold. Contem- plating our social systems indicates that this must be true. The life cycle of companies follows similar patterns in very different industries and even in differ- ent countries. Problems in economic development are much the same regardless of continent, social heritage, or even availability of raw materials. Economic systems have behaved in about the same way over the last hundred years even though the developed countries have shifted from agricultural to urban societies, from independent to central banking, from individual entrepreneurship to large corporations, and from communication delays of weeks to seconds. In fact, social systems are dominated by natural and Psychological factors that change very little,

6.4 Resistance to Policy Changes

Complex systems resist most policy changes. When a change, even a substantial one, is made in a system, behavior often remains the same. The reasons lie in

Notes on Complex Systems 11

the counterintuitive nature of I complex systems and in their insensitivity to param- eter changes.

A policy is composed of both a structure (that is, what information sources are selected and how they are used) and parameters (determining how much influence from the information and how much action). "Policy" here means the tule that describes how the available information will be used to determine action. The insensitivity of a system to most of its Parameters means that the system is also insensitive to most modifications that would be called policy changes, because often the policy changes are only changes in degree of information influence or action. Here lies the explanation for the stubborn nature of social systems. When a policy is changed, the many system levels shift slightly and offer a new ensemble of information to the policy point in the system. The new information, processed through the new policy, gives nearly the old results,

65 Control Through Influence Points

Complex systems have a high sensitivity to changes in a few parameters and to some changes in structure. Thus the converse of parameter insensitivity is true too.

There are a few points in any system to which behavior is sensitive. If a policy at one of these points is changed, Pressures radiate throughout the system. Be- havior everywhere seems different, But people have not been persuaded or forced to react differently. As they respond in the old way to new information, their actions change. (Examples of these have been seen in Chapter 5.)

The parameters and structural changes to which a system is sensitive are usually not self-evident. They must be discovered through careful examination of system dynamics.

66 Corrective Programs Counteracted by the System

Active corrective programs imposed on a social system can have far less than their anticipated effect because they tend to displace the Corresponding internal processes. As seen repeatedly in Chapters 4 and 5, the active corrective programs shift the system balance so that the corresponding natural processes encounter more resistance and reduce the load they were previously carrying. For example, in Figure 4-4 the underemployed-training program processed 19,100 people per year, and yet the net upward flow from underemployed to labor increased only 11,300. The 60% efficiency of the new program is explained by the decline in the natural upward mobility that existed previously. This tendency of a system to resist and to counteract an applied force must be carefully considered. Compen- sating counteraction can be disastrous if the applied programs are expensive. The external financing required may be impossible to sustain. Only applied programs of intrinsic low cost are feasible. Probably no active, externally imposed program is superior to a system modification that changes internal incentives and leaves the burden of system improvement to internal Processes. 112. Chapter Six

6.7 Long-Term Versus Short-Term Response

Change in a complex system commonly causes short-term responses jn the opposite direction from the long-term effect. These "worse-before-better" se- quences will be particularly troublesome to the political leader faced with reviving an urban system. The conflict between the short run and the long run is found repeatedly. In Figure 4-3 the underemployed-training program first reduced the number of underemployed and then led to a reversal, with a final value slightly higher than at the beginning. In Figure 4-8c the low-cost-housing program pro- duced an initial attractiveness, with rising underemployed-arrival rate which eventually fell 17% below the initial value. In the slum-housing-demolition pro- grams of Figures 5-10 through 5-17, the unfavorable political aspects of housing reduction and the counterpressures caused by the necessary relocation of people within the area will appear faster than the more favorable aspects of job avail- ability and economic improvement.

This conflict between short-term and long-term system responses partly ac- counts for the unhappy state of our present urban systems. As voter pressure and political expediency combine to favor short-run considerations, the stage is set for long-term degeneration.

6.8 Drift te Low Performance

Complex social systems tend toward a condition of poor performance. Their counterintuitive nature causes detrimental design changes. Also, the opposite direction of short-term and long-term responses leads to policies that produce a less satisfactory system. For example, a particular change in policy may improve matters for a period of a year or two while setting the stage for changes that lower performance and desirability further in the future. But the natural interpre- tation is to observe that good resulted from the change and when matters become worse the original efforts are redoubled. The intensified action produces another short-term improvement and still deeper long-term difficulty. Again the complex system is cunning in its ability to mislead.

6.9 On Modeling

A Model. A simulation model is a theory describing the structure and interrela- tionships of a system. The fact that the simulation process is to be used does not of itself make the theory correct. Models can be useful or useless. They can be soundly conceived, inadequate, or wrong. They can be concise and clear and describe only those characteristics of the reak system necessary to give the behavior characteristics of interest, or they can be verbose, obscure, and cluttered with unimportant detail so that they confuse rather than inform. They can be structured with recognition of the dynamic principles of feedback-system behavior, or they can simply be a catchall for observed fragments of the system while omitting the essential structure. Correct concepts of structure must guide model-building.*

*See References t, 4, and 6.

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Everyone uses models. A written description is a model that presents one aspect of reality. A mental image used in thinking is a model, it is not the real system. The simulation model differs in being logically complete. It describes a dynamic Process and can manipulate rates and levels to generate a time history in accord-

ance with the statements of which the model is composed,

Model Validity. A model should always be created for a purpose. The adequacy of the model can only be judged in terms of that purpose. There is no possibility of absolute proof that a model is appropriate for its objective. But the model can be evaluated in several stages.* The basic assumptions (in Appendix A) can be checked against available experience and data. The dynamic behavior of a model (as in Chapter 3) can be compared with the real systems it should represent. Changes in the model (as in Chapter 4) can be related to similar changes that have occurred in reality.

Modeling to Create Symptoms. The first step in modeling is to generate a model that creates the problem. Only if we understand the processes leading to the difficulties can we hope to restructure the system so that the internal processes lead in a different direction. If the model is to create the difficulties, it must contain all the interacting relationships necessary to lead the system into trouble. The troubles are not imposed on the system from outside the structure being modeled. The model will be a closed model which is not dependent for its inherent characteristic behavior on any variables transmitted across its boundary from the external world.

The concept of the closed boundary and the development of a simulation model which has within itself all of the generating mechanisms for the problems of the system is essential to successful investigation of complex systems. A system study should start without emphasis on the correction of difficulties. Instead it focuses attention on the causes of difficulty and their removal. Removing causes may take action quite differeat trom that aimed at alleviating symptoms. The cost of removing causes is often far less, the influence is much deeper, and the improve- ments last longer.

Adequacy of Information. In the social sciences failure to understand systems is often blamed on inadequate data. The barrier to progress in social systems is not lack of data. We have vastly more information than we use in an orderly and organized way. The barrier is deficiency in the existing theories of structure. The conventional forms of data-gathering will seldom produce new insights into the details of system structure. Those insights come from an intimate working knowledge of the actual systems. Furthermore, the structuring of a proper system theory must be done without regard to the boundaries of conventional intellectual disciplines. One must interrelate within a single system

the economic, the psy~

chological, and the physical. When this is properly done, the resulting structure provides nooks and corners to receive fragments of our fabulous store of knowl- edge, experience, and observation.

Much of the behavior of systems rests on relationships and interactions that are believed, and probably correctly so, to be important but that for a long time will evade quantitative measure. Unless we take our best estimates of these telationships and include them in a system model, we are in effect saying that they make no difference and can be omitted. It is far more serious to omit a relationship that is believed to be important than to include it at a low ievel of accuracy that fits within the plausible range of uncertainty. In this particular aspect the kind of modeling discussed here follows the philosophy of the manager or political leader more than that of the scientist.* If one believes a relationship to be important, he acts accordingly and makes the best use he can of the information available. He is willing to let his reputation rest on his keenness of perception and interpretation.

A shortage of information is not a major barrier to understanding urban dynamics. One can say the same for other complex systems. The barrier is the lack of willingness and ability to organize the information that already exists into a structure that represents the structure of the actual system and therefore has an opportunity to behave as the real system would. When structure is properly represented, parameter values are of secondary importance. Parameter values must not be crucial because cities have much the same character and life cycle regardless of the era and the society within which they exist. Similar patterns emerge in cities having quite different economic constraints and social traditions.

*This reference to the difference between an operating man and a scientist is made in the spitit of the conventional image of science. Of course, the successful scientist also operates on subjective observation and moves ahead in his work on the basis of available information, gathering such facts as he can and making assumptions where he must,

7 Interpretations

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. How to use the results of a system study is an important part of the learning process. The cities and their problems are here today. They will not wait for ultimate answers. Because one must act on the best evidence available, it seems entirely proper to interpret as one proceeds, but to remain open to new evidence and changing conclusions. This chapter presents opinions arising from the urban-dynamics study. As stated earlier, these conclusions should be accepted only after establishing that the assumptions used here fit the particular situation,

An Implicit Goal. These recommendations assume that the most desirable way to reverse the present condition of cities is to restore economic Vitality and to absorb the present underemployed groups into the main stream of productive activity, Some might argue to the contrary that today's underemployed Negro minority is less apt to rise in status by diffusion into existing economic activity

than by coalescing into a self-respecting, self-disciplining, and self-leading group. Were the latter the more promising course of action, Negro concentration in high-density slum areas might be a necessary prelude to self-gencrating social change. This study assumes that extreme concentration of economic and social groups is detrimental and that success will be more easily achieved in a single economic system than in two separate and parallel systems.

7.4 Outside the City

This book focuses on an urban. area and its improvement. But no conflict need exist between the well-being of that area and the health of the surrounding urban and rural areas. A healthy city is a more effective economic converter for upgrad- ing the underemployed than is a decaying city. A healthy city generates new industry, managers, and skilled labor beyond those who can remain employed within the city area. These men and enterprises leave to start nuclei of rising economic activity at other places.

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The policies for controlling population balance that the city must establish are not antisocial. No purpose is served by operating a city so that it is a drain on the economy of the country and a disappointment and frustration to its occupants. An urban area that maintains effective internal balance can absorb poor people from other areas at a faster rate than can one that is operating in deep stagnation. The heaithy area does not act as a drag on the other parts of the country by requiring assistance from the outside. Furthermore, the well-balanced urban area can contribute to raising the standard of living of the entire country.

7.2. The City in Its Environment

Urban Evolution. A city starts with empty land area having intrinsic economic potential. Business develops. People move to the new economic opportunities. Housing is built to support the growing population. During the growth period the average age of housing is relatively low. The housing is occupied by those employed in the growing business activity.

When the first land area has become filled, the city geographical pattern has become a central commercial core surrounded by dwelling units. The housing stands as a barrier to expansion of the area devoted to business. In time the ring of housing deteriorates until it is no longer attractive to those who are fully employed with satisfactory income.

Then a second phase of housing construction starts outside the old city as the managerial and labor classes build a new ring of housing in the available land area outside the first ring of housing, which is now deteriorating. Until this time housing available for the underemployed had been so limited that the under- employed population could not rise above what the city system could absorb. But as the deteriorating inner ring of housing is vacated by management and labor, the housing near the center of the city is occupied by those with the lowest skills and the smallest income. Their presence in the dwelling units prevents demolition, and the housing continues to restrict expansion of the commercial area. The declining housing and its occupants generate city expenditures, cause tax rates to rise, and

decrease the likelihood of new industrial activity. The central city becomes progressively more unattractive to the kind of manufacturing activity that could provide upward mobility for the underemployed. The central city begins to be dominated by office and professional activities, which place a pre- mium on proximity to each other and to transportation systems.

After a period of adjustment the outer suburbs with their skilled labor and managerial talent begin to be self-sufficient, with the development of industrial activity within their borders and in the ring of open country outside the suburban boundary.

The stage is then set for a second phase of deterioration. The oldest housing in the central city will eventually reach the point where it must come down and at that time it will be replaced with new structures, probably tending toward premium housing for those engaged in the managerial and professional activities

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still located in the central city, As this replacement of the slum areas with new structures proceeds, the nearest suburban areas age and deteriorate and become technologically less attractive than new construction. The managerial and labor populations will move to new buildings. These inner suburban arcas will then become the outward-moving sium-housing ting of the future.

The urban dynamics discussed in this.book do not apply solely to the present core city. The concepts apply to all areas. Each is in some phase of the growth and stagnation life cycle. Each, given past circumstances and policies, can be expected to complete the cycle into decay. If decline is to be avoided in areas that now appear heaithy, urban dynamics must become better understood. Quite different urban-management policies must be accepted,

The Limitless Environment, This study conceives an urban area as an organic living complex set in an unlimited environment. This implies that the urban area

and its internal policies determine its own condition and evolution. The unlimited environment means that people are available from outside for migration into the area whenever the area appears more attractive than the point from which people may come. Conversely, the environment will absorb those who find the area less attractive. This relation between a particular urban area and its surroundings has existed throughout the history of the United States. For any particular area relative to the remainder of the country, it will continue to be true, The surround- ing environment may be represented by other urban as well as rural areas, and mobility between urban areas may supersede the more dominant past mobility from country to city.

The Attractiveness Concept. Unrestricted mobility between the urban area and its environment has an important corollary. For any class of person, conditions in the area must be approximately equal in attractiveness to conditions elsewhere. As an example, conditions in a city for people in the lowest economic class will not be substantially better or worse than the conditions in other parts of the country from which there is free mobility.* If the city is more attractive, inward migration will occur until it is overloaded. Unable to cope with the influx, the city falls to the lowest attractiveness level with which it communicates. Any hope for changing the conditions in a city rests on an examination of total attractiveness and its components.

The term "attractiveness" is used here to describe the variable that modulates the flow of people to and from an urban area. As the area becomes more atiract- ive, the inward flow increases and the outward flow decreases. Attractiveness is perceived in different ways by different people. The

components of attractive-

ness are weighted differently. But the distribution of all perceptions of attractive- ness, as seen by the distribution of ali kinds of people, results in the flow of population. This net composite effect in the model generates "average" attractive- ness, which regulates movement of "average" people.

Attractiveness is a composite concept combining a large number of influences. Attractiveness in the model is defined by such variables as upward mobility, avail- able housing, public-expenditure rate, accessible jobs, and special government programs. Other attractiveness factors obviously exist. Climate may affect the at- tractiveness of a particular city, but this would not usually be a dynamic variable which itself is affected by the internal conditions of the city. Remoteness may affect attractiveness. Political restrictions may be considered a form of unattractiveness. Immigration restrictions may detract from an otherwise attractive city.* Attract- iveness components of the city shift with the city's conditions. They vary with the Stage in the city's growth and stagnation life cycle. The internally generated attract- iveness is a concept essential to the theory of urban behavior presented here,

The free population exchange with a limitless environment means that the city is powerless to change its composite total attractiveness. However, because the attractiveness is made of many components, there is a wide range of choice as to the separate values of these components. Some attractiveness components can be improved if others are simultaneously made less favorable so that the com- posite remains the same. It is in adjusting the components of attractiveness, while keeping the total attractiveness the same, that the opportunities for the city rest.

The Stagnant Urban Condition. The urban area that has passed its phase of population growth and internal development and has settled into equilibrium. exhibits a set of characteristics here called the "stagnant condition." In this stagnant condition the area has an excessive housing/industry ratio. The excess housing is in the underemployed-housing category, including housing in declining areas, slum dwellings, and abandoned housing. The amount of housing is too large compared to industry because the number of housing and industrial strac- tures each tends to be the same as when the area was in healthy economic balance. But aging has reduced the population employed in the industrial structures while at the same time increasing and changing the character of the population occupy- ing the housing. Even in terms of population, the housing may be excessive. When the economic potential of the area falls far enough, the population may decline below what the housing could accommodate at the normal population densities of the economic class that occupies the housing, In the underemployed category there can simultaneously be excessive housing and very crowded living conditions.

politcal stress inherent in West Berlin is a strong negative factor which must be balanced by superior physical and economic attractiveness if a population is to be maintained.

The crowding, however, is not a reflection of housing unavailability but of eco- nomic conditions. Some dwelling units are abandoned, while others ate crowded because the tenants are unable to pay for maintaining and operating the total available housing.

The stagnant urban area has too high a ratio of old industry and housing to

new. This happens because the economic life of a new unit is shorter than that of a declining unit, As shown in Figure 3-4 the number of buildings in various economic categories is proportional to the average lifetime in each category. The city that attempts to save old structures to extend their remaining small contribu- tion speeds its own decline, The stagnant urban area has too high a ratio of underemployed to labor. This is a direct consequence of the high proportion of industry and housing in the oldest-age categories. Until there is continued renewal through aggressive repair and demolition, the area will inexorably sink. into stagnation.

The declining condition of a city is accelerated by policies or conditions that encourage concentration of any one economic group. For example, an effective transportation system which brings people into the central city from remote suburbs contributes to the blighting of the area it traverses. Without the transpor- tation system the rebuilding of inlying areas would be more likely to occur. Concentration allows industry to be located in one place, labor in another, management in a third, and the marginal underemployed group in a fourth. The mobility multipliers that depend on population ratios in the model (such as Equations 25 and 38 in Appendix A) assume that the populations are in close proximity and communication with one another. This communication sets one of the land-area limits on the validity of the model. Some aspects of the model do not apply to areas so large that different groups have no contact through normal living activities and school systems.

Soaring Municipal Costs. The increase of costs as the urban area ages is a reflec- tion of the shifting balance that results from laws and administration that permit and encourage excessive immigration of the Poor and speed the exit of the more affluent. As the poor begin to dominate, their political power is felt. Their short- term interests increasingly dominate their own long-term welfare and that of the city. As shown in Appendix B, if this political power is too great, the rising taxes and the accelerating decline can continue to the point where the urban area begins to collapse economically and all population classes decline.

73 Alternatives Open to the City

Pursuing unachievable goals can lead only to frustration. Much urban planning fails to distinguish the possible from the impossible. Until the difference is clearly understood, the future of cities remains in doubt. Attempting the impossible can foreclose even those goals that might have been achieved.

Two quite different kinds of action can be chosen in dealing with a complex system such as an urban area. One is to make a frontal assault with direct-action

programs aimed at correcting deficiencies. A quite different approach is to alter the internal system which has created the deficiencies.

It is often said that only a massive federal commitment of money will solve urban problems. But if the city is unable to help itself, where is this massive federal commitment to come from in a country that is already largely urbanized aad where many sections seem destined to become as blighted as present ghetto areas? Even if the massive financial support were available, there is no certainty that it would have the desired effect. Chapter 4 showed sufficient adverse effects from common urban-development programs to suggest that the intuitive selection of massive programs may be ineffective at best and a waste of money and actively detrimental at worst.

A properly conceived system study aimed at the improvement of a complex system should start by developing a clear understanding of how and why the difficulties have been created. If this is well done, one discovers the causes of the observed symptoms. When the system behavior is understood, the internal incentives that are creating difficulty can usually be altered at much less expense than would be necessary for direct-action programs aimed at reducing symptoms. Furthermore, the massive action program, if it does nothing about the underlying causes of difficulty, simply comes into conflict with the operation of a system already set at cross purposes. The internal forces in most social systems are so powerful that they will likely dominate any effort to treat symptoms, if treatment does not reach the true structural causes. Conversely, if the causes can be reversed, an internally generated revival can proceed faster and with more lasting effect than if the treatment comes from the outside.

Outside help for the city cannot be sustained forever if the effort is directed toward an unnatural goal that the city itself cannot even maintain, to say nothing of achieve on its own.

If the dynamic structure suggested in this book is correct, the city, because of population interchange with its environment, cannot hope to improve simul- taneously ail aspects of life for its inhabitants. The total attractiveness of a city can improve only as the entire communicating environment improves. .

On the other hand, the city can exchange improvement in one attractiveness component for decline in another and thereby alter its economic and social effectiveness. The character of a city is determined by its population. At any time

population is a result of past movement to and from the city and the social and economic conversions that have occurred within. The two components that seem most influential in determining movement to the city and upward economic mobility inside are jobs and housing. Much of this book has focused on the interplay between work opportunities and housing. There appears to be little possibility of increasing the availability of both simultaneously. In special situa tions other attractiveness factors might be unfavorable enough so that both jobs and housing could simultaneously exist in excess and remain so in. equilibrium. These unfavorable factors would most likely take the form of strong legal or

psychological forces repulsing immigration. In the absence of such conditions, housing and jobs appear to be the most powerful influences in determining the equilibrium condition of an urban area.

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

The cities have reached their present condition by following policies that look attractive for the short run. But because long-run effects are often the opposite, short-run emphasis eventually leads to difficulty. Education to increase public understanding of urban dynamics and generate popular support of long-range goals might allow changes that would reverse the decline of metropolitan areas. Decaying regions move. Our past programs that try to rebuild the physical area without integrating the underemployed into an economic revival merely shift the troubled area to a new location. Given time, a disintegrated area will certainly be rebuilt if the area has economic potential, but the next-oldest bordering area will then fall victim to concentration of the underemployed population.

If the concept of attractiveness equilibrium between areas is correct, a city will not be able to outrun the needs of the underemployed by providing ever more low-cost housing and welfare. The city that attempts this will inundate itself with the less fortunate of the world in a cycle where effort does not improve conditions but only increases population without in fact improving the lot of that population. in an effort to improve short-run conditions by alleviating symptoms of a defective Social system, the city does long-run harm to the very group it is trying to help.

In taking the longer view, a city must recognize the slowness with which change will come. Time scales are probably about correct in the simulation profiles in Chapter 5. If so, even after appropriate policies are adopted substantial change will not occur for one or two decades. The greatest danger is that impatience will reverse the policies before they have a chance to be effective. Political leaders will face another problem. Policies that lead to urban revival will give the superficial appearance of favoring upper-income groups and industry at the expense of the underemployed. If the city has already reached the point where the under- employed are numerous and politically powerful, these programs for restoring the economic health of a city may not be open for Practical political consideration.

'The urban system is a complex interlocking network of positive- and negative~ feedback loops. Equilibrium is a condition wherein growth in the positive loops has been arrested. But such a positive loop is in Precarious balance between growth on one side and conversion into a negative loop with intrinsic declining characteristics on the other. Internal shifts in the incentive structure of the system. can be powerful in determining the path that is followed.

A city in better economic balance than the decayed areas would have a lower

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underemployed population at any one time but a higher flow from the outside through the underemployed group into the labor group. The balanced city would serve all sectors of the population more effectively. By accepting a larger flow of underemployed, the balanced city would contribute more to raising the standard of living of the surrounding environment by taking in the underemployed and giving back skilled labor, managers, and industrial activity generated in the urban area.

It appears from the model simulation results in this book that a better urban balance can be achieved by altering the laws and policies under which our cities operate. The change would aim at encouraging a revised pattern of using land area and replacing old structures. The changes needed in laws and administrative practices would not require a more coercive legal structure. A new system should be able to operate with less government encroachment by eminent-domain pro- ceedings than employed at present for urban renewal. Our present system is characterized by tax and zoning regulations that encourage private enterprise to act in ways that have produced the present degeneration in the older urban areas. A different tax and legal system should be devised so that actions in self-interest by land and building owners will produce a city that evolves toward a new and better equilibrium condition.

74 Maintaining Economic Balance

If the city is to survive as a healthy economic unit and as a satisfactory place to live, it must be managed under an ensemble of policies that induce constant renewal at a rate that matches the relentless march of deterioration. By contrast, present laws, zoning regulations, and tax structures all conspire to produce a city with declining industry, slum housing, and a population mix that inhibits eco- nomic revival.

The city, by shifting taxes off those who are already too numerous, encourages a still greater influx of the underemployed, who tip the balance downward in a spiral of urban decline. By shifting the tax burden onto those who generate the least municipal costs, who have the greatest mobility, who need not live in the aging structures, and who have the least reason to remain in the city, the city encourages the departure of the people and industries most necessary for its revival.

By favoring rent ceilings the city often accelerates the deterioration of housing into the housing classes that are already too large for the well-being of the city.

By believing that the problems of the city are beyond its control, the city lays its problems at the doorstep of a higher level of government and corrective action is deferred. By asserting that the city is the inevitable recipient of the under- employed and the misfits from other parts of the country, one creates the impres- sion that the city is a victim of circumstances. By accepting old structures and their consequences as a condition of nature rather than as reflections of the legal and tax structure, people fail to see the true causes of decline. These attitudes are then used to justify ignoring the fact that the city is creating its own condition.

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Kinds of Industry. The theory of urban dynamics presented here indicates that the relationship between working and living is basic to urban evolution. If so, the kinds of commercial activity in the area are important. ' a By encouraging the wrong kinds of industry, the city establishes an unfavorable

'balance of trade" in some of its poorer areas. In these areas there is insufficient product manufactured and service sold to the outside to maintain the inner community. Local merchants and professional activities, while "commercial" in nature, do not serve the purpose. They end up selling to the inside and buying from the outside without themselves generating an "export." The area tends to be a net purchaser until the standard of living is driven down to be in balance with the "export" flow,

The "foreign-exchange" problem is similar to that faced by a developing country. Some commercial activities, such as warehouses, occupy land area but generate very little in payrolls to the community.

Policies need to favor industries that are profitable, pay 4 high wage rate, and carry on labor-intensive activity. Such industries should be perceived as a great service to the community rather than as ones to be penalized and saddled with the burden of carrying the cost of the urban area they alone are able to revive. The declining urban area needs to be made an effective part of commercial interchange. If the people in these areas begin to contribute economically, they acquire the purchasing power to become consumers and indirectly justify and generate their own jobs.

Taxes. Taxes, in the representation of an urban system presented here, affect mobility of people of ali classes and the construction of housing and industry.

City administration has generally not been based on any cost-benefit concept telating revenue to expenditures within segments of the city. The tax structure tends to penalize those who can contribute most to the well-being of the city, while favoring those who generate costs to the city. Such a strong bias tips the city too far toward population and, within the population, disproportionately increases the group least able to contribute to a successful city. in the short run, the conventional tax policies seem humanitarian and appear to be a desirable social force. But in the long run the policies produce economic decline and trap in poverty the very people they are designed to serve. And as the balance in the city shifts toward the underempioyed population, the political power shifts too, giving further dominance to the downward forces. It is characteristic of our complex social systems that actions that appear to alleviate difficulties in fact often produce trouble. As the trouble deepens, the presumed treatment is intensified in a well-motivated but misguided effort to reverse the process. A spiral develops which drives the system harder and harder against the crisis limit.

This urban-system study suggests that, if economic balance of the city is to be realigned, there must be a revision in attitude toward various classes of city activity.

People are the fundamental generator of municipal expenditure. People require welfare. People require police and fire departments. People require transportation. Sag

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People use schools. People demand city services. Unless the people are eco- nomically able to support these services and politically responsible for authorizing them, the urban system is almost sure to be self-defeating. The one facet of a city most closely identified with people is housing. If the urban theory of behavior proposed here withstands wider examination and criticism, the presént trend to shift taxation away from housing will need to be thoroughly re-examined. Only if cost and revenue are closely coupled will the city be responsible in its expendi- ture. Only if the revenue is highly correlated with the people who require the expenditure will the city have a self-regulating system which generates a population able to sustain a healthy city and to pay for the urban services they desire.

The most significant variables seem to be various ratios between industry and housing, which suggest that the attitude toward industry needs to be substantially reversed. Industry has been perceived as a politically impotent sector of the city onto which to load rising demands for revenue. But industry is not without retaliatory power. It can leave, and it does. It can also shift its mix, leaving

the city with the kinds of industry that contribute least to maintaining urban vitality. Desirable types of industry should be seen as an asset, as an essential element in solving the city's problems, and as a sector of the city to be encouraged through favorable administrative regulations, zoning practices, and tax policy. Enterprise of the right kind costs the city very little by its presence. It polices its own internal land area. It buys water and other utilities. In modern construction built to proper standards, it demands little of fire departments. Industry of itself does not require schools. But on the favorable side, industry exports the products and services that generate a favorable balance of trade and make it possible for the area to generate the revenue necessary for importing the goods needed for survival and gracious livin,

Tarcexempt institutions need to be re-examined. They too should be judged on the basis of how they contribute to the city's cost and revenue balance. It is neither sufficient nor proper simply to contrast the lack of tax revenue from a tax-exempt institution with the tax revenue which might conceivably come from a highly taxed industrial complex on the same land area. If the tax-exempt institution causes the city no expense in its own right and produces no revenue, then it could almost be perceived as nonexistent. The land area might simply be subtracted from what is considered to be the city and the institution would be perceived as neutral. On the other hand, if a tax-exempt institution is estab- lished in areas that would otherwise contain deteriorated housing, the creation of the tax-exempt institution may help correct the land-area imbalance of the city. But, if the institution attracts a population that creates a cost load on the city and does not pay its own way, the institution could be considered detrimental. In other words, classes of institutions differ markedly in how they affect the cost-revenue balance of the city. The presence of such institutions, the regulations under which they operate, and their relation to the city should be examined in terms of what they do to the long-term revitalization and maintenance of the

city.

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If industrial taxation is seen as a means i . is of encouraging the proper kinds of industry and the proper industrial behavior, quite different tax ieuctures would

re - ee : residential land cana eslining areas, commercial tax rates should be reduced Quite the opposite of moving toward a payroll tax, the ci i h a » the city shou! s tax credit based on salaries and wages paid oo residents of theta come his would serve multiple purposes, It would improve the balance-of-trade position of the local area by favoring high-wage industries. By encouragin; employment of those living nearby, it would help reverse the city trend toward ever-imcreasing costs of public transportation. This urban study suggests the desirability of Teversing residential tax trends. 'he high taxation of undeveloped land may force housing construction in areas where it should not occur. Reduced assessments on aging structures favor the survival of the very structures that should be removed. A flat tax per dwellin; unit, regardless of age or condition, might do muck to create internal incentives that would maintain a favorable residential balance in the urban area. Some form of personal-residence-amortization deduction against personal income tax might produce a favorable bias in housing renewal. Assessing the residential tax more pearly in Prepertion to the city costs generated by the different classes of popula- ce! control the proporti i i better serve the needs of all Classes, ont of population cesses so that te ayeaa These comments about tax structure are included to illustrate the type of exploration into causes that shouid be Precipitated by a system study. The form

of the final conclusions should come from the resolution of doubts and counter- Proposals. 'Tax structure realignments should be devised to help make the city self-sustaining. The city does not serve an effective social function for any popula- tion class by putting itself in a position where desirable industry leaves and the disadvantaged population comes. Such evolution as has occurred in the past moves the underemployed away from sparsely settled areas that have potential for economic development into old and declining areas that cannot revive under the existing mode of operation.

Land Zoning. Just as the tax laws need Fe-examination, so do the land-zoning peeing. the present time zoning favors excess ratios of housing to economic ity and favors segregation of activities into blocks that favorable interaction. Be Ste fo0 lange For There should be a reconsideration of i i

7 Property rights. Do the property rights

of the landowner include the right to generate decay which blights the nee

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urban system? Through zoning and taxation it should be possible to design a system that encourages owners to take self-protective actions that generate re- newal,

Zoning tends now toward limiting areas where industry is permitted. These areas permit both industry and housing, with industry sharply restricted and housing virtually unlimited. But should not the reverse attitude exist? Suppose residence were restricted to particular areas. Other areas, even in metropolitan tegions, could be restricted to agriculture only and taxed at appropriate {ow rates to maintain open areas. Industrial areas would be specified but would not be open to residential construction. The blocks for each of these would be smaller and more intertwined than in present land usage. Zoning might specify proximity of high- and low-density housing areas to bring different economic classes closer together and to enhance the opportunity for upward mobility.

75 Choice of Urban Pressures

A complex system can operate in any one of many different modes. Some modes are desirable, others are not. Some modes are firmly self-sustaining, others tend to terminate their own existence.

If a mode of behavior is to be sustained, there must be some restraint against which the system presses to locate and maintain the particular mode and to anchor the system against drifting into some other mode of operation. This pressure against a restraining force will appear as some form of social, psychological, or economic pressure within the system. Each decisive and sustainable mode of operation is characterized by its own pattern of pressures. A system without internal pressures is probably one whose behavior mode will drift in an uncon- trolled manner until it is captured by a set of pressures that represent a self- sustaining mode.

The life cycle of an urban area (as in Figure 3-1) carries the area through several sequential modes. In the early growth mode, the growth forces are restrained by Pressures from shortage of capital and lack of management and labor. As the land area becomes filled, these pressures decline and the mode of behavior begins to drift toward equilibrium and stagnation. In equilibrium a new set of pressures appear that tend to maintain the mode: (1) buildings become old, (2) industry declines, (3) population balance shifts, and (4) taxes rise. This mode is highly stable. Jt does not within itself contain natural or psychological processes that will shift the mode to one of revival (as illustrated in Figure 5-16).

