CONSEQUENCES OF TEN URBAN POLICIES IN THE NASHVILLE URBAN DYNAMICS MODEL

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Introduction

The objective of this thesis is to construct a simulation model which will represent certain facets of the city of Nashville, Tennessee, and will illustrate the consequences of various improvement policies. The model is a tool which helps respond to the question so often raised: "What will happen to the rest of the city -- to its people, housing, business and tax base -- if one policy is enacted as opposed to another policy?" Because of the interrelationships known to exist between various components of a city, it is important to understand the secondary, and tertiary consequences of a particular policy. It is known that what happens to the availability of jobs, for example, eventually affect to one degree or another all other urban considerations of a city.

A city the size of Nashville is a very complex social system, with many different components. This complexity makes it very difficult to intuitively understand all the ramifications of various policies. In Chapter III, this difficulty is illustrated by policies intended to improve housing and jobs. In this case, the policies actually made the situation worse in the long run, rather than better. An action that at first appears to be beneficial, but in time makes the situation worse, is described as counterintuitive (a certain action was believed to produce one response but ended up producing a totally different response). This counterintuitive behavior is a characteristic of all complex systems, and to understand them requires construction of a model which will help point to the consequences of different policies. Like all models, it will not produce an exact description of what will result, but it will point to the general direction in which the system, or in this case the city, will go.

The model used in this analysis is based on the urban dynamics model developed by Jay W. Forrester, and is presented in his book, Urban Dynamics.[1] The description of the model used here is intended for someone not familar with Forrester's work. The model is a computer simulation model, composed of three primary sectors, housing, industry, and population. Each of the three primary sectors is divided into sub-sectors based on economic class. The model is also composed of three secondary sectors, taxes, jobs, and city development programs. Since it is nonlinear, an incremental change in housing, for example, will not necessarily result in proportional percent changes in the other sectors.

The description of how the model was developed and the resulting consequences are presented in three chapters. The first chapter puts the Nashville model into the context of general systems theory by outlining the overall structure of the model and the individual components of the model. This chapter concludes with the criteria that will be used to evaluate the policies evaluated in Chapter III. The second chapter presents the parameters of the model that make it relevant to Nashville. Using data supplied by the 1970 U.S. Census, the Nashville Metropolitan Planning Commission, and the Metropolitan Public Schools, the signifi-

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[1]Jay W. Forrester, Urban Dynamics (Cambridge, Mass.: The M.I.T. Press, 1970), pp. 274-80.

cant parameters in the model have been particularized into the Nashville Urban Dynamics Model. A description of how the parameters were determined is presented in this second chapter. The third chapter shows the "normal" dynamics of the model, then the consequences of various policies intended to improve the city. Chapter IV consludes with an evaluation of the policies and recommendations of a "best'" policy.

Following the body of the text are Appendices A and B. Appendix A contains a brief description of DYNAMO, the computer language of the model. Reading this aids in reading the graphs presented in Chapter III, as well as in forming a basis for understanding the actual equations used in the Nashville Urban Dynamics Model as presented in Appendix B.

Chapter I

The Nashville Model

The study of systems dynamics becomes most significant when it is placed in the context of real world applications. This chapter serves as a basis for understanding systems dynamics in the real world context of a simulation model of Nashville, Tennessee. The model is an attempt to simulate the dynamic interaction of different components, such as housing, industry, jobs and migration, within Nashville, in order to determine the consequences of various urban policies over time. The model is composed of the same structural relationships expressed in Jay Forrester's "Urban Dynamics" model, however, the relative relationships between the components within the Nashville model have been tailored to represent the relative relationships in Nashville. The model has been tailored to represent Nashville by using existing data on Nashville. This data is presented in Chapter II.

This chapter describes the Nashville model at two different levels of detail. The first describes the structural relationships. The structural relationships express fundamental assumptions that form the basis of the model. The second level of detail is an examination of the various model components and their interrelationships. Included in this discussion is an explanation of the criteria used to evaluate different policies presented in Chapter III.

The model is a series of interconnected mathematical expressions believed to represent social, economic and to a degree, political relationships in Nashville. In order to define the relationships that exist, the interactions that take place within the model must be separated from actions outside the model. This is accomplished by defining the boundary of the model, which is considered to be a closed boundary.

Boundary of the Model

The boundary of the model is considered closed, because all the interaction which is essential to the behavior of the model is included in the boundary. For the Nashville model, the boundary is rather easy to define. It consists of natural as well as governmental barriers. The natural barrier that defines the boundary is the steep surrounding terrain. Almost 53 percent of the undeveloped surburban land has a slope, in excess of 20 percent, that limits growth.[2]

The governmental boundaries that define the model are the city limits of metropolitan Nashville. These result from the incorporation

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[2]Planning Commission, Metropolitan Government of Nashville and Davidson County, Tennessee, Analyzing Surburban Development (Nashville: Central Printing Office, February, 1973), p. 38.

of old Nashville and the surrounding Davidson County, in 1962, into one metropolitan government with a single taxing authority, school system, etc.[3] This was done to consolidate and equalize the wide variation in public service that had been provided by the many small previous governments.

The terrain slope has in the past, and will continue in the future, to limit the growth beyond the city limits of Nashville. This natural barrier to growth means that urban and suburban development will be limited to the model area being studied. From the point of view of relating a theoretical boundary to an actual situation, Nashville is an excellent city to study. The entire metropolitan area is encompassed and controlled by a single governing body. This single governing body, in theory, has the power to control and coordinate policies that determine how successfully Nashville is managed. It is realized that policies enacted by the state of Tennessee or the Federal government can affect the growth or decline of Nashville's population and economy. This study