But the revival mode of Figure 5-16 is also one that generates pressures. The new equilibrium of Figure 5-16 exhibits an excess of jobs and a shortage of housing. The mode encourages more industry when excess industry is already visible. The mode continues slum-housing demolition even though that housing is in demand and is not in extreme decay. Everyone within the system will see these pressures and will be unanimous in wanting to relieve them. Managers will See economic opportunities for which they need more employees. Potential em- ployees will exert pressures for more apartment construction so they can move

to the work opportunities. But with the elimination of the housing pressure comes @ period of drifting between modes and almost certainly the capture of the system by the old stagnation mode with its excess housing and declining industry.

Growth modes are not forever sustainable, so we must always look toward the choice of some equilibrium mode. Each equilibrium mode that is sharply de- finable and free of indecisive drifting will generate its characteristic pressures. In choosing a mode, we are choosing the ensembie of pressures under which we want to live. To sustain that mode we must be willing to accept and, in fact, maintain the corresponding pressures.

The more desirable equilibrium modes of a system seem to exhibit pressures that are easy to alleviate, and alleviating them eliminates the desirable mode. The undesirable modes will often have pressure patterns from which escape is difficult. The equilibrium toward which urban areas now move is stable, undesirable, and accompanied by pressures that do not yield to intuitively chosen corrective programs. The revival mode in Figure 5-16 depends for its existence on pressures that can be easily eliminated by obvious changes in policy.

These shifting equilibrium modes with their associated pressures are seen in all complex systems. For example, a family, by its spending pattern, can choose the solvent mode where it must resist the Pressure to overspend its income, or it can yield to consumption pressures, move into a debtor mode, and must then Tesist the pressure of creditors trying to collect. As another example, a company can resist the pressure to overcommit itself in sales promises, but if it does not it must accept the pressures resulting from late delivery, falling quality, and narrowing profit margins. Another example of shifting from one equilibrium to another is probably illustrated by the response to unemployment pressures in an economic system whereby the corrective action permits a drift into a price-wage spiral and inflation mode.

The suggestion here proposed that population in an area be maintained in balance by iimiting housing is directly the opposite of some proposals that depend on limiting work opportunities to control population.

Urban Transportation. The assumptions incorporated here in the model of an urban system, contain implications about urban transportation systems, The trans- portation system is intimately involved in how population classes, industrial

classes, and housing classes interact. The model coefficients and nonlinear tables imply, even if indirectly, statements about spatial interaction within the system.

Urban transportation systems can encourage land separation into large nonin- tercommunicating sectors. The better the transportation system, the less the interleaving of population classes and the less the proximity of housing to industry. As sector separations increase, commuting cost rises rapidly in transportation cost, in psychological trauma, and in time lost from productive activity. Furthermore, transportation can span the deteriorating areas, helping to hide them and making renewal less pressing and less likely. This Suggests that urban transportation planning might better be focused on transportation between industrial centers.

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Interindustry communication would favor industrial decentralization into numer- ous islands that interleave residential and open areas. The transportation would serve the communication needs of effective economic activity but would not be primarily for long-distance commuting from home to work.

The urban planner must plan in terms of the pressures his system is to generate. We now yield to economic pressures, allow and encourage excessive construc- tion in response to high-land-price pressures, and exchange these economic pressures for psychological pressures that come from congestion and commuting. But an urban plan that aspires to a different equilibrium than we now have must be firmly based on a public understanding and willingness to live with the corresponding pressures.

76 The City—Master of Its Own Destiny

It has become popular to talk of massive financial aid from the federal govern- ment to solve the problems of American cities. But, if the system analysis in this book contains the proper concepts, money, even if available, may be no solution. Given present laws and administrative practices, the problems of a city may respond by growing in size and difficulty to match any available financial sup- port.

But the urban dynamics exposed by this investigation imply that the city can change from the inside. Whether or not it will, assuming that the validity of the study is sustained, depends primarily on political leadership and improved public understanding leading to support for policies that can reverse urban decline. A city need not wait for the national problems of poverty and the underemployed to be solved.

The city, by influencing the type and availability of housing, can delay an increase in the immigration rate until internal balance is re-established. The city must press for removal of aging housing before deterioration creates an imbalance in the urban system. Because aging is continuous, the renewal

process should be continuous instead of occurring in waves several decades apart. At the same time industrial parks should be established within present decayed residential areas to generate jobs for those already living in the city. Favorable city regula- tions and new tax policies should be designed to attract the kinds of industry most needed for revival. The ensemble of new policies would be aimed at restrain- ing the processes of urban stagnation.

The proposed new policies of urban management do not imply additional hardships on present urban residents except for relocation within the area. Reloca- tion will be caused by three streams of change:

1, Slum demolition for gradually consolidating land into parcels large enough for the needed industrial centers (and any associated landscaping, parks, etc.).

2. Voluntary relocation from underemployed housing to worker housing as upward economic mobility makes such improvements in living conditions pos- sible.

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3. Economic relocation arising from revival activity as older housing is replaced by new housing and declining industry by new enterprise.

The city has been presented here as a living, self-regulating system which generates its own evolution through time. It is not a victim of outside circum- stances but of its own internal practices, As long as present practices continue, infusion of outside money can produce only fleeting benefit, if any. If the city needs outside help, it may be legislative action to force on the city those practices that will lead to long-term revival. Such outside Pressure may be necessary if internal short-term considerations make the reversal of Present trends politically impossible. The revival of the city depends not on massive programs of external aid but on changed internal administration. Appendixes

A The Model—A Theory of Urban Interactions

This appendix describes the model used in this book to represent an urban area. The model is stated in mathematical equations. These equations provide a specific and precise notation. 'They say nothing that could not be said in English, but mathematical symbols have precise definitions and are far less ambiguous than words. Relationships between variables are shown pictorially in flow dia- grams.*

A brief discussion of general system structure and the specific structure used here for an urban area is in Chapter 2, which should be reread before continuing,

Figure 2-4 shows the Principal system levels and associated tates of flow. The choices of the degree of aggregation and of the principal levels and rates are critical to the success of system modeling. There are as yet no explicit rules for guiding such choices, But it is usually necessary and sufficient to penetrate into the system one or two layers of detail below the point at which the trouble symptoms appear. If the symptoms involve housing and employment, the proc- esses of building housing, generating jobs, and Tepresenting population flows will need to be included. Figure 2-4 illustrates the basic framework of the urban model. The flow diagrams in this appendix show each system rate and the inputs that control it. As each flow diagram is encountered the reader may want to refer to Figure 2-4 to maintain his over-all perspective.

A.L Underemployed Sector Figure A-I contains somewhat more detail than was first encountered in Figure 2-7. The figure shows the underemployed level U by the upper rectangle and

"For more explanation of equatioa structure, the appropriate sotvtion interval DT, and the flow-diagram apiem, see References 1 and 6. Equations are in the format recognized by the DYNAMO compiler in the DYNAMO IH version. The manusl for DYNAMO I has not yet been publisied, but the weacecse referred {o Alexander Pugh, DYNAMO User's Manual (The M.LT. Press, Cambridge, Massachusetts, 1963) for a general Srenation. The new DYNAMO contains an algebraic translator and does not imit the choice ot equations as did the earlier version,

133 Underemployed C> birth cate UBR UR, 137A oa UTA, 120, A 26,

UB I" UIP, 148, A Underemployed LCHCD, 150, births

h birth 15 Pal

Labor to underemployed (TU, 30, Rey

4

Underemployed OTL, 9,)— 6 Underemployed to tabor \ a \ o ¢ S. +--=-OL, 29, 1) Labor \ c UD \ og 'Underemployed +-——$ AMMP \ / UDN departures 1, Attractiveness for i Underemployed I a" / migration moltiplier, I I f departures, normal: j s oon perceived ! indererap! { oy servals,nommal 1G 7 ! i Attractiveness for / fi i Ungeempiore I Atanas Vi ae { multiplier AMP Attractiveness for / }

niggaon 'multiplier percept time

UHPM

UAMM, ona,

(AMM)

Underemployed

arrivals mobil ruler,

Attractiveness

for migration multiplies

3

YUM, 21, A) Underemployed umn) mobility Underemployed/ Underemptoyed/ 'housing program housing mukiplier job multiptier rate (SHAM,98, Aba 2

ry { H Sour, 137, 4) Gone, 149, Ro" \ Uadsremployed/ Underemployed job Low cost LA beusing ato vali houciog program \ 6 \ housing population UEM, 27, A \ 7 density LEM, 40, A i \ \ "DUH, 95, L) 'Tax per capita, normal \ \ Underemployed housing

V4 ys ' a \ \ aderemployed Jo-——-oc, 121,49 Tax cotsions OO TPCSR, 147, A) Tax per capita subsidy program \ t ~s. GL, 29, 1) Labor (MP, 52, LO LPS fenagerial profesional 9 Labor family se

OR MPES Managerial-professionai family size Figure Al Underemployed sector.

the five rates of flow that communicate with it. The details are shown for three of the flow rates—underemployed arrivals, underemployed departures, and un- deremployed births. In the diagrams, levels are shown as rectangles and rates are shown as valve symbols. The auxiliary equations in the circles are algebraic subdivisions of the rate equations. They are part of the rate equations and can be substituted into the rate equations and made to disappear. They are kept separate because they have individual conceptual meaning and represent iden- tifiable aspects of the urban system. Explanation of the model wiil follow the sequence of the equation numbers.

A compact listing of equations as actually entered in the computer will be found in Appendix E. The same equations appear in the same sequence in this appendix but with explanation and with the definitions of symbois following the equa- tions,*

Equation 1 is the rate equation describing the arrival of underemployed into the area. The underemployed, as used here, are the potential wage earners. Total underemployed population will, in Equation 9, be computed as underemployed multiplied by underemployed family size.

UAKL=CULKELSK) CUAND CAMMP.K) 4k VANE .05 161,56

UA ~ UNDEREMPLOYED ARRIVALS (MEN/YEARD

u ~ UNDEREMPLOYED CMEND

t ~ LABBR CMEND

UAN = ONDEREMPLOYED ARRUVALS NORMAL CFRACTION/ YEAR?

AWMP ~ ATTRACTIVENESS~FOR-MI GRATIQN MULTIPLIER PERCEIVED COIMENSI@NLESS)

Equation 1 is a product of three terms. The first is the sum of underemployed and labor populations, which is here taken to Tepresent the size and activity of the urban area which attract people from the outside. The second term UAN is a "normal" multiplier which represents the fraction of existing inhabitants U +L that would come to the area each year. With a UAN value of .05 in Equation 1.1, the statement is made that under normal circumstances the inflow to the area would represent 5% of the underemployed plus labor inhabitants. As we will sce in Appendix B, numerical values for these coefficients are not critical to the results obtained in this book. The "normal" area is best thought of as one nearing the end of its growth phase. It has neither the dynamic vitality of maxi- mum growth rate nor the depressed activity of the stagnation phase.

Equation I contains the third term AMMP. This is a modulating term repre- senting the attractiveness of the area compared to normal. The normal value of AMMP is i. A more attractive area will have a multiplier higher than I and

~The format of the equations with related definitions bas been generated by the "DOCUMENTOR" program, which merges the model file in Appendix E with the file of definitions ia Appendix C.

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a less attractive area will have a multiplier lower than 1. As the area becomes more or less attractive relative to its surrounding environment, the multiplier value changes.

In Equation I the letters K and L, after the period following the symbol group for a variable, represent points in time. The equation system is evaluated at uniformly spaced intervals in time. The "present time" at any particular point in the computation is known as time K. Time L is the forthcoming period at which the equations are next evaluated and time J is the previous instant at which they were last evaluated. Rates of flow are presumed to be constant during the intervening time intervals* and cause the levels to change from the value at one time period to the value at the next time period. The rate of flow UA.KL is the underemployed-arrival rate that will exist during the forthcoming time interval from time K to time L. As a rate of fiow, it depends on constants and on system levels, not on other rates. All three of the variables on the right-hand side of Equation 1 are system levels.

Equation 2 describes the perception by the outside underemployed of the attractiveness of the particular urban area. The perceived value will be different from the true value when attractiveness is changing. The true value is generated in Equation 3, but Equation 2 generates a time delay representing the time for the image of the urban area to change in the minds of those who might migrate from a distant point. The perception-time delay is here taken in Equation 2.2 as 20 years. In an earlier day the delay would perhaps have been longer. At the present time, with television and more rapid communication, the time might be somewhat shorter.

AMNP K=AMMPS JECOT/AMMP TD CAHMed "AKMP J? 2b AWNP=1 2614N AMMPT=20 2.250

AWMP = ATTRACTIVENESS-FOR-MIGRATIGN MULTIPLIER PERCEIVED COI MENSIGNLESS)

AMMPT = ATTRACT! VENESS-FOR-HI GRATIGN-MULTIPLIER PERCEPTION TIME CYEARS)

AMM = ATTRACTIVERESS=FOR=MI GRATION MULTIPLIER COI MENS IRL ESS)

Equation 2 is listed as a level equation but actually combines within itself a rate equation which causes the level AMMP to change. The perceived value AMMP is always moving toward the true value AMM. The rate at which it moves depends on the difference between AMM and the value of AMMP. This differ- ence is divided by the perception time AMMPT to create the rate of change in the perceived value.

All level equations must be given initial values. The level equations fully

=The time interval between successive evaluations of the equation set is made short enough so that the assumption of constant rates in the intervening interval is satisractory.

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determine the existing condition of the system and must have values from which to start the computation sequence. Equation 2.1 with a value of 1 says that the perceived attractiveness of the city is initially normal.

Equation 2 describing a system level is not represented in Figure 2-4 showing the principal levels. The perception delays will affect the transient responses of the system but will have no effect on equilibrium values. In equilibrium the perceived value AMMP will be equal to the true value AMM, because, if AMM does not change, the delayed value AMMP will move toward it and take on essentially the same value.

The true present value of attractiveness to the underemployed is described by Equation 3. This is the actual, but not the perceived, attractiveness. As seen in the flow diagram of Figure A-1 the attractiveness-for-migration multiplier AMM. is generated by 6 inputs. Five of these are active system variables and the sixth is a coefficient AMF which is available for system experimentation.

In Equation 3 multiplication has been chosen as the most appropriate way to combine the components of attractiveness. This asserts that if one component doubles in value the attractiveness variable doubles, regardless of the values of the other variables. Under extreme conditions this formulation might be open to some question. However, it seems far more suitable than combination by addition. Some of the components of attractiveness are sufficiently influential that by themselves they can effectively suppress inward migration. A linear additive formulation would not be able to give this dominant position to one of the component influences. As written in Equation 3, any one of the multipliers becoming 0 will cause the attractiveness multiplier AMM to become 0 regardless of the values taken on by the other inputs.

AMMeK=CUAMM.K> CUHM6K) CPEM«K) (UJMeK) € UHPM 6K) CAMP 3A AMF=1 3.1,€

AMM = ATTRACTIVENESS -FOR-MI GRATION MULTIPLIER COIMENSI@NLESS)

UAMM ~~ UNDEREMPLOYED-ARRI VALS-M@BILITY MULTIPLIER CDIMENSIQNLESS?

UHM = UNDEREMPLOYEDANBUSENG MULTIPLIER (DiMENSIGNLESS)

PEM = PUBLIC~EXPENOITURE MULTIPLIER COI MENSIGNLESS)

WM = = UNDEREMPLOYED/J@B MULTIPLIER CDI MENS IBNLESS)

UP ~ UNDEREMPLOYED-HOUSING-PROGRAM MULTIPLIER CDI MENSI@NLESS>

AMF = ATTRACTIVENESS -FOR-MIGRATION FACTOR CDE MENSIGNLESS)

All system formulations are to some extent a compromise. The test is one of adequacy and a balance between the simplicity of modeling and the complexity of real life. The multiplicative arrangement of Equation 3 seems to be a sub-

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stantial improvement over linear addition in matching the system being repre- sented. Going further into some form of multidimensional arbitrary table of values does not appear justified.

The input multipliers to the attractiveness-for-migration multiplier AMM are generated in table look-up operations to allow for nonlinear relationships between the source variables and their influence on attractiveness,

Equation 4, which describes the effect of upward economic mobility on atirac- tiveness of the area, is such a table function.

UAMMAK =TABL EC UAMHT ,UH.K 9, « 15, 6025) aA

TAWA B/ TALES Rel yT

UAMM = UNDEREMPLAY ED"ARRI VALS=MaBILI TY MULTIPLIER COI MENSI@NLESS>

UANMT = UNDEREMPLBY ED-ARRiVALS~M9BI LI TY-MULTEPLIER TABLE

UM > UNDEREMPLAYED maBrLiTy CFRACTIGN/Y EAR)

AMM

Equation 4 is not the usual algebraic computation. It designates a procedure. The word "TABLE" which is not in parentheses and not Separated by an asterisk {used as a multiply sign) is read by the DYNAMO compiler as an instruction. Jt says that the table of values UAMMT is to be entered with the variable UM. The table range is from 0 to . 15 in steps of .025 in the variable UM. The output of the table yields the underemployed-arrivals-mobility multiplier UAMM. This table appears graphically in Figure A-2. The value of UM, available from else- where in the system, is used to enter along the horizontal axis, Going vertically to the curve and reading the value on the vertical axis yields a value of UAMM,

Equation 4.1. The successive values correspond to the range of UM from 0 to -15 in the specified steps of .025,

; aan

UAMM- Underemployed arsivals aaobility multiplier 1

ay

05 os a Te ais 'UM Underemployed mobility Figure A2

ae —te

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Figure A-2, like most of the functional relationships used, revolves around the concept of a normal system. At the normal operating condition the value of the multiplier is 1, Here an upward mobility of .05 per year is taken as normal. This means that 5% of the underemployed each year move into the labor category. As the mobility declines toward 0, the attractiveness multiplier falls from 1 to

point where excess housing is available. If UHR falls still further it does not create still greater attraction because more than adequate housing is already available. Al the right end of the curve, when UHR iakes on higher values, the severe crowding and housing shortage becomes a Strong influence toward reducing inward migration. The meaning of "housing" in this context must be taken relative to the social situation under consideration. If economic and housing circumstances in the surrounding areas are desperate, housing in the particular area might be construed as a place to sleep in the street. The meaning of housing in an

UHM.K =TABHLC UHMT, UHReK, 0,2, 625) SA URMT=2 65/2 0972.2/1 6 7/12 4/.2/01/ 005 344,T

UM = UNDEREMPLay ED/HeUST NG MULTIPLIER (DIMENSIONLESS)

UMT = UNDEREMPLOY E0-Hausi NG-HUL TIPLI ER TABLE

wR = DEREMPLOY ED/HBUS! NG RATIB CDi MENSIONLESS)

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E Hee 0 5 fi re 2

UHR~ Underemployed/housing ratio Figure A3

underdeveloped country might be quite different from the meaning of housing in an American city. Similarly, were the model to be used to represent a gold-rush camp, housing might mean a tent and would be represented by a table having relatively less influence compared to the economic promise.

Some social scientists who read the typescript of this book have objected to this housing multiplier on the basis that studies show that housing is not a strong determinant in regulating urban migration of the underemployed. Such an empirical fact and the curve in Figure A-3 are not necessarily contradictory. The computer runs for the stagnant city show operation toward the upper knee of the curve in the left-hand region where there is unoccupied housing in the city at the low end of the economic scale. In this region to the upper left, the curve in Figure A-3 levels out and migration is not sensitive to housing. The observed lack of sensitivity appears to come, not from lack of potential influence from housing, but from the tendency of the stagnant system to operate in a region where housing has lost its dominance.

Equation 6 defines the underemployed /housing ratio UHR on which Equation 5 depends. It is the ratio of the underemployed population to the total number of people that could normally be housed in the existing underemployed housing. The underemployed family size UFS is defined in Equation 9. It has a value of 8, representing the ratio of total underemployed population to those defined as underemployed for job-seeking purposes. The underemployed-housing popula- tion density is taken as 12 persons per housing unit. A housing unit is the same

UHR. K=CU.R*UFS)/ CUM. KEHPD) 6A UHPO=12 6 1,o

UR = UNDEREMPLOYED/HBUSING RATI@ CDIMENSI @NLESS>

u ~ UNDEREMPLOYED (MEN)

FS UNDEREMPU@YED FAMILY SIZE (PEGPLE/MAND

Ww UNGEREMPLEYEO HOUSING CH@USENG UNI TS)

UHPD ~ UNDEREMPLOYED-HOUSING POPULATION DENSI TY <PEBPLE/HOUSING UIT)

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3 ly Eq. 4. pat $ { = gEaI Fi : yo = i eet

ot I L

G 5 r is z 25 3

'TRCR—Tax per capita ratio Figure A-4

physical piece of floor space as it moves from premium housing into worker housing and deteriorates into underemployed housing. However, its use changes in the different categories to represent the crowding imposed by economic pres- sures. The housing unit is taken as normally accommodating 12 persons in the underemployed population, 6 persons in the labor population, and 3 persons in the managerial-professional population.

The attractiveness of the urban area has been made to depend on the rate of per capita public expenditure. Equation 7, which is illustrated in the table of Figure A-4, shows the assumed dependence. The tax per capita ratio TPCR with a value of I is taken to represent the public-expenditure rate in the outside environment. The tax expenditure within the area is relative to the outside standard. A ratio of 1 gives a multiplier of 1. The curve suggests that the tax per capita ratio is influential and curves upward. In other words, a tax per capita tatio of 3 would raise the multiplier to 4. At the low end one can argue that the curve might be drawn more steeply and actually intercept the horizontal axis before TPCR falls to 0. At 0, there is no public expenditure. Chaos and anarchy might characterize the area and effectively repel further immigration to the area.

PEM.K =TABHLCPEMT, TPCR«K 5053505) T,A PEMT=42/66/1/1 66/2 04/322 /4 [eras

PEM - PUBLIC-EXPENDI TURE MULTIPLIER CDIMENS I@NLESS?

PEMT = PUSLEC-EXPENDI TURE-MULTIPLIER TABLE

TPCR = TAX PER CAPITA RATIZ CO! MENSI@NLESS)

Equation 8 computes the tax per capita ratio. First the tax collections within the area are divided by the total population. To this is added any tax per capita subsidy to the area from outside the system. This total expenditure rate per capita

is then divided by the value taken as normal in the outside environment. The

normal is represented as $250 per year per person to cover all public services.

Equation 9 gives total population for use in Equation 8. It takes the three categories of wage-carning population, multiplies each by its family size, and totals the three categories. I

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TPCR K=CC TC .K/P 4K)+ TPCSP.K) /TPCN 8,4] 5 TPENS250 861,C i UIT 3 TPCR = TAX PER CAPITA RATI@ COIMENS/@NLESS) a if fy Pata Te = TAX COLLECTIONS COBLLARS/YEAR) 22 Ct P= POPULATION CHEN) z ch HH TPCSP - TAX-PER-CAP{ TA*SUBS1 DY PROGRAM COBLLARS/ im PERSON/Y EAR) 5 CCOoN TRCN = TAX PER CAPITA NORMAL CODLLARS/Y EAR/PERSGN) i : f 5 ct H I

PAKECMP.KD CUPFS)4-CLAK) CLFS)#GUaK) CUFS) 944 3 t SEH HAH 5 aa = + wFSsS 94,0 oC ct i =e 1 is 2 2. LFsz6 9.2,C UR-Underemployed/job ratio . ; UFS=8 943,40 Figure AS Pe =

POPULATION CHEN Equation 11 describes the influence of a low-cost-housin, TO} ivi . am. Li WP. 7 MANAGER! AL-PROFESSIONAL (MEN Spaces were accounted for in Equation 5. Here in E, ti iP Be ctrmi ne MPFS = MANAGER! AL-PROFESSIGNAL FAMILY SIZE arises from the I . : n Equation 11 the attractiveness CPEBPLECHAND s from the low-cost-housing-construction activity and the image of aid to the L ~ LABBR CHEN) underemployed which this creates. It says that active low-cost-housing const LFS = LABOR FAMILY SIZE CPEOPLE/MAID tion creates attracti b . g ruc- v = UNDEREMPLBY ED CHEW i tes veness above and beyond what arises from the physical housi UFS = WNDEREMPLAYED FAMILY SIZE CPEBPLE/MAND units. This is partly because of the atmosphere of activity in behalf of the under- employed and also because the living units will be seer as more attractive than The underemployed/job multiplier in Equation 10 is an important relationship i cl deteriorated units composing much of the underemployed-housing pool in the urban system. Available evidence suggests that job opportunities are itself. strongly influential in determining regional attractiveness. UNPHeK=TABHLC UHPHT, UHPR.K,0, 405, 01) tha UWM.K=TABHLC LMT UR.K)0,35 025) 10,4 WMT 2145 71,9/2 4/8 1464,T ~ UHPM = UNDEREMPLAY ED-HBUSI NG-PRAGRAM USMT=2/2/1.69/1 6/9/61 04/03/0210 15/01 005/402 10.1,T I COIMENSIONEES MULTIPLIER

LUM = UNDEREMPLOYED/JOB MULTIPL! ER UHPMT = ONREREMPLOY EO-HOUSI NG-PRAGR AM-MUA TI PLIER CDI MENS {ONL ESS) WMT ~ UNDEREMPLOYED/08 MULTIPLIER TABLE UAPR ~ UNDEREMPLOYED-HOUSING-PRAGRAM RATE cHOUSES/ (R= UNDEREMPLOYED/UB8 RATIG COIMENSIGNLESS) YEAR/MAND 3 Equation 10 as shown in Figure A-5 has the standard value of 1 when the Lo) underemployed/job ratio is 1. The curve is steep in this normal Tegion. As the i ri ai underemployed decline compared to available jobs (at the left) the multiplier 3s, chtt im tises until, when there are sufficient excess jobs, additional jobs have little more Ee i! ime Ey effect, The curve should therefore level out at low values of UR. In the opposite ga _ direction, the curve descends steeply but with reducing slope. An underem- 3 Z pte im mia ployed /job ratio of 2 reduces to.2 the attractiveness. Ata ratio of 3, inward mobility ze! t has been effectively suppressed. As seen in Figure 3-14, the city during its growth z i rt phase tends to have insufficient housing and excess jobs. By contrast, the situation e cor reverses rather quickly as the land area becomes filled and as aging of the housing of ELIT a mb on increases the available underemployed housing and underemployed population, UHPR—Undevem progam nue * while aging industry reduces available jobs. Figue a . _

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Figure A-6 illustrates the relationship in Equation 1}. Normal is taken as no low-cost-housing program. As the program increases in terms of the fraction per year of the underemployed who are given new housing, the attractiveness of the area rises progressively more steeply.

The input to Equation 11 is the underemployed-housing-program rate UHPR computed in Equation 12. This divides the low-cost-housing units per year being built by the number of underemployed to yield the fraction per year receiving

new housing.

UHPRAK ACHP. K/U.K T2yh UHPR ~ UNOEREMPLOYED-HBUSING-PROGRAM RATE CHOUSES/ YEAR/MAN) LCHP ~ LOW-COST-HOUSING PROGRAM (HOUSING UNI TS/ YEAR) ¥ = UNDEREMPLOYED ¢MEND

At all times a social system can be expected to have simultaneously an inward flow and an outward fiow. All people are not identical in their preferences. Urban attractiveness is not seen the same way

by everyone. A given level of attractiveness may be drawing some people in while pushing others out.

AR

135.2,C

UD.KL= CUDN) U.K) CUDM.K?

UONS 02

w ~ UNDEREMPLOYED DEPARTURES (MEN/YEARD

UON = UNDEREMPLOYED DEPARTURES NORMAL CFRACTION/ YEAR?

u ~ UNDEREMPLAYED CMEND

UOM + UNDEREMPLOYED-DEPARTURE MULTIPLIER COI MENS F@NLESS)

Equation 13 has the same structure as Equation 1. It is the outward flow rate expressed in terms of the fraction of the existing underemployed population that would normally leave each year. This normal is then multiplied by the factor UDM, which determines how the actual outward flow at any particular time is related to the normal. An outward flow of 2% per year has been inserted to represent the normal.

The underemployed-departure multiplier UDM is described by Equation 14 and Figure A-7. For lack of more specific evidence the relationship is taken as the reciprocal of the inward attractiveness AMM. When AMM doubles, the outward flow is reduced by half and vice versa.

Equation 14 has a technical complication that will be encountered in several of the other tables. The relationship has a symmetry not on an arithmetic linear scale but in terms of ratios both above and below 1. In other words, doubling and quadrupling the value of AMM has the inverse effect of halving and quarter-

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4 T inn! (tI eo UDMT & Bqldl fy Z 4 8 i g 3. 24 ae z 6 5] = a Cory =H AMM "12s 35 3 = Los aati 2 a 0 i H 3 AMM- Attractiveness for migration multiplier

Figure 4-7

ing. The appropriate scale to give proper weighting to the function i logarithmic, The term "LOGN" in Equation 14 is a funstion indicator se 'nike TABLE designator itself. It causes the DYNAMO compiler to take the natural logarithm of the variable AMM. The multiplier 1.44 converts from the natural logarithm (base e) to a logarithm on the base 2. The table look-up then proceeds in terms of the value of the base-2 logarithm of AMM. Figure A-7 shows both the logarithm used in the table and the cortesponding value of AMM.

UDM-K=TABHLC UDMT, 1,444 LBENCAMMK) » 335 1) Tash UDMT=8/4/2/1/.5/.25/.125 14.457 ty

WOM ~ UNDEREMPLOYED-DEPARTURE MULTIPI wont COL MENSIBNLESS) MER > UNDEREMPLOYED-DEPARTURE-MULTIPLIER TABLE AMM = ATTRACTIVENESS ~FOR-MI GRATION MOLTI PI COIMENSI@NLESS) HIER

Equation 15 is described as the underemployed birth rate but i 2 e is actually th net difference between birth rate and death rate. It is one of the flows inte the underemployed level and has the value of .015 of the underemployed each year.

UB.KL=CULK CUBR) 15,R is UBR=.015 W5eIyC oly UB = UNDEREMPLOYED BIRTHS (MEN/YEAR)

u ~ UNDEREMPLOYED (MED UBR = UNDEREMPLAYED BIRTH RATE CFRACTION/Y EAR)

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Equation 16 is the level equation which accumulates the flow into and out of the underemployed pool. It is one of the principal system levels appearing in Figure 2-4.

UeK Us HECOT) CUA JK UB IKELT Us JK UDe JK "UTE eK? 16yL U=1200 16.1,8

u > UNDEREMPLBYED CMEND

UA ~ UNDEREMPLOYED ARRIVALS CMEN/YEAR)

UB = UNDEREMPLOYED BIRTHS CMEN/YEAR)

ATU = LABOR TS UNDEREMPLOYED CHEN/YEARD

uD ~ UNDEREMPLEYED DEPARTURES CMEN/Y EAR)

UTL = UNDEREMPLOYED T2 LABOR (MEN/YEAR?

The level equations are integrations. They accumulate the rates of flow to generate the changing system states. The level equations change the time shape of variables, that is, a constant rate of flow becomes a uniformly changing level, a straight line rising flow rate becomes a parabolic increase in the level, etc. The Jevel equations are essential to creating time-varying behavior in a system. The Tate equations and their associated auxiliaries are algebraic equations which would instantly reach their final values without time transients if there were no level equations.

The solution interval DT in Equation 16 represents the interval between evalua- tions of the equations of the system. In a proper model formulation the interval DT has no intrinsic relationship to the real behavior of the system except that it must be short enough not to influence the behavior of the simulated system.

It should not be used to introduce time delays. It need not be equal to the basic unit of time measure except by coincidence. A rule of thumb for selecting the solution interval is to make it half or less of the shortest delay in the system. One year is used here because only much longer dynamic responses are involved in this system study.*

Equation 16, being a level equation, must have an initial value as given in Equation 16.1. The initial values are arbitrary and not important. They are chosen to be compatible with an early stage of growth when 3% of the land area is occupied. .

Two positive-feedback loops are visible in Figure A-1 and the preceding equations. One is the birth rate. involving Equations 15 and 16, where the under- employed generate a birth rate that increases the underemployed. The other positive loop is the one involving the underemployed in Equation 16

and the underemployed arrivals in Equation 1. The underemployed attract more under- employed, who further increase the underemployed.

The effective positive-feedback loop involving the underemployed operates on. the difference between the underemployed arrivals and the underemployed departures. As the multiplier AMM shifts, these two loops can be converted from

*Sce References 1 and 6.

a composite Positive loop in which growth increases size to further increase the growth rate into a set of loops with neutral net consequence when the arrival rate equals the departure rate, As the multiplier AMM becomes still smaller, the loops Pass through the transition point and become a net negative loop in which the decrease tate of underemployed is proportional to the underemployed group and, if this effect were to run to completion, the underemployed group would move exponentially toward zero in the typical decay pattern of a negative-feedback loop. In operation this set of loops maintain their positive-feedback character during the internal growth phase of an area and then in stagnation take on values

which, along with the other three flows, hold th econ ne pe s ¢ number of underemployed at

A.2_ Labor Sector

The flow diagram of Figure A-8 shows the structure of flows between labor and the underemployed, and the labor birth rate. The labor pool is influenced by 6 flow rates—upward mobility from the underemployed, downward mobility back to the underemployed, Jabor arrivals from outside the area, labor departures, ipward mobility from labor to the managerial-professional group, and labor __ The flow from underemployed to labor represents upward economi flit in Equation 17. It is taken to depend on the underemployed actually working UW. Of this working group a normal fraction of .1 per year make the transition to the labor class. This normal value is modulated by the multiplier UMMP, which combines the influences of the various economic and social conditions oF the city. The last term of Equation 17 is the upward mobility produced by an underemployed-training program. The underemployed-training program UTP is not itself dependent on the condition of the urban area, It is one of a number of special programs that can be applied from the outside in an effort to modify

the condition of the area. (These pro; i$ are described 1; ii rt through (509 programs are descril later in Equations 140

UTE KL=CUMND CUN.K) CUMMP.KD+ UTP ok T7,R UMN=.1 T7616

UTL = UNDEREMPLEYED To LABOR CHEN/Y EAR) WN = NRERENPLOYED MOBILITY NORMAL CFRACTIONS ut ~ UNDEREMPLOYED WORKING CHEN) ~ UMMP - UNDEREMPLOYED-MABILITY MULTIPLIER P: COLMENSI ONLESS) SRCEIED UTP = UNDEREMPLOYED-TRAINING PROGRAM CMEN/Y EARD

fimnation 18 gives the number of underemployed that are working in terms of the total underemployed multiplied by the fraction of hold jobe ip! ip) Ny ion of the underemployed that UP OLR, 134, A) Labor "eh rate art Labor/job ratio Labor layo UALR > 2 fraction Poa I [iB we MLR, 4 4 \ Labor births = MER, 58 A \ -l 28 35s TN, - Re BER \ (Y Eee + (UTLN, 153, 8) LTPG, 141, A AN

4 Underemployed

U, 16, b Ons, Labor ' (LT, 32, R=} \. Labor to manager 3 » \ \ iS oP UTLN, 133, 8) \

/ f GA dL RY OD, R)

' Labor arrivals. Labor departures

\. Underemployed . to labor _ perception UMN \ om nderemptoyed) UTLPT mobility, normal) —G~

+

¢

(UTP, 140, AD 'Underemplayed training, Program

sen

t I t I \ UTLP UMMP i Underemptoyed ' Underemployed to nobly 2 alii I labor, perceived » x aot 2 i ¢ I MMPT t 1 i - u 'Underemployed { 4 4 t mobility multiplier I I tion time prep ' Underemplyed II Tr t 'Underemployed i Hi mobility factor / 7 i UMF { i UMM ° No(UAMM. 4,4) 6 'Underemployed ~. Pal mobility etl smultiptier je--@uR, 37,4) aderemplojedfjod \ ratio /

i f

LUM.

"oor, J+--QTPCR, 8 A vaderemployed "Tax per capita ratio rauttiplier 7

Nour, 14,4) \ Labor/job ratio.

ef LAUM, 45, A WHUM, 87, A TCM, 127, A

Figure 4-8 Labor mobility and birth rate.

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UW KECUKD CUFWAO 184A

WW = WNDEREMPLOYED WORKING CMEND

uw ~ UNDEREMPLOYED (MEN)

UFW = UNDEREMPLOYED FRACTIGN WORKING CD} MENS IGNLESS)

The fraction of the underemployed working UFW is expressed in Equation 19 and Figure A-9 in terms of the underemployed /job ratio. UFW.KETABHLCUFWT URSK 40,4, 19

WEWT=49/48/.5/633/.25

19,8

196157 LFW ~ UNDERENPLBYED FRACTION WARKI NG DIMENSION Ess) UEWT = UNDEREMPLOYED-FRACTIGN-WORKING TABLE 'R= WNDEREMPLAYED/.BB RATIG <DIMENStBNLESS)

In Figure A-9 the assertion is made that when the underemployed outnumber available jobs by a factor of 2, all available jobs will be filled and therefore half of the underemployed will be occupied. Similarly, when there are three times as many underemployed as jobs, one-third will be occupied and when there are

four times as many underemployed as jobs one-quarter will have employment.

1 ¥ mi T To

Se FS I UFWE

23 Eq. 19.1

£5 as = ae ae i

ollie 1

° v 2 3 4

UR-Underemployed /job ratio Figure Ag

Going downward in the value of UR from UR = 2, the same inverse relationship does not hold. When UR equals 0, it implies an overwhelming excess of jobs compared to the underemployed. Even under such circumstances only 90% of the underemployed will be working rather than all. At the 1 to 1 ratio, with jobs and people exactly in balance, the matching of the two and incentive and ability to work will decrease employment to 80%.

Equation 20 is a first-order exponential delay like Equation 2 and produces a 10-year perception delay between actual upward mobility and that which influences AMM in Equation 3.

Equation 21 gives the fraction of underemployed observed as making the upward transition each year. It is the upward rate perceived divided by the total number of underemployed. 150. Appendix A

UTLPKEUTLP JHCDT/UTLP TD CUTLe JK UTEP JD 2054 uTLes75 200 1,N UTLPT=10 20.7,€

UTLP ~ UNDEREMPLOYED Td LABOR PERCEIVED CHEN/Y EAR)

UTLPT = UNDEREMPLBYED~1@-LABQR PERCEPTION TIME CY EARS)

UTL -~ UNDEREMPLOYED 78 LABBR CMEN/Y EAR)

UMK SUTLPAK/ULK rar

ww + UNDEREMPLOYED MOBILITY CFRACTIGN/VEARD

UTLP) = UNOEREMPLOYED Te LABOR PERCEIVED CMEN/Y EAR)

u ~ UNDEREMPLAYED CHEN)

Equation 22 defines a variable UMMP called the underemployed-mobility multiplier perceived. "Effective" in this context might be a better term than "perceived." The equation produces a 10-year delay between the inputs from Equations 24, 25, and 27 before they effectively create the flow rate from under- employed to labor. This delay represents training time and time necessary for social

influences to become effective. Like the other perception times, it has no influence on the equilibrium conditions of the system and rather minor influence

on transient behavior.

UMMP..K=UMMP ..-COT/UMMPT> (UMM, JUMP oJ) 225L 'UMMP2T 22.1,N UMMPT=10, 2242,C

UNMP = UNDEREMPLOYED-MABILITY MULTIPLIER PERCE! VEO CDIMENS /BNLESS)

'UMMPT - UNDEREMPLOY ED-MABI LETY-MULTIPLI ER PERCEPTION TIME CYEARS)

UMM = UNDEREMPLEYED-MOBILITY MULTIPLIER ¢OIMENSIBNLESS)

The multiplier UMM in Equation 23 combines three system conditions that influence upward mobility. The fourth term UMP is not a part of the real-life system but a technical parameter permitting experimentation with the effect of

this equation. 23,4 23.1,C

UMAR 2CLSMaK) CLUM«K2 CUEMSK CUMP? UMFS1 UMM - UNDEREMPLOYED-MOBILI TY MULTIPLIER

COEMENS EBNLESS) LSM = LABOR-SUPPLY MULTIPLIER (Oi MENSIBNLESS)

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LUM = LABBR/UNDEREMPLOYED MULTIPLIER COFMENSI@NLESS) UEM = UNDEREMPLAYED EDUCATIONAL MULTIPLIER <DIMENSIGNLESS) UMP ~ UNDEREMPLOYED-MaBILITY FACTAR * COEMENSIONL ESS)

Equation 24 and Figure A-10 describe a telationship between the labor/job ratio and upward mobility from underemployed to labor. Its purpose is to increase upward mobility when there is a labor shortage and an excess of labor jobs and to decrease upward mobility when there is a labor excess and a shortage of the more skilled positions.

USMeK=TABHLCLSHT gLR.K 0,2, 65) 2a A USMT=2.8/2 1704/42 24et,t ots

USM ~ LABBR*SUPPLY MULTIPLIER <DIMENSIGNLESS> LSMT - CABOR-SUPPLY -MULTIPLIER TABLE LR = LABBR/.BB RATIO COIMENSESNLESS)

The normal condition is taken for a labor/job ratio of 1, at which point the multiplier has a value of 1. As the ratio LR declines, indicating fewer in the labor group compared to available jobs, upward mobility increases to 2.4 times normal. At the right-hand extreme, when labor is double the number of available jobs, upward mobility is reduced to one-fifth of normal.

, mo LSMT a By Mt a. = cn 7 FA NI pene ECC e $ 1 1s 2 ER+Labor /job eatio

Figure A-lO

Equation 25 and Figure A-11 describe an influence on upward mobility owing to the ratio of labor to underemployed. This curve asserts that, as the labor group decreases relative to the underemployed, there is less skilled labor in evidence, and fewer jobs to serve as examples for the underemployed, Under these circum-

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% cna

e LUMT.

Fy 2g. 25.1 i ag =

<i Fi

ga

i

z

30

4 3

r 2 3 LUR~Labor /underemployed ratio Figure A-il

stances upward mobility is more difficult. This is the factor that Tepresents the influence of dominant blocks of underemployed in one area where they are not intermingled with other economic groups. It covers ail social effects including school segregation and the unavailability of more affluent groups to emulate. Once the underemployed/labor ratio is high enough, increasing it further has little ef- fect. As it falls off, the influence increases.

LUM.K =TABHLCLUMT)LUR.Ky 0, 5, 1) 25,4 LUMT= 62/67/4/102/1 03/105 250497

LUM = LABR/UNDEREMPLOYED MULTIPLIER (Oi MENST@NLESS) LUMT - LABOR/UNOEREMPLOYEO MULTIPLIER TABLE LUR = LABOR/UNDEREMPLOYEO RATIC CDI MENSIGNLESS)

Equation 26 provides the labor/underemployed ratio LUR needed in Equa- tion 25,

LURSK=L K/UAK 26,A

LUR = LABGR/UNDEREMPLOYEO RATIO COIMENSIGNLESS)

L ~ LABOR (MEN) u ~ UNDEREMPLOYED CHEN)

Upward economic mobility has been made a function of the tax per capita tatio TPCR. This is intended to reflect primarily the effect of education in upgrad- ing economic skills. Equation 27 and Figure A-12 show the extent of dependence that has been assumed. Falling tax expenditure has an increasingly adverse effect, while rising expenditures begin to saturate and show progressively less effect.

STABHLC UENT, TPCR.K 4043505) 2T,A

62/0 /1/ 103/165 106/107 2teiyT

GEM = UNDEREMPLGYED EQUCATIONAL MULTIPLIER COLMENSIGNLESS)

UEMT = UNDEREMPLOYED=EDUCATIGNAL-MULTIPLIER TABLE TCR - TAX PER CAPITA RATIO CDIMENSIQNLESS)

tT TT TTT

Be ares 4 ge tape So SerEeEeee g2 cco = 1 gay I 1

23 Cu Pett i

Be Cc]

° i t i

' 1 1s 2 a 3

TPCR—Tax per capita ratio Figure A-12

Equation 28 gives the labor birth rate as the net of births minus deaths at a slightly smalier annual increase tate than used in Equation 15 for the under- employed,

LB.KL=CLeK) (LER) 2a,R 286140

LB + LABOR BERTHS CMEN/YEARD Lt = LABOR CMEND LBR = LABAR BIRTH RATE CFRACTION/Y EAR?

Equation 29 is a level equation accumulating the flow rates into and out of the labor pool.

LaK=L. COT) CUTLe KELBs KL TMeJKELA JK =LO WK eL TUSK) 2954 &=14000 296TyN

t = LABOR CHEN UTL = UNDEREMPLAYED Ww LaBaR CMEN/YE AR) te ~ LABOR BERTHS (MEN/YE AR)

u ~ LABOR W MANAGER (MEN/YE,

LA = LABBR ARRIVALS MENA EARS

to 7 LABGR DEPARTURES (MEN/YEARD

LTE = LABBR Te UNDEREMPLBYED CMEN/Y EAR)

Equation 30 provides a dropout rate from the labor category into the under- employed category contingent on the labor/job ratio.

LTU.KL=CLAK) CLLF AK? 30,8 LTU + LABOR 7B _UNDEREMPLaYED CMER/YE AR)

L = LABBR CHEN) LUF = LABBR-LAYBFF FRACTION CFRACTIQN/YEAR?

Equation 31 and Figure A-13 describe a sharply increasing dropout rate as the labor population exceeds available jobs. Under sustained, severe unemployment

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LLF Labor layot? fraction

oie

0 S

v is 2 LR—Labor /job ratio Figure A-13

it is assumed that the marginal individual in the labor category is forced eco- nomically into the underemployed category, that as he stays there his skills decline in relation to the economy, and that he does not represent a special pool having preferred access back to the labor category. Under normal conditions, with labor and jobs in balance, the dropout rate is taken as 3% per year. Ata 2 to I excess of labor to jobs this rises to 30%.

LLFK=TABLECLLFT LR aK 502565) 34h LLFT=0/.017.03/.4/.3 BUA,T

ELF = LABOR-LAYGFF FRACTION CFRACTION/Y EAR? LLFT = LABBR"LAYOFF-FRACTION TABLE ur = LABBR/JOB RATIO COIMENSIBNLESS)

Figure A-14 shows how the upward mobility from labor to the managerial- professional group is generated.

Equation 32 defines the flow rate. As with most of the other flow rates it is described in terms of a normal fraction of the labor group. This is modulated by the multiplier LMMP, which represents the more important economic and social influences. The added term LTPG provides the possibility of an externally applied training program to increase this flow rate.

LTMoKLECLMND CLK? CLHMP.KD4LTPG 4K 32,8 LN 602 32.1,C

LIM = LABJR To MANAGER CMEN/YEARD

UMN = ABBR MOBILITY NORMAL CFRACTION/V EAR?

L = LABBR MEN)

LMP = LABBR-WOBILETY MULTIPLIER PERCEIVED COLMENS I@NLESS)

LIPG = LABOR-TRAINING PROGRAM CMEN/YEARD

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& Labor S. 3 \, & Labor mobility, normal = \ .7PG, 1, AD i \ Labor traitng progrem ! \ / LMMP \ i Labor mobility \ / tauhiplier, perceived \ { { a iT LMMPT \ _Labor mobility \ 'multiplier pecception time \ 1 \ i t ! 1 1 i H t { i ! i 1 l i i l i ! aN Sorrcr, 4a) l 1 eg i eae, a th Jus I 'manegement _~. i DIM aio M a New si 1 management iT (DT, 116, L ~~. \._ ectning ndosey 70M 13.2) ure busi \ oe estes BM. \ Matare tasiness a" ~ management a ~s aa

Figure A-I4 Labor-to-manager mobility.

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Equation 33, like Equation 22, provides for a delay between changes in the system levels and their influence in changing the mobility rate from labor to tion delay, it is more in the nature of a

management. Although called a percep i ining and adaptation to social conditions. On the

functional delay involving traini basis that the transition from labor to management takes longer conditioning than that from underemployed to labor, the delay is taken as 15 years instead of 10.

LIMP SKELMMP JECOT/L MMP TD CL¥Me J=LNMP 0S S3yL Uae =t 35019 UMMPT=15, 350250

LMP - LABOR-MOBILITY MULTIPLIER PERCEIVED

¢ DI MENS JBNLESS) UMPT - EABOR-MOBILI TY-MULTIPLIER PERCEPTION TIME

HEARS) UM = LABBR-MBBILETY MULTIPLIER CDI MENS 13 NLESS)

Equation 34, following the pattern already desctibed, combines the three multipliers influencing labor mobility and includes a technical factor LMF for

model, experimentation. S4yk

LMMSK=CMSMaK) CHLM6ID CLEM@K) CLMPD LMFE1 STAC LMM = LABOR-MBBILITY MULTIPLIER (DEMENSL@NLESS? AGH = MANAGER-SUPPLY MULTIPLIER (DI MENSI@RLESS) MM ~ MANAGER/LABOR MULTIPLIER COI NENSI@NLESS) LEM = LABBR EDUCATIONAL MLTIPLIER

CDI MENS I@NLESS) UNF - LABZR-MBBILI TY FACTBR CDi MENSI@NLESS? scribe the influence of management availability that Equation 24 influenced mobility from

Equation 35 and Figure A-15 de d labor mobility is easier

on labor mobility in the same way underemployed to labor. In a manager shortage upwar

than in a manager excess. 35,4 35.1,7

MSM.K =TABHLCMSMT, MRK 9052 5¢25)

MSMT=2.03/2.02/2/146/1/45/ 2/017 009

= WANAGER-SUPPLY MULTIPLIER CDLMENSTBNLESS)

= WANAGER-SUPPLY MULTIPLIER TABLE = MANAGER/J2B RATIB CDIMENSIGNLESS)

Llel EMT mR

Equation 36 gives the ratio needed in Es divided by available managerial jobs.

quation 35 computed as managers

_—

The fa, ie Model-—4 Theory of Urban Interactions 157

& cf MSMT a Copt 381 2? { i i l i ; l l z im 2 no ° 4 t is MR-Managet /job ratio. Figure A-15 MRK AIP KAN K

MRO = MANAGER/ 8 3 MANAGER AL-PROPERS OAS LaNLESS Wi = MANAGER was Mae aNAL CEN

Equation 37 computes the avail

i ¢ available managerial jobs i

in the 4 agerial , . A fhe three age categories and the number oe jobs in terms of industry units in type of productive unit, managers assumed to be needed

MI K=CNEAKD CHENO+CMB.K) CHBMO+-C D1 KD CDI STA NEM=S ; oe 37.150 a, 37.256 37.3,

La MANAGER BBS CMEr NE ~ NEW ENTERPRISE mh Now > yee ree PRODUCTIVE UNETS) rey RISE MANAGEMENT CMEN/PREDUCTI VE

bil ~ MATURE BUSINES: ten _ matune-eusi S CPRODUCTIVE UNITS) iD ESS MANAGEMENT CMER/PREDUC TIVE.

wi 0} = DECLINING INOU! ISTRY CPREDUCT: 1M = DECLINING ND 4VE UN 75) US TR PRODUCTIVE INT MANAGEMENT CMEN/

A new-« i i it i ween mange eae unit in Equation 37 is characterized as needing mana; © same unit i inde. sand 'Ge mature business unit uses twlenae many mente enn . ines the changing wens reaionships of this kind define aging mit and pean nd io ine popes ich appear as the phases of growth and stagnation e a manager/labor multiplier MLM in Equation 38 and Figure A-16 is similar ~ im

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5 I 2 MLMT_ Es Eq, 38.1 — EB) 2 4 ta = 2 =

05 ry 1S MER~Manager/labor ratio Figure Al6

to the multiplier in Equation 25. It describes the effect on upward labor mobility of social proximity between the labor group and the managerial group.

MEMOK=TABHLCMLMT sMER.K 05025005) S8,A MLMT= 62/6 7/1/162/103, 38.1,T

MLM ~ MANAGERAABGR MULTEPLIER (DI MENSIBNLESS) MMT = MANAGER/LABOR MULTIPLIER TASLE. MLR = MANAGER/LABOR RATIC CDIMENSIGNLESS)

The manager/labor ratio is computed in Equation 39.

MLRSKEMP.K ALK 39,4

MLR - MANAGER/LABOR RATIO CDIMENSIGNLESS) we ~ MANAGER] AL~PRBFESSIGNAL (MEN). L UABBR CHEN)

Equation 40 and Figure A-17 state an influence of tax expenditures through education on labor mobility. The relationship is similar to that in Equation 27.

LEM.K =TABHLCLEMT, PCR 4K 5043505) AOA LEMT=.2/4.7/1/103/16¢5/ 106/167 4001,T

LEM =~ LABGR EDUCATI@NAL MULTIPLIER

CDEMENSTQNLESS) LEMT = LABBR-EDUCATIONAL-MULTIPLIER TABLE. TPCR = TAX PER CAPITA RATI2 COIMENSIGNLESS)

Figure A-18 illustrates the network of relationships that control labor arrivals

and departures,

In Equation 41 the labor-arrival rate is a normal fraction of the labor level multiplied by the modulating term LAMP.

In Equation 42 a perception-time delay of 15 years is used between the actual conditions of the city and the perceived value, which controls arrival rate.

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P WI g LEMT zg Eq. 40.1 g g2 gy = 3 + a! arti i i} = F I § iam °% s t Es 2 co 3 TRCR~Tax per capita ratio Figure A-17 EASKL=CLAN) (Lak? CLAMP.KD. AR LAN=.03 ATIC

LA ~ LABOR ARRIVALS CMEN/Y EAR)

LAN = LABOR ARRIVALS NORMAL CFRACTION/YEARD

u > LABOR CHEN)

LAMP = LABBR-ARREVAL MULTIPLIER PERCEIVED CDI MENS {@NLESS)

LAMP.X=L AMPs SeCOT/LAMPT) CLAMS J-LAMP. JD. 42 yb LANP=T AZ615N LAMP T=15 42.226

LAMP - LABBR-ARRIYAL MULTIPLIER PERCE! VED CB) MENSI@NLESS)

LAMPT = LABQR-ARRIVAL-MULTIPLIER PERCEPTION TIME YEARS)

LAM = LABARWARREVAL MULTIPLIER CDFMENSIQNLESS)

The labor-arrival multiplier in Equation 43 is a product of four active terms and the experimental factor LAF.

LAM.K=CLAJMoK CLAUMSK) CLATMAK) CLAHMaK) CLAP) ASA

LAF=1

LAM = CABBR-ARRIVAL MULTIPLIER COI MENS IQNL ESS) LAUM = LABOR-ARRI VAL 2B MULTIPLIER CDI MENSI@NLESS) LAUM = LABOR@ARRIVAL UNDEREMPLOYED MULTIPLE ER CDI MENS IBNLESS) LATH = LABOR-ARREVAL TAX MULTIPLIER COI MENS FBNLESS) LAM + LABBR~ARRI VAL HOUSING MULTIPLIER COE MENS FONLESS) LAF = LABBR=ARRI VAL FACTOR COFMENSIGNLESS)

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\ \

LDN

Labor departures, iL

LAN \ Labor arrivals, normal \ normal \ \ f \ 1 I \ i H I é I I i LAMP i i Labor arrival i ! multiplier, perceived I 42 f I to LDM I \ @DMT) i $e Labor departure I roullplier i i r i / Labor arrival factor LAF =

Nee

f i { Nair, 134, A) Laber/jab ratio Fs WHPD Labor Worker housing, family size population density Se Libor arial underemployed tax multiplier 'mnultiplicr 45 46 2 UR, 25, AO- ~~OTR, 122, A) 'Tax ratio

Laboranderemployed ratio.

Figure A-l8 Labor arrivals and departures.

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LAIM~ Labor artival job muttiplier a

s

1 1s LR-Labor /job ratio Figure A19

Equation 44 is similar to Equation 10; it describes the influence of job avail- ability in making the city attractive to labor. The relationship is illustrated in

Figure A-19, A

41,7

LAJHAK STABLECLAJMT pL Rok 092, 025) LAIMT=2 6 6/206/204/108/1/ 04/42/01/205

LAJM ~ LABGR-ARRIVAL JOB MULTIPLIER COLMENS [SNL ESS)

LAJMT > LABOR@ARRIVAL-J@B-MULTIPLIER TABLE

wR ~ LABGR/BB RATIC CDIMENSIGNLESS)

Equation 45 and Figure A-20 describe the social attractiveness of the city in terms of the ratio of labor to underemployed. When the ratio of labor to under- employed is 2, the multiplier value is taken as 1. A higher proportion of labor makes the city slightly more attractive. A lower percentage of labor makes the city progressively less attractive as a place into which labor desires to move.

ABSA 4501,T

LAUM.K=TABHLC LAUMT y LURK 9 0455 1) LAUMT= 04/68/17 02/1463/T03 LAUM = LABBReARRI VAL UNDEREMPLOYED MULTIPLIER COIMENS}@NLESS) LAUMT - LABBR-ARRI VAL -UNDEREMPLOYED-MUL TIPLIER

TABLE LUR = LABBR/UNDEREMPLOYED RATI@ (Ol MENSIQNLESS)

The labor-arrival tax multiplier LATM in Equation 46 and Figure A-21 repre- sents the influence of the city tax rate on the inclination of labor to move into the city. When rates are reasonable, they have little effect, but should they become

unusually high, they have a depressing effect,

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'LAUM- Labor arrival underemployed multiplier

1 2 3 4 s LUR-Labor/underemployed satio Figure A-20

LATMAK =TABLECLATMT, 1.644% LBGNC TRaK) 9-25 492) 46,A LATMT=1.2/1/ 07/03 49601,T

LATM ~ LABGReARRIVAL TAX MULTIPLIER CDEMENS I@NL ESS) LATHT = LABBR<ARRI VAL=TAX-MULTIPLIER TASLE

R = TAX RATIC CDIMENSI@ALESS) s Wo LATMT i ee @ CPRRRERS = j BE : aee 3 a =< 4 L ° 8 16 i 7 4 'TR Tax ratio Figure At

Just as housing in Equation 5 influenced the arrival ne the underemployed, ing i i i 22 influences the arrival o! . housing in Equation 47 and Figure A-22 in! v 2 relationship is represented as rather steep above a labor/housing ratio of one. At a ratio of 3, inward migration is almost suppressed.

LAHM.K=TABLEC LAHMT,LHR.K,053y 05) 4A

LAHMT=103/102/1/65/ 02/0 17005,

LAHM = LABOR-ARREVAL HOUSING MULTIPLIER ABOR-ARRI VAL" SING-MULTSPLIER TABLE - R—ARRI VAL"HOUS ue - TABOR ABUSt HG RATIC COIMENSIGNLESS>

47.47

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&

4 im To 1 =e Ho tama CLL

8 Eq. 474

: i. 2 3 i

3 if Ki z ion 4 }

° $ 1 as 2 2s 3

EHR—Labor/housing ratio Figure A-22

The labor/housing ratio in Equation 48 is labor multiplied by family size and divided by available housing and housing density. At the worker level a housing unit is assumed to be occupied dy six persons,

LeKLFSD/ WH. Ke WHPDD ABSA

48.7,0 UR - LABORAHBUSING RATIO COIMENSIGNLESS)

L = LABOR CHEN)

LFS = LABOR FAMILY SIZE CPEOPLE/MAND

wH 7 WORKER HOUSING CHBUSING UNITS)

WHPD - WARKER-IBUSING POPULATION DENSITY (PEOPLEY

HOUSING UNI TD

Equation 49, which applies to labor departures, is the standard form of the basic rate equation. Normal departures per year are expressed as a fraction of the labor population. This normal fraction is then modified by a multiplier that describes whether the urban area is causing a departure rate greater or less than normal,

LO.KL=CLOND CLK CLOMAKD 49K LON= 602 4941,0

tD LABGR DEPARTURES CMEN/YEARD LON LABQR DEPARTURES NORMAL CFRACTIGN/YEAR)

= LABBR CMEND ~ LABAR-DEPARTURE MULTIPLIER COIMENS FGNLESS)

L Lom Like Equation 14, Equation 50 as shown in Figure A-23 sets departure influence as the reciprocal of arrival influence. As the city becomes more attractive to labor, arrivals increase and departures decrease.

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. Loo ft LDMT Eq. 50.1 g. q a i. & i zy 8 = um &: ro 3 $ 1 7 4 ¢ 10020AM) 3 a a ° i 2 3 LAM-Labor aval multi Figure A-23 LDM.K STABHLC LOMT, 1. 44LOGNC LAMSK) y=3 391) 50,4 LOMT=8/4/2/1/45/0254 0125 506t,T

LOM = LABBR-DEPARTURE MULTIPLIER CDi MENSIGNLESS) LOMT = LABAR=DEPARTURE-MULTIPLIER TABLE LAM = LABBR-ARRIVAL MULTIPLIER (DIMENSIONLESS?

A.3 Managerial-Professional Sector

The fiow diagram in Figure A-24 shows the managerial-professional level, its related flow rates, and the structure controlling birth rate and managerial arrivals and departures.

Equation 51 is the net birth rate (births minus deaths) in this population sector with three-quarters the value found in the labor sector and half the value in the underemployed sector.

MPB.KL=CMP 4K) CMPBR) Sisk MPBR=.0075 S16i,o

MPB ~ WANAGERIAL~PRBFESSI@NAL BIRTHS CMEN/YEAR)

P > MANAGERIAL-PROFESSI@NAL (MEN)

MPBR - MANAGERIAL-PROFESSI@NAL BIRTH RATE CFRACTION/YEARY

The level equation which accumulates the managerial flows is given in Equation 52. The initial value, as for the others in the model, is selected to give an internally consistent set for starting the system with the land area 3% filled.

Cy 'Managerial professional birth rate

MPBR

=e MAN Maaager arrivals, normal \ 4

MAMP 'Manager arrival smulplir, pececived 54

'Manager departures, 'normal

t 1 4 1 MDN 1 1 1 ay

f ¢ ay Y f 4 a M MAMPT lanager arrival f — wultiptier pevception ime

MAM

Manager arrival 'multiplier

R, 36, AD. wa.

iger/job ratio ~

PH, 78, LO

(PHEM, 72, adn. Premium housing \ MATM \ (MATMT) Manager arrival / \ ager ari / MPFS Y tax matiplic 7 Managesial-professionat population ratio 3° PHPD nyse - Premium housing \ 58 oR, 12, AD Population density @, 3, LO q ' Labor OU, 16, Ly Underemployed

Figure A-24 Manageriai-professional sector.

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MP .K=MP oC OTD CL TMs JKTMPB.IKEMA oJK=MDeJK> S2yL MP=3900 5241,N

WP = MANAGERIAL~PRAFESSIQNAL (MEN

LIM ~ LABGR TW MANAGER CMEN/Y EAR)

NPB = MANAGER AL~PROFESSEGNAL BIRTHS CMEN/Y EAR? MA = MANAGER ARRIVALS CMEN/YEAR)

Li ~ MANAGER DEPARTURES (MEN/YEAR?

Normal managerial arrivals are defined in Equation 53 as 3% per year of the managerial group.

MA KLE CMAN) CHP.4K) CHAMP 4K) 535k

MANZ 03 Bato

MA ~ MANAGER ARRIVALS CMEN/YEAR? WAN = MANAGER ARRIVALS NORMAL CFRACTISN/Y EAR)

lg ~ MANAGER] AL-PROFESSIGNAL CMEND MAMP = MANAGER"ARREVAL MULTIPLIER PERCEIVED CDI MENSIBNLESS)

Equation 54 gives the perception-time delay between the true state of the city and its condition as perceived by arriving managerial-professional persons. The delay of 10 years is smalier than in the other population sectors on the assumption that communication and awareness in this group will cause perception to follow

reality more rapidly.

AMP .KEMAMP . J+-CDT/MAMPD CMAMe J-HAUP 4) S44L MANE = Shel MAMPT=10 54.250

MAMP = MANAGER"ARRIVAL MULTIPLIER PERCEIVED DIMENSIONLESS) MAMPT = MANAGER@ARRIVAL*MULTI PLIER PERCEPTION TIME

(YEARS) MAM = MANAGER@ARRIVAL MULTIPLIER (D1 MENSIQNLESS?

The manager-arrival multiplier in Equation 55 consists of the product of the four active terms representing urban conditions, and the experimental test factor

MAF.

= CMAJMAK) CHAPHAK) CHA THe) (MAHHAK CMAP) 55,4 55.1,€

MAM = MANAGER@ARRi VAL MULTIPLIER COIMENSIGNLESS? MAJM = MANAGER-ARRIVAL JOB MULTIPLIER

COL MENSFONLESS) MAPM = MANAGER-ARRIVAL POPULATIGN MULTIPLIER

COIMENS IBKLESS)

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MATH ~ MANAGER"ARRIVAL TAX MULTIPLIER CDEMENS IGNLESS)

MAHM ~ MANAGER-ARRI VAL HOUSING MULTIPLEER C01 MENS LONL ESS)

WAF = WANAGER-ARRI VAL FACTOR COIMENS I@NLESS).

Asin Equations 10 and 44 available work conditions here influence managerial arrival, as described in Equation 56 and Figure A-25. The relationship is a rather steep function of job availability. In this telationship more than pure job count is involved. The central, steep section of the curve extends from a manager/job

a" iz Coo = t MAIMT 4 2 mina } Eq. 56.1 Ba ror rer

2 Sri i

i \ & im a : i [

i Peseeens SS oT TT ml it ° 3 us 2

n MR~Mannges/job ratio Figure 425

ratio MR of .75 up to 1.25, Varying degrees of underfoading and overloading of managers, as well as varying degrees of using full competence and ability, can occur. Less than fully effective employment can exist even though every individual may hold a position.

MAJMGK =TABLECMAJMT MReK 0524625) 565A WAIMT=2, 7/2..6/268/2/1/ 64/ 62/01/.05 5601,7 MAJM = MANAGERSARRIVAL JOB MULTIPLIER C DIMENSIONLESS)

MAJMT ~ MANAGER-ARRE VAL-JOB-MULTIPLIER TABLE mR ~ MANAGER/.BB RATIC (Oi MENSIGNLESS)

As in Equation 45 the manager's desire to come to the city is asserted to depend on the population mix, as expressed in Equation 57 and Figure A-26. As the

MAPM.K =TABHLC MAPMT MPRGK 0, 01,02) STA MAPMT=.3/67/1/1 02/1 3/103 5701,T MAPM = MANAGER@ARRIVAL POPULATION MULTI PLIER CDF MENS IBNL ESS)

MAPMT - MANAGER*ARRI VAL~P&PULATIGN-MULTIPLIER TABLE MPR = MANAGER/PEPULATION RATI@ COL MENS! @NLESS)

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zo I ep iT 23 beet ig:

2 Coe

gE of a 7 rc 7 t MPR ~Manager/population ratio

Figure 4.26

ratio of the managerial-professional group to the population MPR falis too low, the area is seen as socially unattractive and inward mobility is depressed.

Equation 58 computes the ratio of managers to labor-plus-underemployed classes for use in Equation 57.

MPR KEMP AK/CLAKA+UAKD SBA

MANAGER/POPULATIGN RATIG (01 MENS1GNLESS)

WR O-

yp ~ WANAGERIAL-PROFESSIQNAL (MEN) L = LABBR (MEN)

u = UNDEREMPLOYED (MEN)

Equation 59 is similar to Equation 46; it describes the influence of the city tax rate on manager willingness to move into or stay in the city. The tax-rate influences are illustrated in Figure A-27.

us Too ahs MAINT £ ms 4 591 a = =! Ba = i oS & = s° Pos 7 San a 2 20R2 4 ° ! L0G 2 (FR) TR—Tax ratio Figure A-27

Availability of housing is introduced as another influence on manager move~ ment, as given in Equation 60 and Figure A-28.

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MATMAK TABLECUATMT, 1.454 LAGHC TRAKD 4-2542) 95h MATMT=164/9/.7/.3 59.1,7 ATM = MINAGER-ARRIVAL TAX MULTIPLIER

<O1MENSIGNLESS) MATMT = MANAGER@ARRI VAL=TAX@MULTIPLI ER TABLE R > TAX RATIB COFMENSI@NLESS)

Bis

2° TT TT iat i f

FH MAHMT 4 4 2 60.E

ia

3

§

2

5s

3

=

a = 2 borer ma i ABS 2 a 3 a is 2 28 3 MHR— Mensger/housing ratio Figure 4-28

MAHMSK=TABL ECMAAMT, MARK, 0,3, 65) 6044 MAHMT=1.03/162/1/05/ 62/41/005 6061,T

MAM = MANAGER@ARR: VAL HOUSING MULTIPLIER

(01 MENSI@NLESS) MAHMT = MANAGER@ARRI VAL-+HOUS! NG-MULTEPLIER TABLE MAR = MANAGERVHBUSING RATIO CO! MENS I @NLESS)

For use in the preceding equation, Equation 61 computes the relationship between the management population and the population that normally could be housed in a Premium-housing residence. At this point in the system a housing unit is assumed normally to serve three persons,

MARAK=CMP.KAMPFS) /(PH,KRPHPDD Gry PHPUSS 61,0

MR = MANAGER/HBUSING RATIC COIMENSI@NLESS)

=P ~ MANAGERIAL-PROFESSISNAL CMEND

WPS = ANAGERI AL-PROFESSIQNAL FAMILY SIZE CPEBPLE/MAN)

PH = PREMIUM HOUSING CHOUSENS UNE Ts)

PHPD ~ PREMIUM-HBUSING POPULATION DENSITY (PEBPLEY 'HOUSING UNIT)

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Manager departures are defined in Equation 62 as having a normal value of 2% per year of the manager group.

MO eKL=CMON) CMP&K) CMOMSK)

624K MONS 202 BAe Li > MANAGER DEPARTURES (MEN/YEAR) MON = MANAGER DEPARTURES NORMAL CFRACTIQNA EAR) we ~ MANAGERI AL-PROFESSIONAL (MEN) MOM =

MANAGER-DEPARTURE MULTIPLIER 'COMMENS! BNLESS).

The manager-departure multiplier MDM is the inverse of the manager-arrival multiplier MAM, as produced by Equation 63 and illustrated in Figure A-29.

* Toy MDMT Eq. 63.1 ge a H 2 4 3 7 2 a 2 ha a i ane 25 35 s r 2 7 3 106 2 MAM) 3 a a ° : 2 3 MAM—Manager artival maltpier Figure A-29 MDM.K =T ABHLCMDMT, 1. 54*LBGNC MAM. K) 9-3 p35 1) 634A MOMT=B/4/2/1/ «5/ 625/4125, 6361,T

MDM = MANAGER-DEPARTURE MULTIPLIER CDIMENSIGNLESS)

MONT = MANAGER~DEPARTURE-MULTIPLIER TABLE

MAM = MANAGER@ARRIVAL MULTIPLIER (DIMENSIONLESS)

A4 Premium-Housing Sector

Figure A-30 shows the structure of relationships causing the construction and obsolescence of premium housing.

Equation 64 defines the rate of premium-housing construction PHC in terms of premium-housing construction desired PHCD multiplied by the factor LCR

MHR, 61, A HAY, 129, A PHCP, 142, 4

WH, 81, 1)

Worker housing

/ (LCR, 138, AD-* / Premium housing Labor construction ratio ra ane program: L 142, A) se PHCN-

bo PHF

Premium kovsing factor

Preaium housing saultiplier

\pxaie, 61, A)

sO

N.

X wag ee

Housing units New enterprise total

Productive units,

10 ptm KQUH, 95, 1) (MB, 03, Le" total Underemptoyed housing Mature businesses a WH, 81, L) Declining industry Worker housing

Figure 4-30 Premium-housing sector.

Manager/housing malo Premium housing average (MPR, 58, ap-—* 1 Manege/population Premio housing rato land meulplice WHLM, 86, A) " SHLM, 99, A ELM, 105, A DILM, 126, 4 (NECP, 165, Ady (NE, 100, LOX

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coming from the job sector and causing limitation in the actual construction rate below that desired if the labor shortage in the city does not pezmit full construc tion activity.

PHC .KL=CPHCO.K) (LCR K? 64K PHC ~~ PREMEUM-HOUSING CBNSTRUCTIGN CHBUSING UNI TS/Y EAR)

PHCD = PREMIUM-HOUSING CONSTRUCTION DESIRED CHBUSING UNITS/VE AR) LCR =~ LABBR CONSTRUCTIBN RATIO CO/MENSIZNLESS>

The premium-housing construction desired in Equation 65 contains the structure seen earlier for flow rates. It describes the desired construction rate as 3% per year of existing premium housing. This normal rate is influenced by the pre- mium-housingmultiplier PHM. Anexternallyimposed premium-housing-construc- tion program can be added through the last term. Desired construction is first generated in this manner so that it can be influenced in Equation 64 by the availability of construction labor.

PHCO.K=CPHEN) (PH.K) (PHM.K)+PHCP 6K 65,4

PHONE 03 6501,

PHCO — PREM! UM-HOUSING CONSTRUCTION DESIRED CHBUSING UNE TS/Y EAR?

PHCN = PREMIUM-HOUSING CENSTRUCTICN NORMAL CFRACTION/Y EAR)

PH = PREMIUM HOUSING CH@USING UNITS)

PHM = = PREMIUM-HOUSING MULTIPLIER (DIMENS!@NLESS)

PHCP = PREM! UM-H@US! NG~CONSTRUCTION PROGRAM (HOUSING UNI TSA EAR)

The premium-housing multiplier in Equation 66 is composed of six terms and the factor PHF, which is again included for experimental purposes to allow introducing test changes into the equation.

PHM. K=CPHAMSK) CPHLMK) CPHPM.K) CPHTMK) CPHEMAK> CPHGMeK? = 664A (PHF)

PHF=1 664,06

PHM = = PREMIUM-H@USING MULTIPLIER COIMENSIBNLESS)

PHAM =~ PREM] UM-HOUSING-ADEQUACY MULTIPLIER Oi MENSI@NLESS)

PHLM = PREMIUMHOUSING LAND MULTIPLIER COEMENS 1 BNLESS)

PHPM ~ PREM UM-HGUSENG POPULATION MULTIPLIER CDI MENS FBNLESS)

PHIM = PREMIUM+@USING TAX MULTIPLIER COIMENS HONLESS)

PHEM = PREMIUM-HOUSING ENTERPRISE MULTIPLER CDIMENSIZNLESS)

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PHGM = PREM(UM-HOUS{ NG-SROWTH MULTIPLIER COI MENSIGNLESS) PHF = PREMIUM-HBUSING FACTAR DIMENSIONLESS)

The Premium-housing-adequacy multiplier as defined in Equation 67 and shown in Figure A-31 is one of two strong influences on the construction Tate. The adequacy multiplier has a value of 1 when the manager /housing ratio is

; Eq6rt iy hh. = I i ep 3. zd? 4 z" iy nm i H 0 3 1 us 2 MER~Manager /housing ratio Figure A-3%

at its normal value of 1. As MEIR fails, indicating fewer managers th: i 3 5 an housin, the construction rate falls tapidly because of lack of need, On the other hand,

as the managerial population exceeds availabl i j i le housing, there is increase the rate of construction. e Pressure to

PHAMSK=TABLECPHAHT,MHR.K,0,2, .25) 67,4 PHAMT=0/.001/ «017 42/1/3/4.6/56/6 6Te15T

PHAM = PREMIUM-HBUSING-ADEQUACY MULTIPLIER COIMENS FGNLESS)

PHAMT - PREMI UM+H@USING-ADEQUACY MULTIPLIER TABLE

MIR - MANAGER/HBUSING RATIO COI MENSIGNLESS)

The land multiplier in Equation 68 and Figure A-32 illustrates the influence of land availability on the construction flows within the model. At very low levels of land occupancy, the area has not yet shown economic importance and the nearly empty land tends to discourage aggressive construction. As land occupancy increases toward the middle region, the rising multiplier indicates economic excitement and potential. Also, all of the common urban activities and services are now present to support further expansion. But as the area approaches the fully occupied condition, the more favorable construction sites have already been used. The less and less attractive locations begin to depress the tendency to build

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o 2 I Tod PUTT q 1 4 2HLMT 4 Z 5 i I Bq. 68.1 I i $4 a zy

0 2 4 4 r) 10

LFO-Land fraction occupied Figure 4.32

until the absolute unavailability of land drives the construction rate to 0 at full land occupancy.

PHLM.K =TABHLCPHLMT,LFO sk y051,01? 68,4 PALMTS64/.9/145/1 5 6/468/109/108/ 1064/4 7/02/0 6841,T

PHLM = PREKIUM-HOUSING LAND MULTIPLIER CDi MENSI@NLESS) PHLMT = PREWIUM-HBUSING-LAND-MULT!PLIER TABLE ~ LAND FRACTION BCCUPLED (DIMENSIONLESS)

As the land fills, the changing values of the land multipliers begin to suppress the growth of industrial and housing structures in the original land area and to set the stage for the other variables to interact into the Stagnation phase.

Equation 69 generates the land fraction occupied as the sum of the land used for housing plus the land used for productive units divided by the land area.

LFO.K=CHUT.KALPHAPUT.KLPP) /AREA, BA

LPHE.4 21,0

LPP=.2 62,0 AREA=100000 3,0

FO == LAND FRACTION OCCUPIED CDEMENS IONLESS)

HUT = HBUSING UNITS ITAL CHBUSING UNI i)

LPH = LAND PER HOUSE CACRESAi2US) NG UID

PUT = PREDUCTIVE UNITS TOTAL CPREDUCTEVE UNI TS) LPP» LAND PER PRODUCTION UNIT (ACRES PRODUCTION

WID AREA = LAND AREA CACRES)

Equation 70 totals the number of housing units in the system. Equation 71 tolals the productive units. HUT.K2PH KWH K+ UH aK 70,4

HUT = HOUSING UNITS THTAL CHOUSING UNITS) PH ~ PREMIUM HOUSING CHBUSING UNITS)

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WH > WORKER HOUSING (HOUSING 1 Ts vi ~ WDERENPLOYED HaUSING Cus a UNLTS>

PUTAKSNEKMBGK+OT 6K TAA

PUT = PRODUCTIVE UNITS TBTAL (PRODUCTIVE uN

NE ~ NEW ENTERPRISE (PRODUCT VE_UNI 75) ms MB» MATURE BUSINESS CPROOUCTI VE UNI TS)

o ~ DECLINING INDUSTRY CPRODUCTI VE UNI Ts

In Equation 72 the Premium-housing population multiplier ilustrated in Fi, A-33 reflects the social composition of the city, Tt tends to depress premivan.

2 Ooo Trey

Hi Pang Aaa: E H is: = 3 al z % 02 cy 06 Fy a MPR— Manager /poputation ratio

Figure 4.33

housing construction if the city is heavily oriented toward labor and under- mployed groups, Under such circumstances the city becomes a less desirable Place for construction of premium housing.

PHPMAK =TABHLCPHPMT sMPR.K 505615 402) 725A PHPMT263/67/1/162/163/163 e447

PHPM = PREMIUMH@USING POPULATION MULTIPLIER COIMENSIGNLESS)

PHPMT = PREME UN-HOUS! NG-PAPULATIGN=MULTI PLIER TABLE

WPR = MANAGER/POPULATION RATIO COIMENSISNLESS)

Equation 73 in Figure A-34 shows the depressing effects of a high tax rate on premium-housing construction.

PHTMAK =TABHLCPHTMT, 1.454 LOGNC TREK) 4925452) TBA PHIMTS142/1/07/05 B.1,T PRIM = PREM UM-HOUSING TAX MULTIPLIER

OI WENSI@NLESS) PRIME = PREMI UM+HO US ING=TAX-MULTIPLIER TABLE = TAX RATIO. COIMENSIGNLESS)

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gM Tor

& FHTMT

3 iz Eq. 73.4

a, =

i tl

2 BA

Z mS

i 3

1

E

aR Gs 5 t 2) $ 6 1002 (18) -2 "1 ° 1 z 3 4

TR-Tax ratio Figure A-34

The premium-housing enterprise multiplier PHEM in Equation 74 aad Figure 4-35 provides a speculative or momentum factor which increases premium-hous- ing construction if there has been a recent history of above-average growth in

> COT

PHEM—Premium housing enterprise noultiplier At

n 5 o co 7 as NEGR~New enterprise growth rate

Figure 4-35 i i terprise tends to encour- new enterprise. In other words, establishment of new en! pri 1 age construction of new premium housing for the managerial-professional class associated with the industrial expansion. PHEM.K=TABHLC PHEMTJNEGR cK yo 1y +155 005) ThyA

PHEMT=42/46/1/1 64/1 08/242 That T PHEM ~ PREMIUM-HOUSING ENTERPRISE MULTEPLER

OI MENS! BNLESS) PHEMT = PREM UBCHBUST NEENTERPRS SZ-MULT] PLIER TABLE

NEGR = NEW-ENTERPRISE GROWTH RATE CFRACTISN/Y EAR)

3 Lit

PHGMT Eq. 75.1

PHOM~Pretaium housing growth multiplier \

° 25 PHOR— Premium housing growth rate Figare A-36

Also, the momentum of recent construction in premium housing itself tends to carry forward and cause still more premium-housing construction, Equation 75 and Figure A-36 provide a link in what is essentially a positive-feedback loop from premium housing through growth rate and back into Premium-housing construction.

PHEM.K: STABHLCPHGMT ,PHGR.K y=. 49015, 605) TS,h PHOMT=42/.6/1/1.4/ 168/202 T5e15T PHGM = PREM! UN-HOUS! NG-GROWTH MULTIPLIER

COIMENSI @NLESS) PHGMT ~ PREM UM-HBUST NG~GROWTH-MULTIPLIER TABLE PHGR = PREMIUMHGUSING GROWTH RATE CFRACTIGNAYVEAR)

number of housing units constructed per year, and then dividing by premium housing to convert to a fractional growth rate. The formulation might also have been made by averaging PHC from Equation 64 and dividing by premium housing.

PHGR.K=CPHK"PHA.KD /CPHAKAPHAT) T6,A

PHGR - PREMIUMHGUS!NG GROWTH RATE CERACTION/Y EAR) PH = PREMIUM HOUSING (HOUSING UNI TS)

PHA = PREMIUMH@USING AVERAGE CHBUSING UNI Ts) PHAT = PREMIUM-HBUSING AVERAGING TIME CYEARS)

Equation 77 is a first-order exponential smoothing or averaging equation which generates the delayed version of premium housing needed in Equation 76, The initial value of PHA is computed so that it will generate an initial premium-hous- ing growth rate of 3% per year.

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PHASK=PHA, JHCDI/PHAT (PH ed -PHALJ) TI yL

PHA=PH=(PHERID <PHAD (PH) TT.1,N PHAT=10 77.2 6 PHERI=.03 TT3,C

PHA = PREMEUM-HBUSING AVERAGE (HOUSING UNITS)

PHAT = PREMIUM-HOUSING AVERAGING TIME CYEARS)

PH = PREMIUM HOUSING CHSUSING UNITS)

PHGRE = PREMIUM-HOUSING GROWTH RATE (NITIAL CFRACTIBN/Y EAR)

The level Equation 78 accumulates the amount of premium housing by adding construction and subtracting obsolescence.

PH.K=PH «JC OT) (PHC, K "PHO JK) TS yb PH=5000 T8s15N

PR = PREMIUM HOUSENG (HOUSING UNITS?

PHC «= PREMIUM-HOUSING CONSTRUCTION CHOUSTNG UNETS/Y EAR)

PHS == PREMIUM-HOUSING BBSOLESCENCE CH@USI NG UNI TS/Y EAR)

Premium-housing obsolescence is defined in Equation 79 as having a normal value of 3% per year. This means that premium housing is taken to have the reciprocal of .03, or 33 years of normal active life in the premium category. But the multiplier PHOM can modify this average age depending on the demand for housing. In periods of high demand, housing will be maintained and will continue to be occupied by the managerial-professional group beyond its normal life. As the managerial group decreases relative to housing and housing becomes excessive, the housing drifts more rapidly into the worker-housing category.

PH 6KL=CPHON) (PH .K) (PHEMeK) 79,R i PHEN=.03, Ae PH = PREMIUM-HOUSING @BSBLESCENCE CHOUSING UNL TSAVEARD

PHON = PREMIUM-HOUSING @BSBLESCENCE NORMAL CFRACTIBN/Y EAR)

PH = PREMIUM HOUSING CHEUSING UNE TS?

PHOM ~ PREMIUM-H@USING-@BSBLESCENCE MULTIPLIER

COLMENS ANLESS),

The premium-housing-obsolescence multiplier in Equation 80 and Figure A-37 is derived from the premium-housing multiplier PHM. To the right, as the urgency of new premium-housing construction increases, the obsolescence rate declines and the average life of premium housing increases. At the extreme left the

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8 Nana ey

g

PHOM—Premium housia obsolescence multiplice

al PRM 1S as 3 1 2 LOG 2 PHM) -3 2 a 0 1

PHM-—Premium housing multiplc Figure A-37

obsolescence rate can climb to almost three times normal, indicating an average

life of about ten years under some imagi i i ; i iginary extreme circumstances where there 18 no managerial-professional population to occupy the dwellings,

PHOM«K STABHLCPHOMT, 1.44 LOGNCPHM.K) 9739397) BO yA PHOMT=2.68/2.66/2/1/ 65/05/02 80.1,7

PHOM ~~ PREMi UM-HOUS! NG~2BSBLESCENCE CDEMENSIBNLESS) MOLTIPLIER PHOMT = PREM! UM-HGUSI NG-@ BSAL ESCENCE=MULTI PLIER

TABLE PHM ~ PREMIUM+IQUSING MULTIPLIER COL MENS I@NLESS)

AS Worker-Housing Sector

Construction of worker housing in Figure A-38 depends on a group of factors equivalent to those explained in relation to premium housing. mone

The level of worker housing is given by Equation 81, which accumulates housing becoming available from premium-housing obsolescence, worker housing being constructed, and outflow of worker housing through obsolescence.

WEAK HH. SECO) (PHB A JKEWHCs IK WH 0K) BIg Wi=21000 8161,N

WH ~ WRKER HOUSING CHBUSENG UNITS) PHO = PREMIUM-HBUSING BBSBLESCENCE CHOUSING UNI TS/Y EAR) wHe = EKER HOUSING CONSTRUCTION CHBUSING UNI TS/

WHE = WORKER HOUSING QBSBLESCENCE CHOUSUNG UNI TS/ Labor construction ratio wae 138, AD-————~>}

ocr, e Worker housing

construction 59

LHR, 48, A oe] HUT, 70,4 -_ HAY, 129, A

Equation 82, like Equation 64, gives the construction rate in terms of the

desired, multiplied by a factor that depends on construction

construction rate labor availability.

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WHC. KL=CWHCD.K) CLOR AK)

G2 yR

wie - MORKER HOUSING CONSTRUCTIBN CHOUSING UNI TS/ WH y HO, 75, Rp ; WICD ~ WARKER-HOUSING CaNSTRUCTION DESIRED Fremiam hooting 'Worker bousing CHOUSING UI TS/Y EAR) bsolescence at LCR - LABOR CONSTRUCTION RATIO CONMENSI@NLESS) po Desired worker-housing construction in Equation 83 is a normal 3% per year maf multiplied by the worker-i using multiplier WHM, plus any external program rene of worker-housing construction. f L Ni WHCD .K SCWHCND CHE AK) CWHMSKD-4HHCPSK 854A WICNZ.03 8341,0 wico

WHEN

WH wm WHCP

~ WORKER-HOUSING CONSTRUCTION DESIRED HOUSING UNI TS/Y EAR)

~ WARKER-HOUSING CONSTRUCTION NORMAL CFRACTIBN/Y EAR)

~ WORKER HOUSING CHoUSING UNTTS)

> WORKER-HOUSI NG MULTIPLIER CBIMENSF@NLESS>

~ WORKER-HGUSING=CONSTRUCTION PROGRAM

CHOUSING UNF TS/YEARD

The worker-housing multipliers reflect the influence of the city system on worker-housing construction and are combined in Equation 84.

TA ECO ANAK CWHUA.K) CWHUMAK) CWH TMK) CWHEMSKD: CHHEMLK) 8A

WHFST 84.1,0

WH = WORKERHBUSING MULTIPLIER COIMENSISNLESS)

WHAM ~ ORKER-HOUSING-ADEQUACY MULTIPLIER CDI MENSIGNLESS)

WHLM ~~ WORKERHBUSTNG LAND MULTIPLIER COIMENSI @NLESS)

WHUM - WORKER-HOUSING UNDEREMPLOYED MULTIPLIER CO) MENSI@NLESS)

WHIM ~ WORKER-HBUSING TAX MULTIPLIER COEMENSIONL ESS?

WHEM — WORKER-HBUSING ENTERPRISE MuL.TI PLIER

. DIMENSIONLESS)

WHEM - WORKER-HBUSING-GROWTH MULTIPLIER COIMENSI@NLESS)

WHE = WORKER-HOUSING FACTOR (DI MENS IGNLESS)

\ Tei, 43,4) / Labor/housing ratio /

N. "S@NEOR, 109, A) 'New enterprise growth rate

The worker-housing-adequacy multiplier in Equation 85 and Figure A-39 shows the strong influence of housing shortage to the right, and housing excess to the left, on the worker-housing-construction rate.

"OTR, 122, A) Tax ratio

Figure A-38 Worker-housing sector.

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WHAM —Worker housing adequacy multipiier

i alll

* 5 t 1s 2 LHR—Labor/housing ratio Figure A-39 WANK =TABHLCHHAMT ,LHR«K 9092025) 85,A B504,7

WHAMT=0/ 605/.9/463/1/148/264/2 08/3

WHAM = WERKER-HBUS!NG-ADEQUACY MULTIPLIER

OI MENSIGNLESS) WHAMT = WERKER-HUSI NG~ADEQUACY-MULTIPLIER TABLE LHR = LABBRAHBUSING RATIO (DIMENSIONLESS)

The land multiplier of Equation 86 and Figure A-40 operates as explained in connection with Equation 68.

2 : I Li {TTI 2 WHEN iy a fe bs a3i z L3 5 % A 6 cy 10 LFO—Land fraction occupied Figure A-40 WHLM.K=TABHLCWHEMT,LFD Ky 051,01) 865A 86.157

WHLMT = 4/69/165/7 06/4 08/169/108/105/ 67/42 /0

WHLM ~ WERKER-HOUSING LAND MULTIPLIER

CDi MENSI@NLESS) WHLMT ~ WARKER-HOUSING-LANO-MULTIPLIER TABLE LFQ = LAND FRACTION @CCUPIED CO) MENSI@NLESS)

Equation 87, as illustrated in Figure A-41, shows the influence of the social balance of the area on the tendency to construct new housing, When the ratio

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a e mm

ai fear Fy 4 g} i= = innm a) ara EEEEEE

FH, i Coo Torr

t z 3 + LUR-Labor/ underemployed ratio

Figure Ad1

of labor to underemployed falls, the willingness to construct additional housing declines because the area has become blighted, obsolete, and undesirable.

WHUMGK =TABHLCWHUMT,LUR.K 0,5, 1) 875A WHU HBAS 2M B/S Qie1yT WHUM ~ WORKER-HOUSING UNDEREMPLOYED COI MENS FONLESS) WATIPLUER

WHUMT ~ aerate HOUSING -UNDEREMPLOYED-WUL TIPLIER CUR = LABBR/UNDEREMPLAYED RATIC (Or MENSIONLESS)

The tax multiplier in Equation 88 and Fi, ure A-42 provides a di . influence on construction as the tax rate rise" Pp 2 depressing

1s £ i iH 3 i 'MT a MEH Ba, 88.1 Z, = i & = q eS £ =

2 Ni

z 4 — é z i res 1002618) 2 3 H i : ; ' TR—Tax ratio Figure A-42 WH THK STABHLCWHTNT, 148% LOGNC TRAK) 5925452) 88,A WHIMT=1.2/17.7/.3 8841,T

WHTM = WORKER-HOUSING TAX MULTIPLIER COFMENSIGNLESS)

WHTMT = WORKER-HBUSING-TAX-MULTI PLIER TABLE

R = TAX RATIO: CDIMENSIGNLESS)

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»

F

'BY WHEMT

22, cai

#2 "i

a 4

2: oe

E + 4

o oy <r ° ; NEGR-New enterprise growth rate

Figure 4-43

As-with premium housing, an industrial growth factor has been introduced into

the willingness to construct worker housing. Equation 89, as shown in Figure A-43, relates new-enterprise growth rates to the worker-housing multiplier.

89,4 896157

WHEM. K= TABHLCWHEMT ,NEGR aK p~o2 5 055 01) WHENT=.3/6 7/1/1621 03/104

WHEM = WORKER-HOUSING ENTERPRISE MULTI PLIER CDEMENSI@NLESS) t 7 "HO USING-ENTERPRISE-MULTIPLIER TABLI war ~ TOR ENTERPRISE GROWTH RATE CFRACTION/YEARD

Equation 90, as diagramed in Figure A-44, provides the momentum factor a ing i ing. A history of successful housin, ker housing on construction of worker housing. : s construction, Sod the building industry organized to provide the construction, tends to maintain the construction rate.

y TH WHGMT Bq. 901 aa3 be #3 ma 86 me % ik. : imi on "aS o 05 a as " WHGR— Worker housing growth rate Figure A4S 048 HGH, K STABHLCHHGHT, WHGR.K y= 15 «15s 605) 90, 90.1,7

WHGMT=.2/.6/17 1464/1872 02

WHGM = WORKER-HOUSING-GROWTH MULTIPLIER COIMENS 1 ONL ESS)

/-

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WHGMT = WARKER-HBUS I NG-GROWTH<MULTIPLIER TABLE WHER ~ WARKER-HBUSING GROWTH RATE CFRACTIGN/YEAR)

Equations 91 and 92 calculate the worker-housing growth rate through the same Procedure used in Equations 76 and 77.

WHGR aK =(WH eK <WHASK) /CWH KAWHAT 91A

WHGR = WORKER-HOUSING GROWTH RATE (FRACTION/Y EAR) Lid — WORKER HBUSING CHBUSING UNI TS>

WHA == WORKER-HOUSING AVERAGE CHOUS! NG UNITS) WHAT ~ WORKER-HOUSING AVERAGING TIME CYEARS)

WHAKEWHA, JECOT/WHATD (HH J —HHA oJ) D2 yh WHAZWH~CWHGR I) CHAT) CWH) Seth WAT=10 920240

WIGRI=.03 92.5,0

WHA ~ WORKER-HOUSING AVERAGE CHOUSING UNITS)

WHAT ~ WORKER-HBUSING AVERAGING TIME CYEARS)

wh ~ WORKER HOUSING HOUSING UNITS)

WHGRI ~ WORKER-HOUSING GROWTH RATE UNETEAL CFRACTIN/Y EAR)

Worker-housing obsolescence in Equation 93 is taken as having a normal value of 2% per year, implying that housing remains in this category 50 years, WHE .KL=CWHOND CWHeK) CWHOM.K) 93,R WHON=.02 936150 WHS = WOE HOUSING @BSBLESCENCE CHOUSING UNI TS/ YEAR) WHON - WORKER-HOUSING GBSOLESCENCE NORMAL CFRACTIBN/Y EAR? asl = WORKER HOUSING (HOUSING UNITS)

WHOM) ~ WORKER-HOUSING-OBS@LESCENCE MULTIPLIER COIMENSIGNLESS)

The obsolescence multiplier in Equation 94 and Figure A-45 modifies the lifetime of worker housing depending on the need for such housing as indicated

WHOM.K =TABHL CWHOMT 91.485 LBGNCWHMSK) p33 7) 94h WHOMT=262/2/106/1/ 67/05/04 Pe TgE WHOM - WORKER-HOUSI NG-OBSOLESCENCE MULTIPLIER COIMENSIBNLESS) WHOMT ~ WORKER HOUSI NG~DESBLESCENCE-MULTIPLI ai

WHM — - WRKER-HBUSING MULTIPLIER (DIMENSI@NLESS)

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x LO im Eco 2 4.1 i peaen= a ve 4 z Hu : ry i WHM 125 B 5 Y z 4 . 1002 CHEM -3 2 a 9 1 2 3 WHM— Worker housing multiplier

Figure A4S

by the worker-housing multiplier WHM. A higher value of WHM leads to a lower obsolescence rate and a correspondingly longer life and vice versa.

A6 Underemployed-Housing Sector

Figure A-46 shows the flows associated with underemployed housing. Obsoles- cent worker housing, as well as construction resulting from an externally generated low-cost-housing program, enters the underemployed-housing category. The underemployed housing disappears from the system through demolition.

The amount of underemployed housing is accumulated in level Equation 95.

The sium-housing-demolition rate in Equation 96 is specified as 2% per year

UHK UH, JRC OD CHHBs K-SHDIKHLCHP ed K? 95 _L

uiz1100 95198

UH UNDEREMPLOYED HOUSING CHBUSHNG UNITS?

WHO — WORKER-HBUSING BBSBLESCENCE CHBUSING UNI TS/

YEAR)

SHD = SLUM-HBUSING DEMBLI TION CHBUSING UNLTS/ YEAR)

LCHP = LOW-CBST-HBUSING PROGRAM (HOUSING UNTTS/ YEAR)

SD. KLE (SHDN) CUH«K) (SHDM.K)-+SHDP oK 964R SHENZ,02 960190 SHD = SLUM+HBUSING DEMBLITICN HOUSING UNI TS/ YEAR) SHON - SLUMHOUSING DEMOLITION NORMAL CFRACTION/ YEAR) H = UNDEREMPLOYED HOUSING CHBUSING 'UNE TS) SHOM = SLUM-H@USING-DEMBLI TION MULTHPLIER: COIMENSTENLESS)

SHOP + SLUM-HOUSING~DEMBLI TION PROGRAM CHBUSE NG UNL TS/YEARD

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(UHPR, 12, A) Low cost housing » construction desired GCHCD, 150, A Dm} LcHe

(LCR, 138, Aponmal LO¥-co8 Bousng

Labor construcdon [e149

ratio

UH GVHO, 93, Rpm] Underempl i Worker housing ployed Rowsing - obsolescence i ae SHDN Shon si it mn hosing URR, 6 A it tion, norms HUT, 70, A if HAY, 123, A 1 \ SHDP, 144, A 1 \ 1 ! ""@SHDP, 144, A) i I H / — Stambousing = \ f demolition factor (UHR, 6, AD'~ Underemployed/ housing ratio

Figore 4-46 Underemployed-housing sector.

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of the underemployed housing, meaning a 50-year life in this category. A muiti- plier introduces the effects of occupancy and pressures on land. The addition of the term SHDP provides for an externaily introduced slum-housing-demolition program.

The sium-housing-demolition multiplier in Equation 97 contains the two active vatiables and an experimental factor that can be changed to explore the behavior

of the system.

'SHOM.K=(SHAM.K) CSHLMK) (SHOP) 9T,A

SHOF=1 97.1,0 SHDM ~ SLUM-HOUSING-DEMBLI TION MULTIPLIER «DI MENSIBNLESS) SHAM = SLUM-HOUSING-ABANDBNED MULTIPLIER CDi MENS IBNLESS) SHUM = SLUN-HOUSING LAND MULTIPLIER OI MENS IBNLESS) SHDF = SLUM-HOUSING-DEMALI TION FACTOR (CDI MENS 1@NL ESS)

Equation 98 and Figure A-47 show the effect of occupancy on the demolition tate. The demolition rate is normal when the ratio of underemployed to housing

SHAM.K =TABLECSHAMT ,UHR.K 052,65) 984A

SHAMT=3, 6/2/17 06/08 9841,T

SHAM) = SLUN-HOUSING-ABANDONED MULTIPLIER

CDIMENSI@NLESS) SHAMT ~ SLUM-HOUS{NG-ABANOSNED-MULTIPLIER TABLE UHR = UNDEREMPLOYED/HBUSING RATIC COIMENSI@NLESS)

4 iam . 'SHAMT £ Bq. 98.1 g ao i j 2 E an = E =

°

0 $ 1 ts 'UBR-Underemployed / housing ratio

Figure A-47

is 1. Deterioration and the demolition i i - ' 4 fate rise rapidly as oc decline (meaning longer housing life) when. occupancy, is above nora and

occupied and demolition rate. In the occupancy interval from .8 to .95, demolition

rises gradually, indicating the tendency to tear do ildi ily, wn old buildings fc as the remaining land area becomes less suitable. The rapid ise inthe net

Cy

imam SHLMT Eq. 98.4 { t

SHLM—~ Slum housing land multiptier

i i és rt

7

w

2 3 io LEO—Land ftaction occupied

Figure 4-48

as the land fraction occupied reaches 1 is to iti

' i couple the demolition and construc- fon under any circumstances where a massive forced construction program, might ' ve land occupancy up to and possibly beyond full occupancy. In other words, i construction is to take place in this region, demolition must occur. ,

SHLM.K=TABHLCSHUNT,LFQ.K, 68, 15 005) 99,0 D SHLMT=1/1.2/1.6/2 2/6 996157 ody SHLH = SLUMSHBUSING LAND MULTI t CDIMENSIBNLESS) meuER

SHUMT = SLUM-HBUS FNG=, AND-MULTIPLIER TABLE LFS» LAND FRACTION SCCUPIEO COIMENSIONL ESS)

A.7 New-Enterprise Sector

The new-enterprise sector in Figure A-49 j imil i housing secon igue AsO, iB 9 is very similar to the premium-

NE.KENE, JHC DT) (NEC. K-NED. JK) F005 Ns NE=200 100.4,N NE ~ NOW ENTERPRISE (PRODUCTIVE UNITS)

NEC = NEW-ENTERPRISE CONSTR IM TSPEGRS UCTION CPROOUCTIVE

NED = NEW-ENTERPRISE DECLINE PI YEAR PRODUCTIVE UNITS MI, 32, A

PUT, 71, A

anol BAY, 130, 4 a LDI. 132, A

NE New enterprise 100 7 H J N, CR, 138, AD—=————0) BE f N, Labor construction ratio 7 / New eaterptise \ 'construction, normal \ i / NECN \ LDC, 131, A) I > « Q aa tof New enterprise average I I f 1

bosin %, New enterprise 10 1 Mature buns rerprie @ ! NECEF + 4 I MBCF H } ee = i \ } ~~. __" _ \ ; ~~ _ wear I Ni \ ; if .. Newenterprise I AM 3 LO "ONECE, 145, 4) averagingtime "I / ew ente construction program Oh, 116, LA / \ main 'Declining industry fo \ 'New enterprise Dee growth rate Desinng adanty \ EDM, 112, A construction facter =, --e} BDM, 115, 4 9 X77 I pie 18, A V7 4 \ PHEM, 74, A \WHEM, 89, A, "QTR, 122, Ay

Tax ratio Enterprise labor! job multiplier' 106

(LFO, 69, AD" Land fraction occupied

S@LRP, 139, 1) . Laborfjob ratio, perceived

Figure A-49 New-enterprise sector.

nin

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The accumulation Equation 100.

New-enterprise construction in Equation 101 is simi Desired construction is modified by

of net construction minus decline is generated by the level

iar in form to Equation 64, labor availability,

NEC. L=CNECD.K)CLOR.KD 101,R NEC = NEW-ENTERPRISE CONSTRUCTION cPRepucT VE UNI TSWV EAR)

NECD = NEW-ENTERPRI SE CONSTRUCTION BES! RED CPREDUCTIVE UNI TS/YE,

~ LABOR cansTRUCTIaN RATIO (Oi MENSHONLESS)

New-enterprise construction desired NECD is taken as 5% per year of a

weighted combination of the different business categories. New enterprise has a weighting factor of one, meaning that a unit of new enterprise is most likely

to form another new unit. Mature business has a weighting factor of .5 and

declining industry 3. Quite Possibly the latter coefficient is too high because it does not appear that declining industry is often a source of new business creation,

NECD.K=CNECHD CHECPANE. K+MBCF: 'MB K+D1 CF DI 4K): CEM Ke NECP AK

102,A NECF 27 102.1,6 MBCF=.5 102..2,6 diers.3 102,3,¢ NECN=.05 102.40 NECD ~ NEW-ENTERPRISE CaNSTRUCTION DESIRED PRODUCTIVE WITISAVE AR? NECN - NEW-ENTERPRISE CONSTRUCTION NORMAL CFRACTION/Y EAR) NECF - NEW-ENTERPRISE-CONS TRUCTION Factor COIMEHSIBNLESS) NE 7 NEW ENTERPRISE cPRepuCTIVE UNITS) WOCF ~ NATURE-BUSINESS-CONSTRUCTIGN FACTOR <DIMENSIGNL ESS) NB 7 MATURE BUSINESS cPRODUCTIVE UNE Ts) DIC = DECLINING=1 NOUSTRY-DONS TRUCTION FACTER COFMENSIBNLESS) BI 7 SECLINENG iNDUSTRY coRaouCTi VE UNI Ts) Gu, 7 ENTERPRISE MULTIPLIER cOIMENSLONL EoS> NECP ~ NEW-ENTERPRISE-CONSTRUCTION PROGRAN CPRODUCTIVE UNI TS/YEAR) The enterprise multiplier in Equation 103 is the product of the five component

multipliers and of the system experimental factor EF,

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EK =C EMMoK) CELM6K) CEL JM aK) CETM«K) CEGM.K? CEP 105,54 eF=1 105.1,0

M + ENTERPRISE MULTIPLIER CDI MENSIBNLESS) EMM ~ ENTERPRISE MANAGER/JOB MULTIPLIER CDIMENS iGNLESS) ELM = ENTERPRISE LAND MULTIPLIER COLMENSI@NLESS) ELUM = ENTERPRISE LABBR/J@B MULTIPLIER DIMENSIONLESS) ETM = ENTERPRISE TAX MULTIPLIER CDI MENSI@NLESS) EGM «= ENTERPRISE-GROWTH MULTIPLIER CDEMENSIGNLESS) EF = ENTERPRISE FACTAR (Oi MENSIGNLESS)

Equation 104 in Figure A-SO states that increasing managers in proportion to managerial jobs increases the likelihood of establishing new enterprise. As the

TH 'MMT. Bq, 108.1

EMM-Eoterprise manager xultiplier

$ 5 we 2 MR—Manager/ob sata

Figure A-50

managerial-professional population grows in proportion to the existing needs of the city, more time, skill, and incentive are available to start new activities.

EMMAK STABHLCEMMT, MRK 40925025) TOK A EMMT = 01/6 15/03 /05/1/ To / 10 1/1092 WORT EMM = ENTERPRISE MANAGER/JOB MULTIPLIER CDI MENS I@NLESS)

EwMT = ENTERPRISE MANAGER/JZB MULTIPLIER TABLE mR ~» MANAGER/JZB RATIC CDIMENSI@NLESS)

The land multiplier BLM in Equation 105 and Figure A-51 describes an economic incentive to build as a function of total land area occupied. The con-

ELMAK=TABHLC ELMT LAB «Ky 051pe 1? 105,4 ELMTE1/1615/1 93/1 08/1 o5/108/4 03/14 67/08 /0 105.4, ELM ~ ENTERPRISE LAND MULTIPLIER CDI MENSI@MLESS)

ELMT = ENTERPRISE-LAND-MULTIPLIER TABLE LFG =~ LAND FRACTIGN @CCUPIED (DI MENSIGNLESS>

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CoH

ELMT br = Eg. 105.1

BLM-Enteeprise and multiplier

9 2 4 6 LFO—Land fraction occupied Figure 451

cepts are the same discussed for Equation 68, When land becomes completely occupied, construction must cease unless demolition takes place.

*ET TTT.

ELIMT b Bq.106.1 1

ELIM~Enterprise labor/job multiplier

3

$ T is LRP-~Labor/job ratio, perceived Figure A-S2

_ Equation 106 and Figure A-52 describe the inclination to build new enterprise in terms of the availability of labor. If the labor/job ratio is low, indicating a shortage of labor, new-enterprise construction is depressed. An excess of labor encourages new construction.

EL. JMeK =TABHLC ELUMT gl RPK 40429625) 10654 ELJMESO/ 6057 615/48/1/165/ 10 7/1 08/168 106.1,T ELUM = ENTERPRISE LABOR/JB MULTIPLIER

COIMENSIBNLESS) ELJMT = ENTERPRISE LABGR/JOB MULTIPLIER TABLE LRP = LABOR/JBB RATIB PERCEIVED COIMENSIONLESS)

The tax multiplier in Equation 107 and Figure A-53 is similar in purpose to those discussed earlier but represents a more decisive effect at the high tax end ETMAK=TABHLCETMT, 1. 54%LOGNC TR.K) -2 91) 107,A

ETMT=143/162/1/48/ 05/6257 01 107.1,T ETH = ENTERPRISE TAX MULTIPLIER (01 MENSIONLESS)

ETMT + ENTERPRISE-TAX-MULTIPLIER TABLE TR ~ TAX RATI@ COIMENSI@NLESS?

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15) mmm ETMT a = Eq. 107. 5 i! Ba a 5 as i 2 = & — 0 . 76 TR 2S a a a 4 w0g2aR) 2 A ° ' 2 3 ' 'TR-Tax ratio Figure A-53-

than was assumed for housing. The multiplier declines to where a tax rate of 16 times normal cuts construction by a factor of 10. ; ;

The enterprise-growth multiplier in Equation 108 and Figure A-S4is a specula- tive and momentum factor tending to encourage construction during a period

2 TEE EGMT

2 Bq, 108.1

i cf ae aaa 2 8

ot 5 H 5

° cc NEGR-—New enterprise growth rate Figure A-S4

of active construction and tending to depress construction during a period when obsolescence exceeds new construction.

EGM.K=TABHLC EGMT ,NEGR, 9015, 605) 708A

EGMT= 02/067 1/148/168/202 108.1,7

EGM - ENTERPRISE-GROWTH MULTIPLIER A EARL SESW ULTIPLEER TABLE = ENTERPRISE~GROWTH-Mt AER = NEW-ENTERPRISE GROWTH RATE CFRACTION/YEARD

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The new-enterprise growth rate is computed in Equations 109 and 110 in the same way as discussed for Equations 76 and 77,

NEGR .K =CNE.K -NEA.KD/CNEAKANEAD

1094 NEGR = NEN-ENTERPRISE GROWTH RATE CFRACTIGN/YEARD NE = NEW ENTERPRISE (PRODUCTIVE UN} TS) NEA = NEW-ENTERPRISE AVERAGE (PRODUCTI VE UNITS) NEAT ~ NEW-ENTERPRISE AVERAGENG TIME CYEARS) NEAQK=NEA, JECOT/NEAT) CNESS-NEA SS) 110,L NEAAN E=CNEGRID CHEAT CRED 11004, NEAT=10 1106240 NEGRI =603 110.340 NEA

> NEW-ENTERPRISE AVERAGE CPRBDUCTI VE UNI TS) NEAT = NEW-ENTERPRISE AVERAGING TIME CYEARS) NE ~ NEW ENTERPRISE (PRODUCTIVE UNI TS> NEGRI ~ NEW-ENTERPRISE GROWTH RATE ENE TIAL CFRACTION/Y EAR)

A8& Mature-Business Sector Figure A-55 illustrates the structure surrounding the mature-business level. New-enterprise decline in Equation i11 represents the aging of new enterprise into mature business. The normal value of .08 per year implies an average life

of 12 years in the new-enterprise category. This is modified by the enterprise- decline multiplier.

NEO.KL=(NEDN) CNE.K) CEOMGK?, 'NEON=.08 NEO =

FAR 44401,C NEW-ENTERPRISE DECLINE CPRADUCTIVE UNI TS/

NEON = serene se DECLINE NORMAL CFRACTIGN/

NE = NEW ENTERPRISE (PRODUCTIVE UNI TS)

EOM = ENTERPRISE*DECLINE MULTIPLIER COIMENSTONLESS)

'The enterprise-decline muitiplier in Equation 112 and Figure A-56 adjusts the decline rate of new enterprise in response to the enterprise multiplier EM. When

EOM.K =TABHLCEDMT, 1.444 LAGNC EMsK) 4-343, 1) 11244 EDMT=2/148/165/1/. 7765/5

0M «= ENTERPRISE-DECLENE MULTIPLIER CDIMENSI@NLESS)

EOMT = ENTERPRISE-DECLENE=MULTIPLIER TABLE

EM ~ ENTERPRISE MULTIPLIER COI MENST@NLESS)

W261)T

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DI, 16, L) Declining industry

114

'Mature business

decline

MBD

~. a

~oa@ eM, 103, 4-7 Eauerpise multiplier Figure ASS Mature-business sector.

appa iam

& eS EDMT

Fi mS Bq. 2d

u H

as H

a sts ca 3 A i H 2 1002 EM) -3 2 "EM~Eaterprise multiplier Figure 4.56

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there is active demand for new enterprise, it is assumed that the existing new

enterprise will retain its vitality for a longer period than when there is no incentive for new construction.

Equation 113 accumulates the level of mature business, taking in the decline

from new enterprise and giving up mature-business decline into the category of declining industry.

MB .K=HB.JECOD (NED. KHBD.IKD MB=1000

113 9b

115.158

MB ~ MATURE BUSINESS. <PRBDUCTIVE UNITS) NED - NEW-ENTERPRISE OECLINE CPREOUCTIVE unt Sf YEAR)

48D = MATURE-Busi Ness DECLINE CPRBDUCTIVE UI Tsv YEAR

The initial value of 1,000 mature-business units in Equation 113.1 is selected, along with initial conditions of the other levels, to get a reasonably balanced

MBD.KL=(NBDN) CHB.) BOM.K) Tay

MBBN=.05 TMI QC

NBD = WATURE-BUSINESS DECLINE CPRADUCTI VE WITS? YEAR)

WBON - MATURE-BUSI NESS DECLINE NORMAL FRACTIONS YEAR)

MB = MATURE BUSINESS <PROGUCTI VE UNE 1S) BOM == BUSINESS-DECLINE MULTI PLEER CORMENS ONL ESS)

Life in the mature-business category is varied in Equation 115 and Figure A-57 depending on the enterprise multiplier EM. This is done on the basis that an

[TTT ie /} "apm 4 mi + Eg.115.1 1 u H Pam an BA 7 a sal i ex as 3 7 2 « & 1002 EM) -3 2 4 2 3

° EM~Enterprise multiplier Figure A-57

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economy very much in need of new enterprise will retain the vitality of existing business longer than one in a state of deterioration.

BON. K =TABHLC BOMT 1 44k LO GHC M&K) 93551) 11S, BOMT=2/1.68/145/1/ 1/09/04 115.1,7

BOM = BUSINESS-DECLINE MULTIPLIER <DIMENSIGNLESS) BOMT + BUSINESS-DECLENE-MULTIPLIER TABLE

eM ENTERPRISE MULTIPLIER (DIMENSI@NLESS)

A9 Declining-Industry Sector Figure A-58 shows declining industry and its demolition rate. Equation 116 generates the number of declining-industry productive units by

accumulating the difference between mature-business decline and declining- industry demolition.

DI K=O} JC DTD CMBD. K-Di Ds dK) 116,b Ot =100 11604,N ot ~ DECLINING INDUSTRY (PRODUCTIVE UNITS? MBO ~ WATURE-BUSINESS DECLINE (PRODUCTIVE UNI TS/ YEAR) DIO = DECLINING-INDUSTRY DEM@LITION CPROBUCTIVE UNE TS/Y EAR)

'he declining-industry demolition rate DID in Equation 117 has a normal value representing a 33-year life in this category, modulated by a multiplier representing, the influence of the demand for new enterprise and the influence of land shortage. The added factor DIDP allows for an externally determined declining-industry- demolition program.

DID.KL=C D1 OND COT &K) COE DMeK)+01 OP 6K F17R 'D1 ON=,03 T4761,0

DIO = DECLINING-INDUSTRY DEMILITI@N CPRBDUCTI VE UNI TS/YEAR

DIDN ~* DECLENING-INOUSTRY DEMALITHON NORMAL CFRACTION/Y EAR?

o = DECLINING ENDUSTRY (PRODUCTIVE UNITS)

DIOM = DECLINING={ NOUS TRY-DEMBLI TION MULTIPLIER COEMENSI @NLESS)

DIOP = DECLENING=1 NOUS TRY-DEMBLI TION PROGRAM CPRODUCTI VE UNI TSW EAR?

The declining-industry multiplier contains the two active variables and an experimental factor.

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MJ, 33, A, PUT, 71, A _omI NECD, 102, A y BAY, 130, A UDI, 132, 4 DIDE, 14, 4 DI (MBD, 124, Renee] . Mature business decline Pectining industry H6 < '. I+---~—-@DIDP, 146, A) Declining industry demolition program iN } \ I / NS Declining ind / DIDN demolition 'new. / Piainine industry DIDE femefition, normal

"DILM (DILMT) Declining industry

Tand multiptier

(EM, 103, AO-7" ~S@LF0, 69,4 Enterprise multiplier Land clin creupied

Figure ASB Declining-industry sector.

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OL OM.K =(DI EM4K) €DELM«K) COL DF? 118,4 O1DF=1 118.1,€

DLDM = DECLINING=INDUSTRY-DEMBLITIGN MULTIPLIER COEMENS IBNLESS)

DIEM ~ CECLINSNG~INDUSTRY ENTERPRISE MULTIPLIER COI MENS BNL ESS)

DILM = DECLINING-INDUSTRY LANO MULTIPLIER COI MENS IBNLESS)

OLOF = DECLINING=(NOUSTRY-DEMBLI TION FACTOR CDI MENS T@NLESS)

In Equation 119 and Figure A-59 the assumed effect of demand for new enterprise on declining-industry demolition is given. This assumes that the more active the new-enterprise-construction rate, the higher will be the declining-indus-

DIEM Declining industry enterprise multiplier

° eM Jas as 3 : H $ 3

3 2 4 ; 1062 EM) EM-Enterise muliptict

Figure 4.59

i ise that is con- demolition rate. This presumes that much of the new enterprise stnucted will be on the geographical site of old enterprise that has reached the end of its effective life.

DY EM.K=TABLEC Dt EMT 1 oAAKLOGNC EM6K) 9-555 1) 119A DIEMT=649/45/07/1/1.6/2 04/4 ADTs OEM = DECLINENG-1 woUsTRY ENTERPRISE MULTIPLIER DEEMT + OROLININS INDUSTRY -ENTERPRISE*MULTIPLIER TA

BLE EM = ENTERPRISE MULTIPLIER CDFMENSI@NLESS)

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i EET 2 rt eibon I 240 Bo Vi p = fe I z Em Cert t a ° 3 v0 LFO—Land fraction occupied Figure A460

The declining-industry land multiplier in Equation 120 and Figure A-60 is similar to the slum-housing land multiplier in Equation 99. It shows a natural tendency for demolition to increase as land usage becomes more nearly complete, and forced demolition at very high land usage, should land fill up and reach

such a point, Actually, in the computer runs in this book, land occupied has never reached the .95 region.

DILM.K=TABHLC OL LMT, LFB Ky 085 7,205) 120,4 DULMT=1/1.2/1.6/2.2/6 120,7,T

ILM = DECLINING-INDUS TRY LAND MULTEPLIER CDFMENSIBNLESS).

DILMT = DECLINENG-FNOUS TRY-LAND-MULTIPLIER TABLE

AFG - LAND FRACTION OCCUPIED <DIMENSI@NLESS)

A.10 Tax Sector

Figure A-61 shows the relationships used for generating tax collections and the tax ratio which influences mobility and construction, Equation 121 computes the total tax collection per year as the Product of the assessed value multiplied by tax assessment normal TAN in the outside world and multiplied by the ratio Of city to outside tax rate TR.

TCsK=CAV AK) (TAN) CTR&K? 121,4 TAN=50 W211 f

TC = TAX COLLECTIONS COQLLARS/YEARD

AV + ASSESSED VALUE (THOUSAND BZLLARS?

TAN - TAX ASSESSMENT NORMAL COBLLARS/V EAR/ THOUSAND OBLLARS)

R > TAX RATIG COIMENS!@NLESS)

CTPCR, 8, Aye

Te Fax collections J a . , Q S. LATM, 46, 4 MATM, 59, (4 TR \geoorl PHIM, 73 A m WHT™M, §3, 4 TAN TR ETM, 107, A Tax assessment, normal Tax ratio 122 'Tax ratio needed

perception time

TRNP Tax ratio needed,

! I H

i 1 i if 1 i} if i 1 \ Manageriai-professional iT i \ 1 a \ \ 1 a a

famity size "es 'Tax per labor person Tax per \ TLP \ management person \ ye me \ 4 DMP, 52, Ly oe DMP, 52, Tax assessment mA, \ fA 'Managerial-professional es indicated s 125 eee --~ AV aoe Premium housing { asccsced WW. 16, LO-— Lrs assessed value value Cadeempioned . Labor family size PHAV 2 'o 18 New enterprise eet SS assessed value UFS Son, 2 \ } NEAV Underemployed hate Premium housing \ rf — family size \ (PH, 78, Lo, \ { 'Tax per underemployed Vy oy son img LY of ON. --"GNE, 100, L) \ we wantar 1 f pity so WHAV fy, Declining \ ee industry assessed > valve ~~aMB, 103, L) TOM Hous Mature business (TeMT) lousing t y Ol, 16, Lo "ax collection a value Declining industry \ multiplier ng ' 127 oF MBAY , ef Saun, 95, 15) Mature business QUR, 26, Agr UHAV \ Underemployed housing assessed value Laborfonderemployed ratio Underemployed \ housing assessed 'own, 81.1) value 8h.

Worker Rousing,

Figure A-61 Tax sector,

—_— a

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TRI L Bg. 122.1

im mn I

TR~Tax ratio 1

Ft ro Cir rane Ss 1 7 * * is 200 2RNP)-2 i ° i 2 3 4 TRNP~Tax ratio needed, perceived

Figure A62

The tax ratio actually assessed is based on the tax ratio which is perceived as needed, as given in Equation 122 and Figure A-62. This relationship Tecognizes that it may not be possible or politically

practical to assess the full amount of

TReK=TABRLCTRT, 1, 48KLOGNC TRNP.KD ,

25h, 1) 122,8 TRIE 05/05/1/108/268/3.6/4 W2615T TR = TAX RATIO COL MENS IZ NL ESS) TRT = TAX-RATIC TASLE

TRNP = TAX RATIO NEEDEO PERCE! VED col MENS! ONLESS).

Equation 123 Tepresents a time delay between the Perception of tax need and the actual need. Here Perceptions mean not only awareness of the need but Political support and voter acceptance of the need. With the 30-year time lag

TRNP K=TRNP. JECOT/TRNPT CTRNeS=TRNP LSD 123, TRNP=TRN W235.7,N TRNPT=30

123.240 TRNP_ ~ TAX RATIO NEEDED PERCEIVED (OL MENSI@NL ESS) TRNPT - TAX-RATIQ"NEEDED PERCEPTION TIME CYEARS> 'TRN + TAX RATIO NEEDED CDI MENS FONL ESS)

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in Equation 123, about a third of the discrepancy between perceived need and actual need will be closed each decade.

In equation 124 the tax ratio needed is com,

puted by dividing the tax assessment indicated by the tax assessment normal.

TRNGK=TAT .K/TAN 124,44

TRH ~ TAX RATI@ NEEDED CDIMENSIGNLESS)

TAL = TAX ASSESSMENT 1NDICATED COBLLARS/Y EAR/ THBUSAND OBLLARS)

TAN = TAX ASSESSMENT NORMAL COBLLARS/V EAR/ THBUSAND DBLLARS)

In Equation 125 the tax assessment indicated is computed as the ratio of the tax needed divided by the assessed value of the property in the city.

TAL KEIN K/AV.K 425,4

TAL = TAX ASSESSMENT INDICATED CDBLLARS/Y EAR/ THBUSAND O21LARS)

W ~ TAXES NEEDED COBLLARS/YE AR) AV ~ ASSESSED VALUE CTH@USANO OBLLARS)

Equation 126 generates taxes needed on a per capita basis, with different assumed needs generated by each population class. For example, the first term is the tax per management person multiplied by the management family size times the number of managers. The tax per management person is taken as $150.00 a year, for a labor person as $200.00, and for an unemployed person as $300.00.

THK =C TMP MPESAMP K+ TL PEL S#L K+ TUPA UFSK U.K) CTCHEK) 126,A

THP=150 126.1,0 TUP=200 126.2,0 'TUP=300 126.3,C

© ~ TAXES NEEDED COOLLARS/YEARD TWP = TAX PER MANAGEMENT PERSON CDBLLARS/PERSON/

YEAR)

MPFS ~ MANAGERIAL-PROFESSIGNAL FAMILY SIZE (PEBPLE/MAN)

NP - MANAGERI AL~PROFESSIGNAL CMEND

TLP = TAX PER LABOR PERSON CDBLLARS/PERSBN/Y EAR)

LFS ~ LABOR FAMILY SIZE CPEBPLE/HAND

t > LABBR CHEN

Tue = TAX PER UNDEREMPLOYED PERSON COBLLARS/ PERSBN/Y EAR)

US INDEREMPLOYED FAMILY SIZE CPEOPLE/MAN)

u UNDEREMPLOYED (MEN)

TCH = TAX-COLLECTIGN MULTIPLIER CO} MENSI@NLESS)

TPETTTT TCMT (7 1 Eq. 127.1

ol i ii [I v 5 tr is z 2s 3 LUR~Labor /anderemployed ratio

Figure 4-63

Equation 127 and Figure A-63 provide a political factor that relates taxes to the labor/underemployed ratio. To the left, as the labor population declines in Ptoportion to the underemployed, the political power moves more and more toward the underemployed group who use tax expenditures but pay less of the tax assessments, and the asserted tax needs of the city rise.

TCM.K=TABHLC TOMT yl UR.K 0,3, 45) 127A

TOMTE2/4.06/105/161/1/ 09/08 W761 57 TOM = TAX@COLLECTION MULTIPLIER (DIMENSIGNLESS)

TOMT - TAX-COLLECTION-MULTIPLIER TABLE

LUR = LABOR/UNDEREMPLOYED RATIC CDIMENSIBNLESS)

Equation 128 is the total assessed valuation of the city as the sum of housing and business.

AV KZ CHAVAKSBAV KD 12ByA ay ~ ASSESSED VALUE (THOUSAND DBLLARS)

HAV ~ HOUSING ASSESSED VALUE (THOUSAND DOLLARS) BAY = BUSINESS ASSESSEO VALUE CTHBUSAND OBLLARS)

Equation 129 computes the total assessed value of housing. Each premium-

housing unit is assessed at $30,000, worker housing at $15,000, and underemployed housing at $5,000.

HAV K =PHAVEPHSIG-WHAVAWH JKEUHAWEUH K 12944

PHAV=30 W294 4,C WHAVE15 12902,0 UHAV=5: 129.35,

HAV = HBUSING ASSESSED VALUE CTHBUSAND DBLLARS) PHAV — PREMFUN-HBUSING ASSESSED VALUE (THOUSAND QBLLARS/HAUSING WIT

PH ~ PREMIUM HOUSING CHOUSTNG UNITS)

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WHA = WORKER-HOUSI NG ASSESSED VALUE (THOUSAND BBLLARS/HOUSING UNIT)

WH ~ WORKER HOUSING (HOUSING UNI Ts)

Way = UNDEREMPLOY ED-HeUST NG ASSESSED VALUE CTHBUSAND DOLL ARS/HBUSING WIT)

OH ~ UNDEREWPLOYED HOUSING CHOUSING UNITS)

Equation 130 tallies the assessed valuation of business units with a value of

$500,000 'for a hew-enterprise unit, $300,000 for a Mnature-business unit, and $100,000 for a declining-industry unit,

BAV.K "HEAVENE KF MBAVKMB.KEDI AV OI 6K 130,4

NEAY=500 13061,€ MBAV=300 130.2, DiAV=100 130.3,0

SAV ~ BUSINESS ASSESSED VALUE (THOUSAND DOLLARS)

NEAV = NEW-ENTERPRI SE ASSESSED VALUE CTHOUSAND GOLLARS/PRADUCTIVE UID

NE ~ NEW ENTERPRISE CPROOUCTI VE UNL TS?

MBAY = MATURE-BUSI NESS ASSESSED VALUE CTHOUSAND GBLLARS/PRBDUCTI VE UNI TD

MB = MATURE BUSINESS PRODUCTIVE UNI 15)

DIAY = DECLINING=I NOUS TRY ASSESSED VALUE CTHBUSANG DOLLARS/PROQUCTIVE UNI TD

Oo ~ DECLINING INDUSTRY CPRODUCTI VE UNITS)

All Job Sector

Figure 4-64 relates the variables involved in computing the employment ratios and then creating the multiplier which makes construction rates dependent on available labor.

Equation 131 gives the labor desired for construction by multiplying the con-

struction rate per year in each category of housing and enterprise by the labor man-years involved in constructing the unit.

LOC.K=PHCD.K#PHCLHTHCD AMHCL# RECO KENECL#LCHCD.K& BIA LOHCL

PHCLe2 131.7,0

wictet 131.2,¢

NECL=20 131.3,C

LOHCL=.6 BAC

LOC = LABOR BEstRED FAR CONSTRUCTION CMEND

PHCD = PREMI UM-HOUS! NG CONSTRUCTION DESIRED CHBUSING UNI TS/YEARD

PHEL = PREM! UM-HBUSi NG-CONSTRUCTION LABBR CHAN YEARS/HBUSING UNIT)

Undeceimployed/ job ratio

(CRT) Labor construction I ratio H t i LRPT

\ { Laborfob ratio

\ t Perception time i 1

jots 136 . I "spur, 143, 4)

1 Us loyed

I Job program i t f i i / 'Premium housi 'construction desired _-UPHCD, 65, A) Worker housing QE, 100, LOS. housing I New enterprise ~\, nee ~-_F N GCHCD, 150, Age . omer ing Low cost housing "OWHCD, 83, labor industry Tan constriction vt Wotker howsing Sonnet desinea xe DIL desired / 4 _ oa NEC L Seneco, 102, A) N. New enterprise New entetpr " 4 "opi, 16,4 'construction labor desired MB, 113, Lar" Declining industry Mature business

MBL Mature business labor

Figure A-64 Job sector,

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WHCD = WORKER-HBUSING CONSTRUCTION DESIRED CHOUSING UNI TS/YEAR)

WHCL ~ WORKER-HBUSING-CONSTRUCTION LABOR CMAN= YEARS/HOUSING UNI D

NECD NEW~ENTERPRISE CONSTRUCTION DESEREO CPROQUCTIVE UNI TS/YEARY

NECL = NEW-ENTERPRISE=CONS TRUCTION LABGR (MANS YEARS/PRODUCTIVE UNITY

LCHCD ~ LOW-CAS T-HOUSING CONSTRUCTION DESIRED CHOUSING UNI TS/YEAR)

LCHCL = (2it~-COS T-HB USI NG-CBNS TRUCTION LABAR CHARS YEARS/HGUSING UNIT)

The labor desired for industry in Equation 132 totals the normal labor employ- ment for each industry class,

LO} K=NESKANELEMB.KEMBL+ OF KDI L 132,A

NEL=20 13241,C

wBL215, 132.2,¢

OIL=10 132.5,C L0r LABOR DESIRED FOR INDUSTRY CMEND

NE > NEW ENTERPRISE (PRODUCTIVE UNITS)

> NEW-ENTERPRISE LABSR CMEN/PRODUCTI VE UNIT) MB ~ MATURE BUSINESS (PRODUCTIVE UNITS) MBL + MATURE~BUSINESS LABAR CMEN/PRODUC TI YE UNI TY Oo ~ DECLINING FNDUSTRY CPRADUCTI VE UNITS) OL = OECLENL NG-INDUSTRY LABBR (MEN/PRADUCTI VE

Equation 133 adds construction and industry labor desired to give the total available jobs.

LJ eK=LDEK+LOI .K 133,A

Ww ~ LABOR BBS (MEN LOC = LABOR DESIRED FOR CONSTRUCTION CHEN LDL = LABBR DESIRED FOR INDUSTRY CHEW

The labor/job ratio LR is given by Equation 134.

LRKAKAK T3A,A

LR > LABOR/JOB RATI@ COIMENSI@NLESS) L = LAER CMEND Ly = LABBR JBBS (MEN)

Equation 135 and Figure A-65 relate labor jobs and underemployed jobs. When the labor ratio is 1, the table states that there is half a job available for the underemployed for each job in the labor category. If the labor/job ratio is low, more of the available labor jobs become open to the underemployed; as the

I

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q

& vuRT

3 Eq. 135.1

Fa

:

2

is

5

4 ~

Bo

° s 1 13 ER—Labot /job ratio Figure 4-65

labor/job ratio increases, the Jobs for underemployed i i

-ases, ed decline on the assumpti that, under the condition of labor unemployment, the work §0es first to the more skilled labor class, leaving less for the underemployed.

ULUR K=TABHLC UJRTALR«K 5042545) 13544 URTE1615/68/45/425/01 135.1,T

ULUR = UNDEREMPLOYEDA. ABaR JOB RATIO war INOLHENSIONLESS)

- EMPLAYEO/L ABBR JOB"RATIO Tas! aR > LABOR/JBB RATIO Cor MENS INL ESS) Me

__ The actual underemployed jobs are then given by multipiying the total labor jobs by the underemployed /labor job ratio as in Equation 136. The added term UIP provides for an externally generated underemployed-job program.

US eK SL SoU KEUUP CK 136,

Wo + UNDEREMPLaYED vas CMEND

LJ = LABOR JOBS (MEN)

ULUR = UNDEREMPLOYEDAL Age JOB RATIO COLMENSIONL ESS)

WP = INDERENPLOYED~ 8 PRBGRAM (MEN)

The underemployed /job ratio can then be computed in uation 137 as th underemployed divided by available jobs. P ¥a °

URAKEUK AUK 137A (R= ANDEREMPLOYED/O8 RATIB. COIMENSI@NLESS)

u ~ UNDEREMPLYED (MEN WwW ~ WDEREMPLAYED JOBS CMEID

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is [J il LcRT H g 24.1381 i 1 £ 5 j Ho rt 4 i or im 0 5 T 1s 2 LR—Labor/job ratio Figure A66

Equation 138 and Figure A-66 express the influence of available labor on housing and enterprise construction. When the labor/job ratio is 1, 90% of desired construction is possible. As labor falls in relation to job Openings, labor is shared by construction and industry, with a Proportionate decrease in the fraction of desired construction Possible. At the upper end there is a tendency for an excess of labor to encourage more construction than would otherwise be undertaken.

UCR .K=TABYLC LCRT LAK 042,45) 158,A LERT=0/.57.9/161/1.15 138.1,T

UCR = LABER CONSTRUCTION RATIO CDIMENS FONLESS) UcRT - UNBOR=CONS TRUCTION-R ATID TABLE LR = LABBR/BB RATIC CDIMENSIBNLESS)

Equation 139 introduces a Perception delay between labor availability and enterprise construction. This is the time taken to perceive the availability

of a labor supply as a factor in locating new enterprise. This level equation is also necessary from a technical standpoint to avoid a closed Joop of simultaneous

URP.K=LAP.SECOT/LRPTD (LR. JL RP.) 139, LRP 21 B9.1,N LAP T=5 139.2,0

LRP = LABOR/.B8 RATIC PERCEIVED (OtMENSIQNLESS) LRPT ~ LABOR/JOB RATIB PERCEPTI@N TIME CYEARS) iR LABOR/B RATIO COIMENSI GNLESS)

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UTP K=UTREUSKACL IPCO, 1, S471, TIMESK) 14044 uTR=0 140.1, SETI=0 140.240

uIP = WNDERENPLOYED*TRAL NING PROGRAM CHEN/Y EAR)

UTR = UNDEREMPLOY EQ=TRAI NING RATE CFRACTIA ti uv = UNGEREMPLOYED (MEN) nen SWT7 = SHETCH TIME 1 (YEARS)

A labor-training Program is given in Equation 141 with the same format as the preceding equation.

LIPGK=t TRELKECLIPCO, 'Ty SHT2, TAMESKD 18144 LTR=0 THI, 'Swi2=0 141.2,

UiPe = LABBR=TRAINING PROGRAM CMENY EAR) ue ~ LABOR=TRAINI NG RATE CFRACTION/VEAR) SWT2 = SWITCH TIME 2 YEARS)

PHCP AKPHCRAPH KAPHLMGKACLIPCO, 1, SWT3,TIME,K) 142 sh PHCR=0 . T4261,0 'Sw7320 142.2,0

PHCP PREM! UM-H USI NG-CANS TRUCTION PROGRAM CHUSING WNETS/VEARD

PHER = PRENI UM-HOUS! NG-CONSTRUCTION RATE SFRACTICN/Y EAR)

Py > PREMIUM HOUSING CHBUSING UNITS)

PHLM = PREMIUM-HaUSI NG CAND MULTIPLIER

ES:

CO) MENS IBNLESS) SWTS = SHITCH TIME 5 YEARS) TM, 32, Re ',

©, 16, LO-—. Underemployed unde! oyed swD Labor training rate teaining / 'Switeh time 2 vn, 4) --@HUT, 70, A) (PH, 78, LO~ "MPHCD, 65, 4) \ { (WHCD, 83, Ae a Premium housing ~~.

27" Housing units total

(PHLM, 68, AD. —-OWHLM, 86, a) a SS 2

Worker housing Worker het

* construction ohne Tend nwitiplier Daa Prog land multiplier

va

y 143 NS — oan swra MaICR 'Switch time 4 Worker housing

construction rate

--OPUT, 11, A) Productive units, total

New enterprise

construction Program 145

""OELM, 105, a) Enterprise land .. multiplier \ \

—— NECR New enterprise 'construction rate

Tax per capita subsidy program

PCS

7 ita eubsid

\ (RBG 131, A) TH Per cwpita cubsigy LCHB, 143, RI

/ _--OWHLM, 86, a) I

\ 27 Worker housing

land multiplier

~-DY, 16, L) Underemployed

—> J > ulpc swry swtio LcHPc I Underemptoyed job Switch time 9 Switch time 10 Low cost housing 'Program coefficient

Program coefficient Figure 4-67 Development Programs.

Equation 142 describes a premium-housing-construction Program. It builds each year the fraction PHCR of the existing premium housing, multiplied by the premium-housing land saultiplier PHLM from Equation 68 so that this equation cannot overfill the land area. The CLIP function again determines the time at which the program becomes effective,

The worker-housing-construction Program in Equation 143 has the same form, It is set up in terms of a fraction of total housing units in the area.

WHCP AK CRAHUT.KAMTILMSKxC PCO, '1sSWThy TEMESKD

143,8 wicR=9 S150 SHTACO 143.2,0

CHEUSING UN} Ts, wR WRKER-4HOUS! NO-CaNSTRUCTION RATE CFRACTIONS YEAR)

HUT = HOUSING UNITS WTAL CHBUS ING UNI Ts) Wim - WRKER-HOUS! NG LAND MALTIPLIER

(Ti MENS IGNLESS) + SW = SWITCH TIME * CYEARS)

WHER = WORKER BUSI NG~CONSTRUCTION PROGRAK YEAR)

Equation 144 provides for a slum-housing-demolition program in which the coefficient SHDR determines the fraction per year of underemployed housing

that will be removed from the system. SWTS gives the time in which the coefficient changes from 0 to the new value,

SHOP .K=SHORHUR KCL IP(O,1, SWTS, 71 MESKD

Thh A SHOR=0 THC SHTS=0 194.246

SHOP + SLUM-HOUS! NS-DEMBL{ TION PROGRAM (HOUSING UNI TSA EAR)

SHOR + SLUM-HBUS! NG—DEMBLI TION RATE FRACTIONS YEAR)

UH ~ UNDEREMPLOYED HaUSING CHBUSING UNITS) SWTS = SWITCH TIME 5 YEARS)

NECR gives the new-enterprise-construction rate productive units, Actual construction from prise land multiplier ELM which prevents

as a fraction per year of total this program is modified by the enter- overfilling of the land area,

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NECP .K=NECR¥PUTKXELMSKRCLI PCO, 1, SWT6, TEME.K) 145,4 NECR=0 14561, 0 SWTE=0 145.2,C

NECP = NEW-EN TERPRISE~CONSTRUCTIGN PROGRAM PRODUCTIVE UN] TS/YEAR)

NECR = NEW-ENTERPRI SE-CONSTRUCTION RATE CFRACTION/ YEAR)

PUT - PRODUCTIVE UNITS TOTAL CPR@DUCTI VE UNITS) ELM = ENTERPRISE LAND MULTIPLIER (DIMENS!GNLESS) SHT6 = SWITCH TIME 6 CYEARS>

In a manner similar to that of Equation 144, Equation 146 provides a program for the demolition of the declining industry.

1D) OP .K=D1 DRED! K#CLIPCO, 1, SHT?, THMESKD 146,4 DEDR=0 146.1, 0 SHT7=0 146.2,C

BIGP = DECLINING~1 NDUSTRY-DEMBLITIGN PROGRAM (PRODUCTIVE UNITS/Y EAR?

DIOR = DECLINING! NOUSTRY=DEMBLITIGN RATE CFRACTION/Y EAR?

Oo ~ GECLINING ENDUSTRY CPRBDUCTI VE UNITS)

SWTT = SWETCH TIME 7 CYEARS)

Equation 147 provides an externally supplied tax subsidy to the area. It enters the system through Equation 8 and affects area attractiveness and education, which influences upward mobility from underemployed to labor and from labor to managerial-professional. It does not directly operate to reduce taxes needed or the tax assessment.

TPCSP .K=TPCSHCLI PL Oy 1, WTS gp TIME.K) TATA Tees=0 TAT.A,C sHTB<0 187.2,0 TPCSP - TAX-PER-CAPITA-SUBSI DY PROGRAM <DOLLARS/ PERSON/Y EAR)

Tes ~ TAK PER CAPITA SUBSIDY CDBLLARS/PERSON/ YEAR) SWT8 = SWITCH TIME 8 CYEARS)

An underemployed-job program can be created through Equation 148, which provides jobs for a specified fraction of the underemployed.

Equations 149 and 150 generate a low-cost-housing program which creates construction directly into the category of underemployed housing. The fraction per year of the underemployed to be housed is entered in Equation 150. The

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UUP sK=UJPCAUMKACLIPCO4 1, STS TEMESKD 148,4 wPC=0 14861,0 SW=0 148,240

UP = UNDEREMPLOYED~J@B PROGRAM (MEN

wre (NDEREMPLBYED-JBB=PROGRAM COEFFICIENT COEMENS I ANLESS)

u = UNDEREMPLOYED (MEN)

SWI SWETQH TIME 9 CYEARS)

LCHP.KL=¢LCHEDK) (LCR KD 149,8 LOHP = Low-oasT-Haus! xg PROGRAM CHBUSING UNI TS/ LCHCS = LOW-CEST+iBUSING CONSTRUCTIAN DES! RED

CHBUSING UNI TS/Y EAR) LCR ~~ LABAR OANSTRUCTION RATIO. COFMENS 1GNLESS)

LCHCO.K=LCHPOx: UeKAMHLMAKECLIPCO, 1, SWT10,TIME.K? 150,A LcHPC=0 150.1,C SWTI0=0 150.2, C

LCHCE = LaW-COST-HOUS ING CONSTRUCTION Ri (HOUSING UNITS/YEARD oestaco

LCHPC - LeW-CBST-HOUS (NG-PRAGRAM COEFFICIENT CHOUSING UNI TS/MAN/Y EAR)

u = UNDEREMPLOYED CMEND

WHLM ~ WORKER-HOUSING LAND MULTIPLIER CDIMENSI@NLESS)

SWT10 = SWITCH TIME 10 (YEARS)

worker-housing land multiplier operates at this poi i i 5 u point. Equation 149 modifies the sult of Equation 150 in accordance with the available labor supply.

A.13_ Simulation-Control Instructions The following two constants specify the solution interval between successive evaluations of the system equations and the length in time of the simulation run.

0721 151,¢ LENGTH=250 BAC

The following instruction controls the time interval between successive entries in the plotted graphs, The interval changes from the PLTMIN value to the PLTMAX value at the time specified by PLTCT. The values here give a plotting Period of five years throughout the simulation run. If PLTMIN js set to 0, no plotting occurs until the transfer to PLTMAX. This, for example, is used for Figure 3-2. If both values are 0, the plotting is suppressed.

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PLIPER.K=CL1PCPLIMEN,PLTMAX,PLTCT,TIMESK) 15254 simulations that examine how the urban area would be changed by modified PLIMINES 15264, policies or conditions,

PLTMAX=5 152.240 i 2.1 AMMP = .449 77.3 PHGRI =0 . 16.1 U = 377310 TBA PLTCT=500 152.3,0 20.1 UTLP = 16847 811 PLTPER- PLOT PERIGD CYEARS) 22.1 UMMP = .802 92.3 BL TMI PLAT penta MINE CYEARSD 20.1 L 392550 95.1 PLTMAX~ PLOT PERIOD MAXIMUM CYEARS) . PLICT ~ PLOT-PERIGO CHANGE TIME CYEARS) 33.1 LMMP = 464 100.1

42.1 LAMP 625 110.3

In the same manner the following instructions control the minimum interval 52.1 MP 71130 113.1

between printed results, the maximum interval, the time of change over, and the 34.1 MAMP = .307 116.1

ability to suppress printing by setting both intervals to 0. I 139.1 PRIPER.K=CLIPCPRTMINPRTMAX,PRICT, Ti MEK) 1538 PRIMIN=50 153-7,0 PRTMAX=100 453.6250 PRICT=160 15363,0

PRTPER~ PRINT PERIGD CYEARS)

PRTMEN~ PRINT PERIGD KINIMUM CYEARS) PRTMAX= PRINT PERIGD MAXIMUM CYEARS) PRICT ~ PRINT-PERIGD CHANCE TIME CYEARS)

Equation 154 is not active in the system. It is a supplementary equation "S" used only for generating values that are to be printed or plotted.

UTLNAK=UTL. Kol TUK 154,

UTLN = UNDEREMPLOYED 12 LABGR NET CMEN/YEARD UTL = UNDEREMPLOYED TB LABGR CHEN/TEARD LTU = LABOR 1 UNDEREMPLOYED (MEN/YEARD

In addition to the preceding active equations and control cards, the complete model contains instructions for the variables to be printed and plotted on lines 154.3 through 156.5 as given at the end of the model tabulation in Appendix E.

Ald The Equilibrium Model

In most of the computer simulation results in this book, the urban area is examined over an interval of 50 years starting from the equilibrium condition that existed at the end of the life cycle shown in Figure 3-1. The equilibrium model is identical to the growth model described in this Appendix except for the constants that describe the initial conditions. Following are the line numbers and modified values used to give system equilibrium as a beginning point for

B Miscellaneous

This appendix contains several computer simulation rans and miscellaneous commentary on systems which will be of interest to some readers but which do not fit in the primary chapters of the book.

B.1 Political Power

The urban model in this book is aggregated to such a high level that many of the urban processes are combined into rather general system parameters. But this does not mean that the model need be ineffective in exploring special ques- tions. Very often a careful examination of an aggregate model leads one to those parameters that represent the conditions of interest. As an example of such a process, we might ask how political influence on tax and expenditure policies of a city might affect the urban condition.

Appendix A (in Section A.10, Tax Sector) contains two places where political considerations are reflected in the parameters of the urban model. Table TRT, Equation 122.1 (shown in Figure A-62) relates the tax rate needed to the tax actually levied. Up to a tax ratio of 1 to 1 compared to the outside environment, the tax levied has been assumed equal to the tax needed. But at higher values of tax need, the actual tax levied falis below the need to reflect a public reluctance and the political infeasibility of raising taxes to the rates needed to finance city operations. For example, in Figure A-62, when the tax ratio needed TRNP rises to 4 times that in the outside environment, the tax ratio actually levied reaches only 2.8 times that outside.

Figure A-63 shows another political relationship. The tax-collection multiplier influences the taxes needed TN in Equation 126 to represent the political influence of the underemployed population. As the labor/underemployed ratio LUR de- creases, the underemployed become more and more dominant. Figure A-63 implies that as the underemployed population gains influence the taxes needed TN are raised above the normal. This reflects voting power in a population that needs tax expenditures and can vote for them yet pays a disproportionately small shares of the taxes.

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Miscellaneous 219

ro RT Bq. 122.1 3] Z > Figure B34] g : TE Ongi é 1 f al TRNP 25 3 1 Fy 100 2¢1RNF) 2 a ° i 2 H ' TRNP ~ Tax ratio needed, perceived, Figure B-

In the next mode! simulation Figures A-62 and A-63 have been changed (as

shown in Figures B-1 and B-2). In the equations of A: endix A and i E these changes are: " PP Appendix

TRT = .3/.5/1/2/4/8/16 122.1, T TCMT = 3.8/2.8/2/1.4/1/.9/8 127.1, T

In Figure B-1 the tax ratio TR is made equal to the tax ratio needed perceived TRNP, even at high values of need. P

. i KI Ti aa Los a a g Lt Figure 3.3 z 3 OS i" : a 3 eee Ss et oe . LUR ~ Labor/ underemployed ratio Figure B-2 20

EME =6 ji

gL 3. PH ED Wa LEH MPA WE

os

aT

UR =U LARA HREM MAST ,LR=2, UR=S,LFO28, TRNow, TR:

Shr New enterprise * : fore y : 3 ' 3 We ft ss ns Byes seehee a sadusssosdss86 fF

SSse3feesSesssguee

a an ae

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S ver g g © Figure B-3 Greater political power of the underemployed as expressed in higher tax tate.

In Figure B-2 political influence of the underemployed has been increased toward the left side of the graph where they dominate the voting population.

tion and availability of jobs. Figure B-3b shows the vising tax underemployed/job tatio, and the decrease in Jand fraction to .56, indicating a 32% decline in occupied land,

Figure B-4 gives the changes in the most interesting system variables as a result

rate, the rising occupied from .82

by only half as much as do other population classes. The power to levy higher taxes never succeeds in outrunning the shrinking tax base and declining construc- tion, which reduces jobs. The short-term effort by the underemployed to improve their condition by raising taxes is, in this example, self-defeating throughout the 50 years.

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Figure B-3 (cont.)

Miscellaneous 223

Time (years) Variable Symbol -5 50 Change (%) 1. New enterprise NE 4,900 626 ~ 87. 2. Mature business MB 7,800 930 — 88, . Declining industry Dr 16,500 18,450 +12, 4. Premium housing PH 110,900 39,600 —64, 5. Worker housing WH 335,600 206,000 —38, 5. Underemployed housing UH 310,100 269'500 2.

7 Managerial- professional MP 71,100 29,400 -59.

8. Labor L 392,600 213,900 9. Underemployed U_ 377,300 285/800 10, Manager/housing ratio MHR 1.07 1.23 IL Labor/housing ratio LHR 17 1.04 12. Underemployed /housing ratio UHR 81 7 13, Manaper/job tatio MR 1.38 129 14, Labor/job ratio LR OT 92 15. Underemployed/job ratio UR 181 2.25 16. Tax ratio needed TRN 2.25 5.75

11. Underemployed to labor net UTLN 3,500 6,300

Figure B4 Changes caused by greater Political power of the underemployed resulting in high

B.2_ Negative Income Tax

How would the city be affected by a form of income maintenance such as the negative income tax for those people whose income falls below an arbitrarily established minimum? Proposals for the negative income tax Suggest that such @ substitute for present forms of welfare would reduce the migration of low- income groups to the city.

The actual effect of a minimum income would seem to depend on how the attractiveness components are arranged in the urban areas and in the surrounding environment. In other words, what areas are made more attractive by a negative. income-tax dollar flow to the underemployed? Altractiveness might be expected

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Figure B-6 Less sensitivity by the underemployed to a shortage of jobs.

to increase most in those areas where economic opportunity is the most unfavor- able characteristic of the area, Consider two contrasting areas in equilibrium with each other and therefore having the same total composite attractiveness. Area A has favorable job and economic opportunities but unfavorable housing and unfavorable prejudice and ethnic factors. Area B has favorable housing oppor- tunities and ethnic-group attractiveness but very unfavorable job and economic conditions. If an outside source of income is made available in both areas, it should enhance the attractiveness of Area B more than Area A.

The stagnant urban area is equivalent to Area B. Its primary unattractive feature : that creates attractiveness balance with other areas is lack of income. In most other ways it is relatively attractive. The negative income tax might, therefore, cause a shift in the underemployed/job multiplier of a stagnant urban area (as shown in Figure B-5). The new (dotted) curve for the table UJMT says that lack of jobs is no longer so important; there is another source of income. Toward the Tight in Figure B-S the new underemployed/job multiplier UJM does not fall as rapidly when the underemployed population begins to exceed job opportuni- ties.

The change in Figure B-5 has been introduced at time = 0 in Figure B-6. Figure B-6a shows an increase of underemployed and underemployed housing while most other system level variables decrease. In Figure B-65 the major

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Miscellaneous 227

Time (years) Variable Symbol 50 Change (%) 1. New enterprise NE 4,900 3,200 35. 2. Mature business MB 7,800 5,500 —30. 3. Declining industry DI 16,500 16,700 +1. 4, Premium housing PH 110,900 90,700 —18. 5. Worker housing WH 335,600 281,900 -16. 6. Underemployed housing UH 310,100 341,100 +10, 7. Managerial-professional MP 74,100 55,700 —22. 8. Labor L 392,600 309,200 ~21, 9. Underemployed U_—-377300 453/800 +20. 10. Manager/housing ratio MHR 1.07 1.02 —5. i, Labor/housing ratio LHR 117 1.10 —6. 12. Underemployed/housing ratio UHR 81 89 +10. 13. Manager/job ratio MR 138 137 =L 14. Labor/job ratio LR OF 92 -5. 15. Underemployed/job ratio UR 181 2.49 +38, 16. Tax ratio needed TRN 2.25 3.30 +47, 17. Underemployed to labor net UTLN 5,500 4,050 -26.

Figure B-7 Changes caused by less sensitivity by the underemployed to a shortage of jobs.

changes are a tise in the underemployed /job ratio and the tax fatio needed. Land fraction occupied declines slightly from .82 to .76. In Figure B-6¢ underemployed artivals increase initially while departures drop and then rise. After the tenth year departures exceed arrivals,

Figure B-7 shows substantial decline in new enterprise, mature business, pre- mium housing, worker housing, manageriai-professional Population, and labor Population. There are increases in underemployed housing, underemployed, underemployed /housing ratio, underemployed /job ratio, and tax rate needed. The area becomes a less effective socioeconomic converter for raising the eco- nomic level of the underemployed, as indicated by the 26% reduction in UTLN.

B3 Parameter Sensitivity

Earlier chapters have stated that complex systems are surprisingly insensitive to changes in parameters (the constants and table functions that describe the relationships within the system). But sensitivity to parameters differs in amount and in kind. The system can be insensitive, in any sense and degree, to some Parameters. To others, the system may show sensitivity of one type but not of another type.

In examining sensitivity of a system to changes in parameters, we should consider three classifications of a parameter:

I. Does it affect either the growth, stability, or equilibrium conditions of the system? 2. Can it be controlled? NESE M838 01 =0

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Figure B§ Worker-housing normal life reduced from 50 yeats to 25 years,

3. Does a change in it affect the selection or use of those other parameters or structural modifications that are to be employed to improve the system?

With regard to the first Classification, many parameters have little effect on any aspect of the system. One example is given later where the average age of worker housing is halved; another example will show that the system is not highly sensitive to the assumptions made about the employment densities in the various business units and the population densities in the housing units.

With regard to the second classification, we are most interested in that subclass of parameters that do affect the system condition and that can be changed or controlled. We usually search for ways to alter the undesirable characteristics of a system. Very often the most significant changes come from changes in structure, but with regard to parameter values we search for those showing sensitivity (by the test in classification 1 above) and, among these, the ones that can be controlled (by the test in classification 2 above). Examples of this subclass were examined in Chapter 5. A sensitive parameter that cannot be contzolled (and often cannot even be measured) is of no interest unless it Tepresents

a hazard by falling on the wrong side of classification 3 above.

In the third classification, we examine sensitive parameters to see if they affect

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are sensitive, uncontrollable, and even unmeasurable. Several examples are given later. One example shows that the detrimental changes produced by the new job multiplier in Figure B-5 as affecting Figures B-6 and B-7 still leave a system that can be markedly improved by the same policy changes regarding stam demolition and industry attraction that were examined in Figure 5-16.

We now turn to examples of various types of sensitivity.

3009 ne Policy Not Affected. Next is an example where a sensitive parameter (classification 1) does not affect the recommendation of policies that improve the system be- havior (classification 3). Here the revival policies from Figure 5-16, which include slum demolition and cacouragement of new industry, are initiated in the system at year 50 of Figure B-6 after the more depressed condition of Stagnation has been created by the changed underemployed /job multiplier of Figure B-5. In other words, Figures B-6 and B-7 showed the equilibrium condition of the urban the change in the underemployed/job multiplier table in Figure 5. With the changed table the condition of the urban area became @ . The question is: Will the

Figure B-S (cont,) tevival policies that were favorable in Fi igure 5-16 still produce improvement when applied to the modified system? One way to answer the question is to generate the conditions at the end of Figure B-6 and at that point in time initiate the Tevival policies. This will be done by "moving" Figure B-6 backward 50 years in time. The computation starts at — 50 years with the standard equilibrium conditions used in Chapters 4 and 5, introduces at that — 50-year point the changed curve of Figure B-5, computes the changes to reach the new state of depressed stagnation at time = 0 (corresponding to time = 50 in Figure B-6), alters the stum-

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+ : Un loyed 4 ' z Cm. undefempioyed see ewe f a 2 » 3 5 . Figure BY Revival policies applied to system when 'underemployed are less sensitive to a shortage of jobs. eens demolition and new-enterprise policies at time = 0, and then computes system & changes for another 50 years,* is is done in Figure B-9, s . ee s = g Figure B-9 shows how the Policies of Figure 5-16 revive the system from the ae more depressed equilibrium reached at the end of Figure B-6, The changes that

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. ng contsol the urban made! in this manner requires the following changes and additions starting with original z : oot = Equation 102 and ending before original Equation 103, Fe PoC ee tt EEF : ors (OTe ME ALtaMNG cuaNces ane Fer SPECIAL RIne Ia aohonee H ae, bed ssstatsed gg ttt ME aagaoeenntuwuannauad go pe inate tear amet & NEE wo evan wet ceevares ged At , + . W220 2 me ° : : : 12.2 ¢ i ' 7 rat : ' 10203 ¢ zo: — Toscana : et ea acon nce.setyraep y PO ee ' . 103.1 SECNI= 05, & Wee . o + 105.2 ¢ a tires A - 33 0 a ' W304 ON g ' 103.5 3 ' 105-6 sete tcrereccakte9 a Ed : 'hese changes leave the model init proviows opetating condition but provide the controls that allowr the special v seg! ree fUbs used in this appendix. Line 102 is modifed to make NEON: variable, Lines 103 through 103.3

g Pet eet eee ceey . Fronide the ewitching between two values of NECN. Lines 1034 ant i © permit a choice of the initial value = 4 of TIME, the internal independent variable within the DYNAM compiler. The slum-demolition policy is é wo already controllable in time through lines 1441 and Ian? te te original model (see Appendixes A = and E).

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Ws 1. New enterprise NE 3,200 8,300 +160. : 2. Mature business MB 5,500 12,900 +135. a 3. Declining industry DE 16,700 19,700 +18, 4. Premium housing PH = 90,700 ~—154'900 +71, 5. Worker housing WH = 281,900 447,100 +59. 6. Underemployed housing UH = 341,100 ——_—178'00 ~48. weeee 7. Managerial professional MP 55,700 108,700 +95. 8. Labor ; E 309,200 586,600 +90. 5 sere, 1 a 9. Underempioyed 453,800 382,400 -16. "SS 8 URE 2 ay rB2 wee sour 10. Manager/ housing ratio MHR 1.02 ait} $15. 1009 Nees 66 1285 asst Ties 11. Labor/housing ratio LHR 410 131 +19. 3 38 548 3p 12. Underemployed/housing ratio UHR 89 1.43 +61. ? o00% 25501 Logs 13. Manager/job ratio MR 137 1.38 +h : 14. Labor/job ratio LR 2 99 +8. cy 15, Underemployed job ratio UR 249 127 ~49, 16. Tax ratio needed TRN 330 1.67 —49, 17. Underemployed to labor net. = UTLN 4,050 10,800 +167.

Figure B10 Changes caused by the revival policies of Figore 5-16 when initiated in an equilibriam system Faving the modified underemployed job raultiplier from Figure Ba

occur in Figure B-9 are summarized in Figure B-10. All the changes are markedly ther : favorable (recognizing that the increases in the housing ratios are a necessary ed accompaniment to economic improvement). In fact, a comparison of Figures B-10 14300 and 5-17 shows that the revival policies produce a much greater effect starting from the terminal conditions of B-6 than from the more favorable stagnation at the beginning of Figure 5-16. One can conclude that the kind of change in Figure B-5 does not alter the desirability of the revival policies that were explored in

Eps 5 Figure 5-16, 3322 7 08 Reducing Sensitivity of Parameters. A further comparison of Figures B-9 and 5-16 . vow shows another important facet of complex systems. When a sensitive parameter is 3 1508 discovered, and it is one that might change (as suggested in Section B.2 dealing with & ATS 4,277 873

000 a Ce) Bas : . ae 12.951 98 1.379 1857 log BS the system designer should look for Ways to make the system insensitive to that @ uncontrollable parameter. This conversion from a sensitive to an insensitive Figure B-9 (cont. parameter has been created here by the revival policies. In Figure B-6 the system

was found to be sensitive to the table change in Figure B-5. But Figure B-11 shows that the system containing the revival policies is no longer sensitive to the table change in Figure B-5. Figure B-11 compares the fiftieth year from Figure B-9 with the fiftieth year from Figure 5-16. The per cent changes calculated in Figure B-11 are caused when the new curve of Figure B-5 has been introduced in the presence of the revival policies. The changes in Figure B-11 should be compared with the changes in Figure B-7. In fact, a surprising thing has happened in going from Figure B-7 to B-11. In Figure B-7, where the change in Table UJIMT.

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Year 50 Year 50

Variable Symbol (Fig. 5-16) (Fig. B-9) Change (%) 1, New enterprise NE 8,000 8,300 +4, 2. Mature business MB 12,800 12,900 +b 3. Declining industry DI 22,200 19,700 =i 4. Premium housing PH — 152,800 154,900 +1 5. Worker housing WH — 450,600 447,600 6. Underemployed housing UH 175,300 «178,800 7. Managerial-professional MP 108,700 '108,700 8. Labor L 600,000 «586,600 9.

Underemployed U —- 335,900 382,400 10. Manager/housing ratio MHR 11 Li7 11. Labor/housing ratio LHR 133 131 12, Underemployed/housing ratio. UHR 1.28 143 . 13, Manager/job ratio MR 1.36 138 +h 14. Labor/job ratio LR 98 99 +h 15. Underémployed/job ratio UR 1.07 127 +19. 16. Tax ratio needed TRN 150 1.67 +L 17. Underemployed to labor net. UTLN 9,200 10,800 +17,

Figure B11 Changes caused by the new underemployed/job multiplier from Figure B-5 when imposed on the revival policies of Figure 5-16.

was added to the original stagnation conditions, the changes are substantial and almost all detrimental. In Figure B-11, where the change in Table UJMT was added to the revivai conditions, not only are the changes slight, but many are in a favorable direction. The revival policies have eliminated the hazard of changes in underemployed sensitivity to job conditions.

In reexamining Figure B-9 we see that revival comes through upgrading the area and creating upward economic mobility for the people already in it. The fall of underemployed in Figure B-9a is caused by the greater flow of underem- ployed to the labor class. The flow of underemployed to labor net UTLN has risen 167%. Figure B-9c shows only a very slight increase above normal in under- employed departures followed by a substantial decline, while underemployed arrivals remain about constant for 20 years and then rise.

Policy Affected by Parameters. In contrast to the parameter variations that do not influence the direction of desirable policy changes, some parameters, if they change, can affect the validity of proposed improvement policies. Usually there are very few parameters that can affect policy recommendations. The one in this example is the only one that is known to exist in this model of urban dynamics, Others may exist, or combinations of several parameter changes might react to defeat the desirability of a policy proposal.

In the following example underemployed movement to and from the urban area has been made much less dependent on availability of housing than in the original model. Figure B-12 shows the new curve for UHMT. It has no effect on the original equilibrium condition of the system because the two curves cross

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T — Underemplayed/housi Figure B42 Less influence of housing on underemployed arrivats,

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Figure B13 Revival policies applied with the less sensitive 'underemployed/housing multiplier from Figure B12.

Figure B-13a shows a decrease in underemployed housing similar to that in Figure 5-162. But now the number of underemployed has risen rather than

Figure B-12. But the example is of more technical than practical interest, at least for cities in the United States. Even the Poorest people in the United States are

different climatic, natural, or political conditions.

This subsection has illustrated that changing parameter values in nonlinear systems can shift the mode of operation so as to affect the design of new policies. A careful search for such influential Parameters should be made before finally deciding on the new policies to be established. hh

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TINE wy we B4 > Normal Population Densities ao we In the urban model, as a unit of factory space ages it is characterized by to OWE w declining employment. The normal cecupancy of a housing unit, on the other wap ome OP hand, increases with the age of the unit. How important are these population we ur assumptions in the urban Stagnation process? mks ot Figure B-14 lists the Population-density coefficients in the basic model and te pH mic substitutes a new set of values which assume no change in employment and a a stae Bs

population densities connected with the age of structures,

Symbol Equation Original Fig. B15

New-enterprise labor NEL 132.1 2 45

Mature-business labor MBL = 132.2 IS 15

Declining-industry labor DIL 1323 1045

New-enterptise management NEM 37.1 4 2

Mature-business management MBM 37.2 2 2

Declining-industry management DIM 373 1 2

Fremium-housing population density PHPD 61.1 3 6

. Worker-housing population density WHPD 48] 6 6

' Underemployed-housing population density UHPD "©! 2 6

Figure B-1é Changes in men per productive unit and in People per housing unit so that densities do not vary with age of structures,

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Figure B-IS New equilibrium caused by the uniform employment and living densities from Figure Bld.

Preferences cause a readjustment in the system, but most of these reverse them. selves. The employment and occupancy densities do not have a substantial in- fluence on the equilibrium condition of the system. Figure B-15a shows that the housing units change to.compensate for the new Occupancy densities. Because fewer people live in each underemployed-housing unit, the amount of housing has risen in response to the greater housing need. Because more people live in each premium-housing unit, the number of units declines to create a new balance between housing and the managetial-professional population. 244° Appendix B

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Figure B-16 Revival policies applied to the Hanan equilibrium and having uniform employment and living densities,

Figure B-13 showed that, even when a parameter change produces no change in the existing equilibrium, it can affect Proposed policy changes. In Figure B-16 we test the influence of the Tevival policies of Figure 5-16 on the urban condition reached in Figure B-15, Under the new urban condition, where employment and living densities do not change with the aging of structures, do the revival policies Produce changes similar to those produced before?

Figure B-16* shows changes caused by the revival policies that are much like those in Figure 5-16. in Figure B-16a labor and worker housing rise, the under- employed and underemployed housing decline, and ali categories of industry rise. In Figure B-16b the underemployed /job ratio improves with the accompanying Pressures arising from the underempioyed/housing tatio. The tax ratio declines as in Figure 5-165. In Figure B-16c the changes are similar to those in Figure 5160.

Acomparison of Figures B-16 and 5-16 shows that the effectiveness of the revival Policies is not influenced by the parameter changes for employment and Popula- ton densities tabulated in Figure B-14,

"The method of obtaining this computer run is 'ruler to that described for Figure B-9, using the modified model described in Section B.3,

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Figure B-16 (cont.)

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B.S Improvement in Externat Environment

The model of urban behavior developed in this book depicts an urban area as an island in an extended environment. People come from and environment as the attractiveness of the area ri

in a depressed city?

Figure B-i7 shows the effect on the urban area if the external environment were suddenly to become more attractive, This is done by halving the under- employed arrivals normal UAN (equation line 1.1) and doubling the under- employed departures normal UDN (ine 13.1). For any given set of conditions

in the urban area, the result is to halve the rate of arrival of the underemployed and to double the rate of departure. €,MB=8,0) =9

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© Figure BAT Halved underemployedvarrival rate and doubled underemployed-departure rate.

Figure B-17 again shows the high degree of independence that complex systems can exhibit in the face of changed conditions, Figure B-17a shows some decline in underemployed and a slight zise in labor, with other system levels almost unchanged. Figure B-17b shows the most significant changes,

even though they appear small. The underemployed /job ratio has fallen some, indicating greater job availability. The underemployed /housing tatio has declined too. The fact that these two variables have changed in the same direction is unusual.

In spite of the apparent small changes in Figure B-17, the attractiveness-for- migration multiplier AMM in Figure B-17d has risen from .452 to 850. The conditions within the urban area have improved to correspond to the improved extemal conditions. However, the new mix of attractiveness components is still not desirable. The area is still characterized by excess slum housing and a shortage of economic opportunity. It appears that improvement in the outside environment, even if it occurs, is not likely to solve the problems of the cities,

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Figure B-17 (cout)

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B.6 Mechanization of Agriculture One occasionally hears that mechanization of southern agriculture, which has forced the migration of the Negro to cities, is Tesponsible for the plight of the

Because the probiems of agricultural mechanization and outward mobility from slum areas have become evident at about the same time, we are led to ask how the two would affect the model of an urban area. Mechanizing agriculture would create greater pressure on the underemployed in rural areas and, other conditions being equal, would cause a higher underemployed-arrival rate UA into the urban. area. This effect can be created by increasing the underemployed arrivals normal UAN (equation line [.1). Such a change would be in the opposite direction from that in the preceding section. Suppose we change UAN from .05 to -1, which doubles the inflow rate, all other things being equal.

At the same time the lack of outward mobility can be represented by reducing the underemployed departures normal UDN (equation line 13.1). By changing UDN from its original value of .02 to -01, the outward mobility is reduced to

half, all other conditions being equal. But, of course, other conditions do not remain equal. T ae

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d 8 ves i : ® $ ft eee cee eee celine 3 3 vas 3 3 © FigureB-18 Doubled underemployed arrival normat UAN and halved underemployed departure normal UDN. ssgaa oP ianeneee eee ee Steen Tee spats of doubling UAN and halving UDN appear in Figure 2-18, Figure

B-18a shows that the urban condition deteriorates, but not very much. The underempioyed population rises and then falls again to near its original value. Figure B-18b shows an underemployed /housing ratio that rises and then declines, The largest change, and one that is detrimental, is the increase in the under- employed/job ratio, which rises from E81 to 2.16 (values from Figure B-18d).

Figure B-18 has 4 times the underemployed-arrival rate and ¥, the departure Tate shown in Figure B-17. Although conditions at the 50-year points in Figures B-17@ and B-18a do differ, the differences are much less than would probably have been expected.

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Figure B-19 Revival policies applied to the system in equilibrium with doubled underemployed arrival normal UAN and halved underemployed departure notmal UDN.

Given the new equilibrium at the fiftieth year in Figure B-18 that results from increased inward pressure from the underemployed and reduced outward mobil- ity, we can now re-examine the revival policies of Figure 5-16 to see if the policy for improvement would fail because of. changed migration conditions. Figure B-19 starts from the final conditions in Figure B-18 and, at time = 0, the slum-demoli- tion and new-enterprise-construction policies are started (as in Figure 5-16).*

In Figure B-19a the changes are similar to those in Figure 5-162. The under- employed population declines and the labor population rises. Figure B-19c shows that the large changes in populations

after the twelfth year occur even though the arrival rate of underemployed exceeds the departure tate. From Figure B-19d the underemployed to labor net UTLN rises from 4,700 to 10,200 per year as a measure of improved upward economic mobility.

Figure B-19b shows the desired changes with a falling underemployed /j 'job ratio, a rising underemployed/housing ratio, and a falling tax ratio needed.

Figure B-19 shows that the doubling of UAN (cepresenting a higher external pressure on the underemployed to move to the city) and a simultaneous halving of UDN (representing a reduced outward mobility) do not defeat the effectiveness of the revival policies.

"This uses the modified model described in Section B.3

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1 2 3 ous : ; C Definitions of Terms ? 3 y Following are the definitions of terms used in this book. The letter group is 8 the abbreviation used in the system model. The definition gives the meaning and 1" the dimensions of measurement. 7 3 * FEE TLONS FOR CITY GROWTH) STAGNATION, AND REVI VAL woeL, ' AME ATTRACT! VENESS -FOR-MI GRATION FACTOR CDINENS! BNLESSS H aa ATIRACTI VENESS-FOR-Mi GRATION MULTIPLIER CDI MENS! BNL ESS) $ AM ATTRACTIVENESS -FBR-MIGRATIAN MULTI PLIER PERCE, oro CDIMENS(@NLESS) 3 APT ATTRACT! VENESS-FOR-MI GRATION-MULTI PLI ER PERCEPTION TIME YEARS) sess S300 24500 2 AREA LAND AREA CACRES) 52 "2000 Se0see tt AY ASSESSED VALUE CTHOUSANO DOLLARS) zim 19589 12 BAY BUSINESS ASSESSED VALUE (THAUSAND DOLLARSD iter cos 8 80m BUSINESS-DECLINE MULTIPLIER CDI MENS @NLESS> ver Ss BOMT BUSINESS-DECLINE-MULTIPLIER TABLE BST 31001 1 o1 OECLINING INDUSTRY CPRBDUCTI VE UNI TS> ans BB 2 iA DECLINING-1NOUSTRY ASSESSED VALUE CTHOUSAND DALLARS/PRBDUCT! VE UNIT) 107.78 100.80 ¥ Dier DECLINE NG~1 NOUS TRY-CONS TRUCTIGN FACTAR COIMENSIONLESS> 3 oro DECLINE NGI NOUSTRY DEMBLI TION CPRDUCTI VE UNI TS/¥ EARS ; 1 OF PECL INING~1 NOUSTRY-DEMOLI TION FACTAR COI MENSIOM ESSs 3 LOM DeGtINING-INDUSTRY-DEMBLITION MILTIPLIER COIMENSION ESS) : 3 D1 OW BECLINING-INOUSTRY DEMOLITION NORMAL CFRACTION/Y CARD ° o1oe BECLINING-INOUSTRY-DEMALI TION PROGRAM CPRADUCTI VE. UNI TS/YEAR) 2 oy OR DECLINING~I NDUS TRY=DEMBLI TION RATE CFRACTIONA LAR) S DIEM DECLINING-INDUSTRY ENTERPRISE MULTIPLIER (DIMENSIONLESS

" DIENT DECLIWING~1 NOUSTRY-ENTERPRI SE-MULTI PLIER TABLE DIL DECLINING-I NOUSTRY LABOR CMEN/PRBOUCTIVE UNI Ty DitK DECLINING-INDUSTRY LAND MULTIPLIER CO/ MENS! @NLESS) Figure B-19 (cont.) DiLMT DECLINING~1 NOUS TRY-LAND-MULTIPLIER TABLE OM DECLINING- NDUS TRY MANAGEMENT CMEN/PRADUCTI VE UNIT) EDM ENTERPRI SE~DECLINE MULTIPLIER (DI MENS! @NLESS) EMT ENTERPRISE~DECLINE-MULTIPLI ER TABLE fF ENTERPRISE FACTOR (Oi MENSI@NLESS) tom ENTERPRISE~GROWTH MULTIPLIER (OI MENSIBNLESS)

EGMT ENTERPRI SE-GROWTH-MULTIPLIER TABLE EI JM ENTERPRISE LABBR/WOB MULTIPLIER (OF MENS IGNLESS) ELJMT ENTERPRISE LABOR/JOB MULTI PLEER TABLE

ELM ENTERPRISE LAND MULTIPLIER COIMENS! ONL ESS). ELMT ENTERPRISE~LANO-MULTI PL1 ER TABLE. EM ENTERPRISE MULTIPLIER (DI MENSIGNLESS)

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EMM ENMT E™ ETMT HAY HUT

ENTERPRISE MANAGER/JoB MULTIPLIER COEMENS! ONLESS) ENTERPRISE MANAGER/UOB MULTIPLIER TABLE

ENTERPRISE TAX MULTIPLIER CDIMENSI@NLESS) ENTERPRISE=TAX"MULTIPLIER TABLE

HOUSING ASSESSED VALUE (THOUSAND DBLLARS)

HOUSING UNITS TOTAL (HOUSING UNITS)

LABBR (MEN)

LABOR ARRIVALS CMEK/Y EAR)

LABOR-ARRI VAL FACTOR CDi MENSTONLESS).

LABBR-ARRI VAL HBUSENG MULTIPLIER (Di MENSI@NLESS) LABOR~ARRI VAL"HBUS FNG=MULTIPLI ER TABLE LABOR=ARRI VAL JAB MULTIPLIER COI MENSI@NLESS) LABOR-ARRI VAL-JOB-MULTIPLI ER TABLE

LABBRARRI VAL MULTIPLIER (OI MEWS I@NLESS> LABOR@ARRIVAL MULTIPLIER PERCEIVED COI MENS I@NLESS) LABOR-ARRI VAL~MULTIPLI ER PERCEPTION TIME CYEARS) LABOR ARRIVALS NORMAL CFRACTIGN/YEAR) LABOR-ARRIVAL TAX MULTI PLIER COIMENSIGNLESS)

LABOR ~ARRI VAL ~TAX-MULTIPLIER TABLE

LABBR@ARRI VAL UNDEREMPLOYED MULTIPLIER (DIMENSIONLESS) LABOR ~ARRI VAL-UNDEREMPLOYED-MULTIPLIER TABLE

LABOR BIRTHS (MEN/Y EAR)

LABOR BIRTH RATE CFRACTIGN/Y EAR).

LOH-COST-HGUSING CONSTRUCTION OESIRED HOUSING UNI TS/Y EAR LOW-COST-HBUSING-CONS TRUCTION LABZR CMAN-Y EARS BUSING UN TD LOW-CAST-HOUSING PROGRAM CHUSING UN! TS/YEAR) LOW-CBS T-HBUS ING-PROGRAM OBEFFICIENT CHOUSING UNI TS/MAN/Y EAR) LABOR CONSTRUCTION RATIC COI MENS FENLESS)

LABOR-CONS TRUCTIBN-RATIO. TABLE

LABGR DEPARTURES (MEN/YEARD

LABOR DESIRED FOR CONSTRUCTION CMEND

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LAB@R=DEPARTURE MULTIPLIER CDEMENS 1 BNLESS) LABOR-~DEP AR TURE-MULTIPLIER TABLE

LABOR DEPARTURES NORMAL CFRACTION/Y EAR)

LABOR EDUCATIONAL MULTIPLIER COL MENS IONLESS) LABBR-EQUCATIONAL-MULT! PLIER TABLE

LAND FRACTION @ccuP! ED COIMENS IGNLESS)

LABBR FAMILY SIZE CPEBPLE/MAN)

LABOR/HOUSING RATIO COL MENS! @NLESS)

LABOR JOBS (MEN)

LABOR-LAYSFF FRACTION CFRAC TI GN/Y EAR) LABBR-LAYOFF-FRACTION TASLE

LABQR-MBBELITY FACTAR (Oi MENS IBNLESS) LABBR-MBBILUTY MULTIPLIER COMMENSIONLESS> LABOR-MOBILITY MULTIPLIER PERCEIVED (DI MENSIBNLESS) CABOR-MOBILITY-MULTIPLIER PERCEPTI@N TIME (YEARS) LABOR MOBILITY NORMAL CFRACTIONA EAR)

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CABOR/.BB RATIC PERCEIVED COFMENSISNLESS) LABOR/JBB RATIG PERCEPTION TIME (YEARS) LABOR-SUPPLY MULTIPLIER COEMENS1SNLESS) LABBR-SUPPLY-MULTIPLIER TABLE

LABOR Td WANAGER (MEN/YEAR)

LABBR~TRATNING PROGRAM CMEN/Y EAR)

LABBR-TRATNING RATE CFRACTIGN/YEARD

LABOR TD UNDEREMPLOYED (MEN/YEARD LABOR/UNDEREMPLOYED MULTIPLIER CO MENS t ONLESS)

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LABOR/UNDEREMPLOYED MULTIPLIER TABLE LABQR/UNDEREMPLOYED RATIO COIMENSISNLESS)

MANAGER ARRIVALS (MEN/Y EAR)

MANAGER-ARRI VAL FACTOR CORMENSI@NLESS)

MANAGERARRI VAL HOUSING MULTIPLIER (OF MENS! @NLESS) MANAGER-ARRI VAL-HOUS{ NG-MULTIPLIER TABLE MANAGER-ARRI VAL Ja8 MULT! PLIER (OI MENST2NLESS) MANAGER~ARRi VAL ~JBB-MULTI PLEER TABLE

MANAGER*ARRI VAL MULTIPLIER Oi MENSi 2NLESS) MANAGER-ARRI VAL MULTIPLIER PERCE! VED CO! MENST@NLESS) HANAGERARRI VAL=MULTI PLE ER PERCEPTION TiME CYEARS) MANAGER ARRIVALS NORMAL CFRACTIGN/Y EAR) MANAGERARREVAL PBPULATION MULTIPLIER (OI MENSI ONL ESS? MANAGER-ARRI VAL~POPULATIBN=MULT! PLIER TABLE MANAGER"ARR! VAL TAX MULTEPLIER CDIMENSIONLESS) MANAGER "ARRi VAL -TAX-HULTIPLIER TABLE

MATURE BUSINESS (PRODUCTIVE UNI Ts)

MATURE~BUSINESS ASSESSED VALUE (THOUSAND OOLLARS/PRaDUCTI VE UNIT) MATURE ~BUS1 NESS = CANS TRUC TION FACTBR CDi MENS! @NLESS) MATURE~BUSINESS DECLINE (PRODUCTI VE UNI TS/YEAR) MATURE-BUSINESS DECLINE NORMAL CFRACTION/Y EAR) MATURE~BUSINESS LABOR CMEN/PRODUCTI VE UNI TD MATURE-BUSINESS MANAGEMENT CMEN/PRODUCTIVE UNIT) MANAGER DEPARTURES CMEN/YEAR)

MANAGER-DEPARTURE MULTIPLIER (Di MENS 1 NLESS> MANAGER-DEPARTURE=MULTI PEI ER TABLE

MANAGER DEPARTURES NORMAL. CFRACTEON/Y EAR) MANAGER/HBUSING RATIS (OI MENSTONLESS)

MANAGER BS (MEN)

MANAGER/LABBR MULTIPLIER CDI MENSI@NLESS) MANAGER/LABAR MULTIPLIER TABLE

MANAGER/LABOR RATIO COIMENS! ONLESS)

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MANAGERI AL~PROFESSIGNAL BIRTHS CMEN/Y EAR)

MANAGER! AL~PROFESSIGNAL BERTH RATE (FRACTIGN/Y EAR) MANAGERIAL =PRGFESSIGNAL FAMI LY SIZE CPERPLE/MAN) MANAGER/POPULATIGN RATIO (Ot MENSIGNLESS)

MANAGER/OB RATIG (OL MENS I@NL ESS)

MANAGER-SUPPLY MUA TIPLIER COI MENS! ONLESS) MANAGER-SUPPLY-MULTIPLIER TABLE

NE@ ENTERPRISE CPRADUCTI VE UNI Ts)

NEW-ENTERPRISE AVERAGE (PRODUCTI VE UNE TS? NEW-ENTERPRI SE AVERAGING TIME YEARS)

NEW-ENTERPRISE ASSESSED VALUE. C THOUSAND DALLARS/PREOUCTI YE UNIT NEW-ENTERPRISE CONSTRUCTION PRODUCTI VE UN} TS/Y EAR) NEW-ENTERPRISE CONSTRUCTIGN DESIRED CPROOUCTI VE UNI TS/YEAR) NEW-ENTERPRISE-CBNS TRUCTION FAC TAR CDI MENS! 2NLESS) NEW-ENTERPRI SE~CBNS TRUCTION LABOR CMAN-Y EARS/PRBDUCT! VE UNI TD NEW-ENTERPRISE CONSTRUCTION NORMAL FRAC TI ZN/Y EAR)

* NEW-ENTERPRI SE-CONSTRUCTION PROGRAM (PRODUCTIVE UNI TS/YEARD

NEW~ENTERPRI SE~CONSTRUCTIGN RATE CFRACTION/Y EAR) NEW-ENTERPRISE DECLINE (PRODUCTI VE UN TSAVEAR) NEW-ENTERPRISE DECLINE NORMAL CFRACTI@N/Y EAR? NEW-ENTERPRISE GROWTH RATE CFRACTIGN/Y EAR) NEW-ENTERPRISE GROWTH RATE INITIAL CFRAC TI ON/Y EAR) NEW-ENTERPRISE LABQR CMEN/PRODUCTI VE NID NEW-ENTERPRISE MANAGEMENT CHEN/PRBDUCTIVE UNIT) POPULATIBN (MEN)

PUBL! C-EXPENDITURE MULTIPLIER COI MENS T@NLESS) PUBL} C~EXPENDI TURE=MULTI PLIER TABLE

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PH PREMIUM HOUSING CHBUSING UN! TS) : TAL TAX ASSESSMENT INDICATED COBLLARS/YEAR/THBUSAND DALLARS) PHA PREMI UNHBUSING AVERAGE CHOUSING UNITS) i TAN TAX ASSESSMENT NORMAL COBLLARS/V EAR/THOUSAND DQLLARSD PHAM PREMI UN-HBUSING-ADEQUACY MULTIPLIER CDIMENSIGNLESS? : Te TAX COLLECTIONS ¢OBLLARS/VEAR) PHAMT PREM! UN-HBUS! NG-AEQUACY-MULTIPUIER TABLE i cu TAX-COLLECTION MULTIPLIER CBI MENS/@NLESS> : PHAT PREMT UN-HOUSING AVERAGING TIME CYEARS) : Tout TAX-COLLECTION-MULTIPLIER TABLE L PHAY PREMIUM-HOUSING ASSESSED VALUE CTHOUSAND DOLLARS/HQUS! NG UNI TD i ita TAX PER LABOR PERSAN CODLLARS/P ERSBN/YEAR) : PHC PREM! UM-HOUSING CONSTRUCTION CHBUSING {NI TS/YEAR) I TMP TAX PER MANAGEMENT PERSAN COBLLARS/PERSBN/Y EAR) PHCD PREM! UN-HGUSI NG CONSTRUCTION DESIREO CHBUSI NS UNI TS/Y EAR : Ww TAXES NEEDED COBLLARS/Y EAR) PHEL PREM! UM-HOUSING-CONS TRUCTION LABOR (MAN-YEARS ABUSING UN] TD I TPCN TAX PER CAPITA NORMAL CDBLLARS/VEAR/PERSEN) I PHCN PREMI UM-HOUSING CONSTRUCTION NORMAL CFRACTIGN/Y EAR) } TPCR TAK PER CAPITA RATIO (OIMENSi@NLESS) i PCE PREM! UM-HBUSI NG-CONSTRUCTIGN PROGRAM CHUSING UNI TS/Y EAR i TCs TAX PER CAPITA SUBSI OY COZLLARS/PERSON/Y EARD H PHER PREMI UM-HOUSING-OBNS TRUCTIGN RATE CFRACTIGN/YEARD : TPCSP _TAX-PER-CAPITA~SUBS! OY PRAGRAM COJLLARS/PERSON/Y EARD I PHEM PREMI UM-HOUSING ENTERPRISE MILTIPLER (OI MENSIONLESS) i TR TAX RATI. CDIMENSI@NLESS) i PHEMT PREM! UM-HOUSI NG-ENTERPRISE-MULTIPLIER TABLE TRN TAX RATI@ NEEDED (DIMENSI@NLESS> i PHF PREMI UM-HBUSING FACTOR (DIMENSI@NLESS) : TRNP TAX RATIO NEEDED PERCEIVED COIMENSI@NLESS)

j PEM PREMI UM-HBUSING-GROWTH MULTIPLIER <DI MENS! ONLESS) : TRNPT ——_TAX-RATIO-NEEOED PERCEPTION TIME YEARS) : PHGMT = PREMI UM-HOUSING-GROWTH-MULT/PLIER TABLE i TRT TAX-RATIC. TABLE PHER PREMI UN-HBUSING GROWTH RATE CFRACTION/YEAR) I TuP TAX PER UNDEREMPLAYED PERSBN

COBLLARS/PERSON/Y EAR> PHGRI ——-PREMIUMH@US! NG GROWTH RATE INE TIAL (FRACTION EAR) : u UNDEREMPLEYED (MEN) PHLM PREMIUM-HOUSING LAND MULT: PLIER CDI MENS! ONLESS) : UA UNDEREMPLOYED ARRIVALS (MEN/Y EAR) PHLMT — PREMIUM+HOUSING-LAND-MULTIPLIER TABLE UAM UNDEREMPLBYED-ARRI VALS HB! LI TY MULTIPLIER COIMENSIANLESS) PHM PREMI UM-HBUSING MULTIPLIER CDI MENSIGAL ESS? UAT UNDEREMPLBY ED"ARRI VALS-M@BILLITY-MULTIPLIER TABLE PHO PREMIUM-HBUSING @BSBLESCENCE CHOUSING UNI TS/YEAR? UAK UNDEREMPLOYED ARRIVALS NORMAL CFRACTIGN/Y EAR) PHOM PREMI UMHBUSING-OBSALESCENCE MULTIPLIER CDI MENSI@NLESS) B UNDEREMPLOYED BIRTHS CMEN/Y EAR) PHONT — PREMF UM-HOUSING-@ BSBLESCENCE MULTIPLIER TABLE uBR UNOEREMPLBYED BIRTH RATE CFRACTIAN/YEARD PHON PREM! UM-HOUSING BESBLESCENCE NORMAL CFRACTION/ EAR) wo UNDEREMPLOYED DEPARTURES CWEN/YEARD PHPD PREMI UM-HBUSING POPULATION DENSITY CPEGPLEAHBUSING UNI TD uoN UNDEREMPLOYED-DEPARTURE MULTIPLIER CDIMENSI@NLESS)

PHM PREM} UM-HOUSING POPULATIGN MULTIPLIER COIMENS? BNLESS) UOMT UNDEREMPLOY ED-DEPARTURE "MULTIPLIER TABLE

PHPMT PREM UM-HQUSI NG-PAPULATIGN-MULTEPLIER TABLE UDN UNDEREMPLOY EO DEPARTURES NORMAL CFRACTIBN/Y EARD ° PRIM PREMIUM-HOUSING TAX MULTIPLIER CDIMENSI@NLESS) UEM UNDEREMPLOYED EQUCATIGNAL MULTIPLIER (DIMENSIONLESS) I PHIMT PREMI UM-HOUSENG-TAX-MULTIPLIER TABLE

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i EMT UNDEREMPLAYEO-EDUCATIQNAL~MULTIPLIER TABLE PLICT ——-PLOT-PERIGD CHANGE TIME CYEARS) I urs UNDEREMPLOVED FAMILY SIZE CPEQPLE/MAND

UNDEREMPLOYED FRACTION WORKING COI MENSIONLESS)

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PLTMAX PUBT PERIGD MAXIMUM CYEARS) uw UFWT UNGEREMPLBYED-FRACTION-WERKi NG TABLE

PLIMEN PLOT PERIGD MINIMUM CYEARS) PLIPER PLOT PERI@D CYEARS)

uw UNDEREMPLOYED HOUSING CHOUSING UNI 18) PRICT PRINT-PERIBD CHANGE TIME (YEARS) 'UHAY UNOEREMPLEY ED-H@USING ASSESSED VALUE (THOUSAND DOLLARS/H@USING UNiT) PRIMAX. PRINT PERIGO MAXIMUM CYEARS) UHM UNDEREMPLOY ED/HBUSING MULTIPLIER (OI MENSI@NLESS)

PRIMIN PRINT PERIGD MINIMUM CYEARS)

PRIPER PRINT PERI@O CYEARS)

PUT PRODUCTIVE UNITS TBTAL CPRADUCTI VE UNITS)

SHAM SLUM-HOUSING~ABANDBNED MULTIPLIER (DIMENSIGNLESS) 'SHAMT SLUM-H@US{NG-ABANDGNED-MULTIPLIER TABLE

UNMT UNDEREMPLOY ED-HBUSI NG-MULTIPLIER TABLE

UHPD UNDEREWPLOY ED-HGUSING PAPULATION DENSITY (PESPLE/HOUSING UNIT) UMP UNDEREMPLOYED-HBUSI NG-PRAGRAN MULTIPLIER COIMENS! BNLESS) UMPMT UNDEREMPLBY ED-HOUSI NG-PROGRAM-MULTIPLI ER TABLE

UHPR UNDEREMPLGY ED-HGUSI NG-PROGRAM RATE. SHBUSES/Y EAR/MAND

'SHO SLUM-HBUSING DEMBLITIQN CHAUSING UNI TS/VEARD UHR: UNDEREMPLOYED/HBUSING RATIG (DI MENSIGNLESS) SHOF SLUM-+HBUSING-DEMOLI TION FACTOR (DIMENSIONLESS) Ww UNDEREMPLOYED JABS <MEND SHOM SLUM-HBUSING-QEMBLI TION MULTUPLIER COIMENSIBNLESS) UM UNDEREMPLOYED/.88 MULTIPLIER COIMENS IGNLESS) SHON SLUH-HOUSING DEMBLITIGN NORMAL CFRACTION/YEAR) UUMT 'UNDEREMPLOYEO/JBB MULTIPLIER TABLE 'SHOP SLUM-HOUSING-DEMOLI TION PROGRAM CHBUSING UNI TS/YEAR) UWP UNDEREMPLOYEO-JOB PROGRAM CMEN)

SHOR SLUM-H@USING-DEMBLI TION RATE CFRACTIGN/YEARD UuPC UNOEREMPLOYED-J@B-PRAGRAM COEFFICIENT (DIMENSIONLESS) SHLM SLUM-HOUSING LAND MULTIPLIER (DIMENSIONLESS) heen UNDEREMPLET ES ER ween FRE NSIANLESS) IN = LTIPLUER TABLE Ji NI Y ED/LAI Je 18 LI ai SwUTCe THe a ceeaes . ! uy UNDEREMPLOYED MOBILITY CFRACTIONA EARD sate SWITCH TIME 2 CYEARS) i MF UNDEREMPLOYED-MOBILITY FACTOR (DIMERS! @NLESS) WTS SWETCH TIME 3 CYEARS) UNM UNDEREMPLOYEO-MOBILITY MULTIPLIER COL MENS 1 @NLESS) ATH 'SWITCH TIME 4 CYEARS) UMP UNDEREMPLOYED-MABILITY MULTIPLIER PERCEI YEO COIMENSIONLESS) SWTS SWITCH TEME 5 (YEARS) i UMMPT UNDEREMPLBY ED-MABIL I TY =MULTI PLIER PERCEPTION TIME CYEARS) SwT6 SWITCH TIME 6 CYEARS) 1 UMN UNDEREMPLOYED MOBILITY N@RMAL CFRACTIBN/Y EAR SWI7 SWITCH TIME 7 (YEARS)] UR UNDEREMPLOYED/8B RATIO CO! MENS [@NLESS) 'SwTe SWITCH TIME 8 (YEARS) i UTE UNDEREMPLAYED % LABOR CMEN/YEAR) swt SWITCH TIME 9 (YEARS) if UTLN UNDEREMPLOYED 1 LABOR NET CMEN/YEARD SHT1O SHETCH TIME 10 CYEARS) UTLP UNCEREMPLOYED 1% LABBR PERCEIVED CMEN/Y EARD

UNDEREMPLAYED~ 10-1 ABBR PERCEPTION TIME CYEARS) UNDEREMPLOYED=TRAINING PROGRAM CMENAY EARD UNDEREMPLOYED-TRAINING RATE CFRACTIQN/Y EAR) UNDEREMPLOYED WORKING CHEN)

WORKER HOUSING CHAUSING UNITS)

WARKER-HOUSING AYERAGE (HOUSING UNITS) WORKER-HOUSING-ADEQUACY MULTIPLIER COI MENS! BNLESS) HORKER-HOUS I NG~ADEQUACY -MULTIPLI ER TABLE

WORKER-HOUSING AVERAGING TIME CYEARSY

WORKER-HOUSING ASSESSED VALUE CTHBUSAND OGLLARS/H@USING UNE T) WARKER"HOUSING CONSTRUCTION CHOUSING UNI TS/VEARD WORKER-HOUSING CONSTRUCTION DESIRED CHBUSING UNE TS/YEAR) WORKER-HOUS1NG-CONSTRUCTIQN LABOR CHAN@Y EARS /HBUSING UNIT) WERKER-HBUSING CONSTRUCTIGN NORMAL CFRACTIGN/Y EAR) WARKER-HBUS ING-CONSTRUCTI ON PROGRAM CHGUSING UNI TS/YEARD WORKER-HBUSI NG~CONS TRUCTIGN RATE (FRAC TIGN/YEAR) WORKER-HOUSING ENTERPRISE MULTIPLIER (01 MENS BNL ESS) WORKER-HOUS 1NG-ENTERPRISE-=MUTIPLIER TABLE WORKER-HOUSING FACTOR (DIMENSIQNLESS)

WORKER-HOUS{ NG-GROWTH MULTIPLIER CDi MENSIGNLESS) WARKER-HBUSI NG~GROWTH-MULTIPLIER TABLE

WORKER-HOUSING GROWTH RATE CFRAC TIGNAY EARD WORKER+HOUSING GROWTH RATE 1 NI TIAL CFRACTIGN/Y FAR) WERKER-HGUSING LAND MULTIPLIER COFMENS IGNLESS)

WORKER -HGUSI NG ANO-MULTIPLIER "TABLE

WORKER-HBUSENG MULTIPLIER DI MENS! BNLESS? WORKER-H@USING OBSOLESCENCE CHAUSING UNE TS/VEAR) WORKER-HBUSINS-<ZBSBLESCENCE MULTIPLIER (Di MENS? GNLESS) WORKER +0 USI NG-BBSBLESCENCE-MUL Ti PLIER TABLE WORKER-HOUSING QBSBLESCENCE NORMAL CFRACTIGN/Y EARD WARKER-HOUSING PEPULATION DENSITY CPESPLE/HBUSING UNIT) WORKER-HOUSING TAX MULTIPLIER COI MENSIGNLESS> WORKER-HBUSING=TAX-MULTIPLIER TABLE

WORKER-H@USING UNDEREMPLOYED MULTIPLIER (OMENS! NLESS) WORKER-HO US! NG-UNDEREMPLOYED-MULTIPLI ER TABLE

are

D Analyzer Tabulation

variable A, a level variable L, an initial value statement N, a rate variable R, a table of values T, or a supplementary equation S. The fourth column lists each variable, equation number, and equation type in which the quantity in the first column is used.

NAME M2, T WED IN EQUATIONS FUR

AMF 3.1 © AMM,3 yA

AMM 3 A ANMP,,2,L/UDM, 14 yA

AMP 2 L UAyTZR 2.1 0 N

AMMPT 2.2 AMM, 2,

AREA 43 CFB, 3A

AV) 128A 1C4121,A/7A1,125,4

BAY 150A AV, a2 8LA

BOM 115A M80, 114,8

BOMT 115.1 T BOM,195,4

Oo 6 WsS7,APUT, 71h NECD, 10244 010,117,2 1IG6T NH BAY, 13094 A.Di 4 132 yA 0100, 16,4

DIAV 130.5 C BAY, 130,4

DICF 102.3 ¢ NECO,10¢,A

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OOM 178° A OD, 147,8

OION 197.1 © DID; A47%R

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OM 37.3 6 MSTA

oy 151 ec

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HAY 129A AV, T28yh

HUT 70 ALF, 69,A HCP, 143,

L 29 Wy RP 9A AR, 26,AAB,28,R

2961 NM LTU,S05RA.TM532R/MLR,S9AAASHTR

UHR) 48,A/.D 49 ,R/MPR, SB A /TNg 12648 ER, 135,AA TPG, 141A

LAT RLF

UAF 347 C LAMAS,A

LAM 87 A LAMG ASA

LAHMT 47.1 T LAHH,AT,A

CAM OANA LAMAR

LAJMT ANT T LAU A

LAM 8S A LANP (42,L/LDM, 5044

CAMP 82 LEASH R

aN

LAMPT 8242 € LAMP A2yL

LAN AT.e7 CLA, AT,

LATM 86 A LAM, ASA

LATHT 46.4 1 LATH,AG,A

LAU 45h LAMAR

LAUMT 5541 T LAUM,A5 A

{828 R Ly 2aeh

LBR 28.1 C LB,28,R

LCHCO 150A LOC,131,4.CHP,149,8

UCHCL 13744 C LOC,13454

LHP' 4 R UHPR,12,4/H,95,L

UCHPC 150.1 C LCHCD, 150A

UCR 158A PHC, 64, R/WHC,82,R/NEC, 101,8 CHP, 1498

CRT 13861 T LCR, 138,A

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LO 131A LS 13548

COL 132A LS 133, A

LOH 50k LDA

LOMT 50.7 T LOM,50,4

LON 49.7 CC LD,89,R

LEM ADA LM Sk

LEMT

0.7

LENGTH 154.7 LF @

Urs LHR ts tir LUT LMF uM CMe

LPT MN: LPH tpP LR

LRP

LRPT LSH USHT u™ LIPG LR LTU LUM cuMT LR

9.2 48 133 yn 31 het 34 BSI 33.7 33.2 S201 961 2 134

B9 139.61 139.2 2a 281 32

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25 25.1 26

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BAY, 15054

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A A PHCD,65,4/PHOM, 80, MMT 38.1 T WLM)SB,A i PH OR PHAThaMene MLR 390A MLM,38,A PHOM 80 A PHB, 79,8 MP 52 LL P49 RAIR 36,4 ALR 39,A NPB, 51,8 PHOMT 80.1 T PHEM,80,A

52.1 N WA,53 ,R/UPR{58,A /MHR, 61 9A /MD, 2 ,R PHON 7311 Photo

TH, 12 6A PHD 6144 CMBR 61,A B54 Ro WP y52yL I PHM 72 A PHM, 66,4 MPBR S441 CMPB,51,R j PHPMT 72.1 1 PHPM,72,A PFS 941 CPO AAMHR, 61,A/TNy 1268 PHIM 75° A PHM, d6,4 MPR 580A MAPH,S7,A/PHPM, 72 yA PHINT 73.1 T PHTM, 73,4 MR 36 AMS, 35, A/MAIM,56,A ZEMM, 104A I PLICT 158.3 ¢ PLIPER ASA bo ce ' eso i PLTHAX 15242 C PLIPER,15248 0 p55) I PLIMIN 152.1 © PLIPER,152,A NE 100 kL MJ,37,A/PUT, 71,4 /NECD, 102,,A /NEGR y 109 A j PLIPER 152) A LTPER, 1525, 100.1 N -NEA,110,L NEA, 110.7,N/NED,117,R BAY, 13044 i PRICT 153.3 © PRIPER,153,A LDL 41324 PRIWAX 153.2 C PRIPER,1534 NEA 110 L_NEGR, 109,4 PRTMIN 155.1 C PRTPER, 15358

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NEAT 11042 € NEGR,109,A/NEA,110,L AREA, 110.1, PUT Ti A LPO, 69,A/NECP 51458 NEAV 130.1 CC BAV, 130,A SHAM 98 A SHDAASF, NE 107 RONE, 100, i SHAMT 98.1 T SHAM,98,8 NECB 102 A NEC, 101,RA0C, 151,A : SHO 96) ROH, 95,L NECF 102.1 C NECD, 10254 i SHOF 97.1 € SHDM,97,A NECL 43143 C LOC, 131,A i SHOM 97° A SHD,96,8 NECN 102.4 C NECD,102,A i SHON 96.1 C SHD,96,R WECP 445 A NECD,102,A I SHIP 144 A SHD,96)R NECR 485.1 © NECP 14548 : SHOR 184.1 C SHOP, 144A NED 117 -RONE, 100,148, 19354 I SHLM 99 A SHOM,97,A NEDN 144.1 C NED,141,8 i SHLMT 93.17 SHLMIS9°A NEGR 109A PHEM, 74, A MHEM, 89,4 /EGM, 108,A i SID 156.6 R NEGRS 110.3 C NEA,110.1,N ' SHTT 140.2 CC UTP4140,8 NEL 432.1 C LOU, 132,A suT10 150.2 ¢ ichp,750,a NER 37.4 CMU,37,A : SwT2 181.2 C LTPG,141,4 e 9 A TPCR, 8,4 i SWTS 182.2 € PHEP 14254 PEM 7 A ANMS,A } SHT4 443.2 6 WHCP S143, A PEMT 7.1 7 PEM, TA : SWTS 184.2 C SHOP, 1A,A PH 78k MAR, 61,A/PHCD, 655A ATUT, 70,8 PHER 9 76,4 I SHI 145.2 CC NECP,145,0 Bet MN PHA, T7gL PHA, 77. 1, N/PHG, 79,8 MAY, 129 gh I SHIT 146.2 DIBPSTRGRA PHCP,142,A I SHT8 T8742 CC TPCSP,147,4 PHA TTL PHER, 76,4 i SWS 148.2 CWP, ThB,A Ta ON } TAL 125K TRN,124,A PHAM 67 A PHI 66,A / TW Brac Teal2 tah ARN, 124k 6101 PHAMS67)A 1 A TPCR,B,A Put THe PHGR, 76,A/PHA, T7pL PHA, 77-1 9M I Th 127A Ny id6,A PHAV 129.1 C HAV, 129,8 I TCMT 12764 7 TCMy12 754 Pe HOR PH, 78, : TIME UTP 5 180,A A. TPG, 14144 /PHCP , 142 4A ATHCP, 1434 PHCD 65 A PHC, Gb RALOCy 154A i 'SHOP ,144 A NECP, 145,A /01 DP, 14.5,A TPCSP 4 187,4 PHCL 134.1 € LOC, 157,A i UWP 5148,AA.CHCD,150,A PLTPER 152A PRIPER , 153 4A

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TPCR8,A PHEMT 78.1 T PHEM, 744A : PCR 8 A PEM, 7,A/UEM,2 7,8 A. EMy40,A PHF 66.1 PHM, 66,A TCS 187.4 C PCSP, 147A PHGM 75 A ot i TPCSP 147 A TPCR AA PHGNT 75.1 T PHGH, 75,4 : TR 122, A_LAT,86,4 MATH, 59,A /PHTM, 73 A WHTM, 88,4 PHOR 76 =A PHGM,75,A ETM, 107,410, 12444 PHGRI 77.3 C PHA, ?7.1)8 TRY 124 A TRNP, 123, /TRNP, 123,41, PHLM 68 A PHM, 66,A PHCP,142,A TRNP 123 LTR 122A PHLMT 68.1 T PHLM,68,A 123.1 8

TRNPT 123.2 © TRNP,123,t : WANT 85.1 1 WHAM,85,a RT 72241 -T Ry 12244 I WHAT 9242 C WHGRY91,A/MHAS92 4L WHA, 92 64,N TU 126.3 Ny 12694 / WAV 129.2 C HAV, 1297 ' Uo 16 LUN 1 RUHR, 6)47P,9,A /UNPR, 12,4 : Wie 82 OR WH SUL

16.1 N 10513, RB, 15, R/UH, 18,4 7012 1,4 wico a3 A wHtyad,R.0c,134,4

LUR,26,A MPR ,58,A/TH, 126A UR» 13 74 WICL 131.2 C LOCA UIP, 1404 USP, 148A A CHEB, 15058 WEN 83.7 CWC, 837A UA 1 Ro U,16 yb. WHCP 6143 A WHCD, 83,4 WAM A AMMS A : WHR 14341 CMHC, 13 yA UAMMT 4.17 UAMM ASA : WHEM 89 AWM, B4,A UAN tel Cc W,TI,R } WHEMT 89.1 TT HHEM, 89,4

B15 RU TEL : WHF 84,7 Cw, 84,8 UR 15.1 CUB, 15,R i WHCM 90° A WM asta uo % Ro Uy 16, WHGMT 90.1 T WHGM,90, A WH 1k A U,15,R WHR 91° A WIGMA9O;A tout ast Tula : WIGRE 92.5 6 WiA,S2.4N . wise iM 86 A WHIM B8,A/WHCP 4743 58 ALCHCD, 1 UM 27) UMM,238 I WIUNT 86.1 To MLMyBeeA PA CHCOs 15048 UEMT 2761 TT UEM;2 754 : WM 84 A WHO, 854 WHOM, 94 58 us 5 © WHRS6A/P,9A/TN,126,4 : Wid 93 OR WHyBT,L UH, 95,0 Ure 19 A Uy 18,4, I WHOM 94 A WHO,93,R FAT 19.1 UFW,19,8 : WHOMT 94.1 TT WHOH,98,A 95 WAR, yA UT, 7048 SHD,96,RAIAV, 129, WHON 93.1 WH, 93,48 9561 N SHOP, 1448 Wied 48.1 CUR ABA WAY 129.5 C HAV, 129,A ; WHTH 88K WHIM 8A Wie 5" A AMSA : WHTMT 8841 T WHTHy@B yA UOT 5.1 T UHM)A WHUM 87 AHN, 84,8 UPD 6.1 CURA GA : WHUMT 87.1 T WHUMyeT A UHM 11 A ANIMAS yA I UPHT 1401 T UHPMT4,4 : UPR 12° A UHPM TTA GR 6A UM, 3 AZSHAM, 98,4 W136 AUR, 17, WH 10 A AN 3A : WHT 40.7 T LUM 10,8 WP 148A Wy 1B 6pA WPC 78861 CWP, 148,A UR 135° A U5, 136,8 ' ULRT 135.1 T ULIR,155,A : UM 27 A ANMy4 A UMF 2361 UNM,oS3A i Um 23 AUP, 22,L : UMP 22k UFL,T7,R 22.108 WPT 22.2 C WNMP, 224, I UN 17,4 C UTLGA7,R : UR 187A UJMy10,4/0F, 19,4 i UIL 17 RUT GL ZUTLP{20,LA 2941 UTLN, 154,8 I UIEN 158 5S } UTP 20k UM2 14 2004 N UILPT 20.2 C UTLP,20yL : uP 180A HL A7,R : UTR 490.1 «UTP y140,4 i Ww 18 ULI 7_R ; Wo BELLARY 484A HUT, 70,4 /MHCD, 854A HGR 91,A I 8161 N I WHAASZ gL HHA,S2 41, WARIO, 93 JR AAV, 129,8 (WA 92° LHR, 97,8

92.1 N :

WHAM 85 A WHM,B4,A ' E Model Equations

Following are the model equations used for the urban area life cycle simulations in this book. A description of each equation is found in Appendix A.

The model used for the simulations that start with the urban area in equilibrium Stagnation are the same as the following except for the changes in initial condi- tions which are given in Appendix A,

Section A.14.

WO OOD ON RAW Fe ON TD,

* NOTE

CTY GROWTH

NOTE -btebbototobiok UNDEREMPLOYED SEC TBR

Be AP ARO ORO RAR OPAR Ar OFOZrOD

UASKLSCUAK+L OK) CUAND CAMMPKY

UAN=.05 AMMP 6K =AMMP od+CDT/AMMPT) CAMMAJ "AMMP J) AWMP=7 AMMPT=20, AMM. K=CUAMMOK) CUHMSK) CPEM.K) CUJMOK CUHPMAK) CAMP)

TABLEC UAMAT y UMAK 40, «15, 6025) TETATADTALTASLArY IBHLC UHMT, LHR 4K 50,2, 225) UHMT=2 05/204/252/16 1/17 4/42/01 405 UPR AK =C Uni UPS) /CUH KA UHP DD

2

BHLCP EMT y TPCR 4K 9043405) PEMT S02 /46/1/1.0672 04/342 /4 TRCRAK ECC TEeK/PoK)+TPCSP aKI /TPCN

50 Pak) CMPFS)4C LK? CLFS)+C UK) CUS)

FABHLC UJMT 4UR.K, 0,3, 025) IJMT=2/2 7169/19 6/17 of a7 03/42/0157 «1/2057 402 UMPMLK=TABHLCUIPHT, UHPR AK, 0, 605, 07) UNPMT=1/142/1 65/1692 64/3

GHPR .K 21 CHP. JK/ULK

UD.KC=CUDN) CULK CUDH.KD

BEzrozaro

RC OR ARP ARO DOM RAR ORD ENO DOB ODM >> ae UPO MORK RO ERE Haw

Model Equations 275

uDN=.02

UOM.K=T ABHLC UDMT, 14 444LEGKC AMHK) 43,3, 1D UDMT=8/4/2/1/45/,25/, 125 Seat BK! UsK> CUBRD

R601 UK =U JECOTD (Une HUB IKEL TU IK = UD JK"UTLoJK) v1200

sebbbi LABBR SECTAR UTLAKL=C UMD CUWAKD CUMMP.K 4 UTPSK UMN,

UsK) CUFWAK? BHLC UFWT, URAK 5054, 1) UFWT=49/.8/.5/433/ 225

UTLP AK =UTL

UMMP.K EUMMP. JC OT/UNMPT) C UMM, J=UMMP J? UM

4

TABHL(LSMT,LR «Ky 04245) AL201 ob Le2 TABHLCLUMT LURK 40,5, 1) LUMT2.2/67/71/1.2/1.5/1 04 LURK =. K/UK UEM.K =TABHLC UEMT, TPCR .K 4043445) Le 1/15/11 LBKLECLeKD CLBRD

LBR=.01 tsar" DTD CUTL. JK#LB JK =L TMeSKELA SKALDK-LTUUK

LTUKL=CLeK) CLLF «KD LL KETABLEC ULFTsLR.K 0,2, 65)

+ LLFT=0/,017.03/.17.3

LTHeK L=CLMND (Lek? CLMMP.K>+L TPG.K UAN.02

UHMP 6K =U MMPS JE CDT/LMMPT CL MMe dLMMP 6 J WNP =1

5 MS Mok) CMLMAK) CLEMSK) CLMPD

FAGHLC MSMT yMR.K 50,2, 425) WSWT=243/208/2/106/1/,5/.8/ 01/405 MRAK=MPAK/MJK

He K=CNE 6K) (NEMO +C MB OK) CHBMD-+(D1 sKOCDLMD

ABHLCMUMT,HLRAK 50, 02» 405) MATE62/6T/1/1.2/1 03

MLRKEMPAKA GK

LEM.K= TABHLC LEMT ,TPCR «Ky 0,3,05) LEMT=.2/.7/1/163/165/1,6/107, LAGKLSCLAND (LAK) CLAMP .K)

LAND ,03,

LAMP.K =U AMP. JSF CDT/LAMPT) CLAMS -LAMP oJ? LAMPET

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4242 wR W361 4

Mad 45 45.7 46 4661 a7 47.1 48 4841

BUNNY YES eS s Boh Gen

a APO DOP AP AP AR a POPO O00 RAP ARO OF DER AIMO DOM AP ARM aK AKIKO zr OW Ero DEE

LAMP T=15 LAMeK =C LAJMeK) CLAUMsK) CLA TMaK CLAHM6K) CLAP)

-STABLECLAUMT ERK 4052625)

06/2 06/20 4/ V6 B/S AL 027 1K 00D STASHLCLAUMT LURK 50555 1) BABA S/d STABLECLATHT, 16 B4ELBGNC TRAK 4-242 2/1461 03

ABLECLANMT LARK 045545) 3/12/17 05/02 7/017405 LeKALFS) / GHHGKAMHIPD)

LON) CLeK) CLOMAK?

LOM.K =TABHLCLOMT, 1.44*LOGMK LAMsK) 9=3 541) LOMT=B/4/2/1/45/025/ 0125

dpbotdcbioick MANAGER I AL=PROFESSI@NAL SEC TAR MPB.KL=CMP.K) CMPBR)

MPBR=.0075

MPAK=MP J+ COD CLTM.UK+MPB eJK MA oJK MO JK) MP=3990

°C MAN) CMP 6K) CMAMP.K

ABLECMAJMT JMR 6K 402, 625)

T2612 ALB 1h /02/ 01/05

ABHLC MAPHT, MPRK 05415002) MT=63/00/9/142/103/1 03

MPRAKEMPK/CL&KFUSK?

MATM.K =TABLECHATHT, 14444 LOGNCTR K) y=24 52

VATE

JABLEC MAHKT, MHR.K 40,3, 05)

93/142/1/45/ 02/61/0058

NHR AK =CHP .KASPF'S) /CPH LKAPHPDD

PHPO=S

MOAKL=CMON) (MP 4K) CHDMGKD

MON

MOMaK 2TABHL(MOMT, 1 «444LBGNC HAMLK) y~3)3, 1)

MOMTE8/4/2/ 1/45/6257 125

spot PREMIUM HBUSENG SEC TAR PHC.KL=CPHCD.K) CLOR.K) PHCN CPHeK)
(PHMSK)+PHCP oK

05 CPHAMSK) CPHLMeK) (PHPMK) CPHIMSK) CPHEM.K) CPHGM.K) (PHFD

PHE = PHAM.K=TABLECPHAMT ,MAR <K 40,25 625) PHAMT=0/.001/.01/42/1/3/4.4 6/5. 6/6
PHLM.K =TABHLCPHLMT FB 6K 05161) PHUMT=54/09/145/1 66/128/1 9/4 8/1 08/0 7/42/0 LF
K=CHUT. KX LPHAPUT. Ra LPP) /AREA

GRIM O Per OOF Hye ay rae ee

RO RODE" Rt> ODOC ET Ham RH AH Gea HOP ORDEr =m am

Model Equations 277

HUT.K=PH KAW EU AK

PUTAK NESKEMB KDE 4K

PHPH,K =T ABHLCPHPMT ,MPR«K 40501, 602) SAT 2/4 5/1 od

BHLCPH THT, 1. 448LBGN TR AK) 9-2 5192)

UT

ABHL(PHEMT ,NEGR «K, =. 14.15, .05)

216/171 4/7 8/2 2

PHGM.K=TABHECPHGMT,PHGR JK y=5 15015, 605)

PHGMT=42/,6/1/1.4/1.8/2,2

PHGR 4K =CPH.K-PHA.K) /(PHKKPHATD

PHA.K=PHAs JHCDT/PHAT) (PH4J-PHA J)

PHAZPH=CPHGR!) CPHAT) PHD

PHAT=10

PHGRI =.03

PHAK=PH aJ#C DT) CPHC.JK-PHO.JK) PH=5000

PHS .KL=CPHOND CPH.K> CPHOM.KD PHON=.03

TABHLCPHOMT , 1 2442 LOGNCPHMAK) 43,3, 1) 8/26 6/2/14 03/3/02

seeoebcbeKABRKER HBUSING SECTOR WH.K WH. COT) CPHO eJK+WHC UK "HHB eK? WH=21000

WHC.KL=CWHCO 6K) CLCRSK)

HAMeK) CWHL Mok? CWHUM.K) CWH TMK) CWHEM.K) CHHGM,K) WHF)

We

WHAM,K=T ABHLCWHAMTLHR.K 50,2 «25?

WHANT=0/.05/.1/.3/1/1.8/344/2 «8/5

WHLMAK 2TABHLEWHLMT,LFO.K0, 1, 019

WHUNT=44/.9/1.3/1 66/1 8/169/1 68/1 0l'/67/402/0 ABHLCWHUMT gL UR .K yO, 5, 1)

57.B/12ABS/AS

ABHLCHE THT 7, MOFLBGNC TR.K) ,=248,42)

2/61/03

ABHLCWHEMS NEGRAK,-22, 05501)

TETATALTAL Arte

ABHLCHHGNT HGR JK y=01 615, 605)

/ 66/1/16 4/ 4687202

WELK WH AK) / HH KAWHATD

WHA.KSWHA, JeCOT/MHAD CH .J-WHA aS

WHAZWH=CHHERID CHAT) (WH

WHAT=10

WHGRI =,03

HB. KLEGHHON CHK CWHEMAIO.

WEN=.02

WHOM .KSTABHLCWHOMT, 1 44 LAGNCWHHKD 43,3 51

WHONT=2.2/2/1.6/1/277 45/08

Arbeit UN DEREMPLBYED HOUSING SECTOR U.K 50H oC DT) CWHB 6 JK =SHOeIKHLCHP 5JK? UH=1100

SHD.KL=(SHON) (UH.K) CSHDMK)+SHOP 6K SHON=.02

SHOMSK=CSHAM.KD CSHLMK> CSHOFD 'SHOF=1 'SHAMeK =TABLEC SHAMT gUHR K 952505

278 Appendix E

9841 99

9961 9904

&e->- gs aa

=a

s a

AP OP BRAM AP OPO BAe E™WH OV Er ah og' Ver Bp yee iB yraraqnnozmer a

SHAMT=346/2/1/ 6/4 'SHLMeK 2 TABHL(SHLMT,LFO.K y «8,14 605) SHLMTS1/1.2/1. 6/2.2/6

NEW ENTERPRISE SECTOR

andeinpnied NESKANE HC DTD CNEC. KN EDWIK)

NE=200 =(NECD.K) CLERK) NECN) CHECFANE KE MBCFe MB .K+DI CRED «> CEMSK)+NECP. K

a EWM.K) CELMoK) CELJM.K) CETMAK) CEGMAK) CEP

e EMM.K STABHLCEMMT UR Ky 0,2, 25) EMMIS 014 015703/45/1/164/167/1.9/2 ELMSK =TABHLCELMT,LFO.K 40, 1, «13

1015/1 43/T 087 1645/1 4/13/10 7/ 04/0 ELIMSK=TABHLCELUMT LAP .£K 40,2, «25) ELIMT=0/ 4605/4 15/087 7/1057 10 17 168/168 ETMSK=TABHLC ETHT, 1.44 LBGNC TRAK) 4~2y by 1) EIMT=163/162/1/68/45/425/01 EGM,K=TABHLC EGHT,, NEGR.Ky~.1, 615, 205) EGHT=42/66/1/1.5/148/2 2 EGR &K=CNE«K-HEAJK) /(NE GK NEAT) NEA.K=NEA, JE CDT/NEAT) (NE aS -N EA oS) NEASNE~CNEGRID CNEATD (NED EAT=10

apbbtcebblobk MATURE BUSINESS SECTAR NED.KL=(NEDN) CNE.K) CEOMSK) NEDN=.08

EDMSK STABHLCEDMT, 164 4*LOGNC EM.K) 9759551)

EOMT=2108/165/1/ 07/45/05

NB 6K "MB, JECOTD (NED. JK=MBD.JK)

'B=1000

'BD.KL=C(MBON? (MB 6K) CBOM.K?

MBON=.05,

BDM.K=TABHLC BOMT, 14844 LOGNC EMOK) 4-343, 1) BOMT=2/1,.8/165/1/07/65/ a

aRebbeere DECLINING INDUSTRY SECTOR HH K=O) CTD CMBO.JK=DI DeJk) =100

D1 D.KL=COF ON CD} 6K) COLDM.K)+D1 DP.K 'D1 ON: COLEM.K) CEL MAK) COIDF)

'ABLEC DI EMT, 1 «8KLOGNCEMAK) 4-3 434 1) F056 1166/2 07 ABHLCDI LMT LED «K y «8, 1, 605) DILMT=1/1.2/1.6/2 2/6

aplobietetobololek TAX SECTER 'AVoK) CTAND CTR 4K?

TRaK=TABHLC TRT, 1.4 9%LOGNC TRNP AK) p=2.54y 1) TRIE63/.5/1/1.B/248/3.674

Model Equations 279

TRNP.K =TRNP. HC OT/TREPT) (TRNAS =TRNPLSD TRNPSTRN

TLP=200

TUP=300

TCMAK =TABHEC TEMT LURK 50,3, 05) TCMT=2/1.6/7 43/1 21/1497 6: AVeK=CHAVAK+BAV.K)

HAV AK =PHAVAPH KWH AVKWH K++ LH AV UH K PHAV=30

00 D1 Av=700

Peper IIB SEC TER Hoe e NODekAPHCL+WHCD eKHHCL+NECO.KANECL#LCHC! 'DoKKLCHCL

WHCL=1 NECL=20

LOI AK NER NELEMB KKMBLEDH Ke OF L NEL=20

MEL=15

dIL=10

LUeK=LOCAK+LOE OK

URKAKASK

ULAR! ABHLCULURTsLRaK 4042505) URT216 15/48/65/025/01

UGK AL Jaki ULSR KEUUP AK

UR K=UAK/USK

LCR, ABHLCECRT,LA.K 4052565) LORT=0/05/.9/101/1415

uu LRP JHC OT/L RPT) CLReJ=LRP oJ).

u LRPT=S

'retook CI TY DEVELOPMENT PROGRAMS UTP.K SUTREUSKHCLI PCO, 1 9SHT1,TIME.K)
UTR=0

SWT1=0

LIPG.K=LTRAL.KHCLIPCO, 1, SWT2,, TI MEK)

LIR=0

SWT2=0

PHCP K =PHCREPH «K*PHL MaKCLI PCO, 1,S¥T3, TEME.K) Baas NOTE LAND MULTIPLIER TERM WHCP .K SWHCRAHUT. KAWHLMSKACLI PC Oy 1,SWT, TIME.K> WHCR=0 NOTE LAND MULTIPLIER TERM 'SWT4=0

SHOP, K=SHOR4 UH KKCLIPCO, 1,S¥TS, TIME.K>

'SHOR=0

SWT5=0

NECP 4K SN ECRRPUT. Ke ELMAK#CLI PCO, 1,SWT6, TI MEK)

280 Appendix E

V5.7 145.2 146 19661 146.2 187 VaT,7 147,2 148 148,17 158.2 we 10 150.1 130.2 150.5 150.6 150.7 151 159.1 152

155.6 155.7 15568 155.9 156

15661 156.2 156.3 156% 156.5 156.6

c NECR=0 NOTE LAND MULTIPLIER TERM c 'SWT6=0

A OFOP.K 201 DREDI .KKCLIPCO,1,SHT7, TH MEK)

c Ot R=0

c SwT7=0

A TPCSP.K=IPCSKCLIPCO, 1, SHB, TI MEAK)

Cc TPC

c 'SuT8

A UP.K UPC UeKRCL I PCO 1, SWT9y TH ME WK).

c UJPE=O

c SWT9=0

R LCHP.KL=CLCHCD.KD CLOR.K>

A LCHCD.K <L.CHPCKUSK#WHLMAKECLIPCO, 1ySWT10, TI ME.K? c 'UCHPC=0

ct 'SWT10=0

NOTE

NBTE CONTROL CARDS

NOTE

£ OT=1

c LENGTH=250

A PUTPERSK=CLIPCPLTMIN, PL TMAX,PLICT, TI MESK c PLIMENS5S:

ct PLTMAX=5

c PLICT=50(

A PRTPER.K=CLIPCPRTMIN,PRTMAX,PRICT, TIMESK) c PRTMIN=50

c

c

s

UTUNSK SUTL.JK=L TUK PLAT USUsL=L sPHEPy WHW »UHZHC 0, GOES) /MP MC 0520055) NE=EyMB =8 01 =0¢0, 406 x »

PLOT UAR=U,LHR=L sMHRoM JMR=1,LR=2 5UR=3(0,2)/ FO28C0,19/TRNDK, TR2TC0,8) PLOT UszA i020, BTL=L L Tuc 6, 6063) /PHO=A ,WHC=W, SHOSKCO,20€38/NECSC, DI De X —_ 0¢0,263)

PRINT 1) (3.ODAV

PRINT 1) (343) 1 yO} D,D1 OPst (3.2)

PRINT 1 GS.3DLASLCHP yL DyLDCCS.2) gl DI (3.62) gL IC3.29

PRINT 1) (3e32L TMs TUsMA

PRINT 2) (S45) MB, MBD, MO pMPC3.02) NEC 563) pNECCS-3) , NECPC343) pP(3e 1) PHC 32) PRINT 2)(343)PHC,PHCP ,PHB,SHD,SHDP

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PRINT 7) 0.3) MSM, NEGR »PEM,PHAM,PHEM PHGM,PHER

PRINT 7) (0.3)PHLM,PHM PHAM, PHPM ,PHTM, SHAM,SHOM

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PRINT 9) (0.3) UMM, UMMP, UR, WHAM

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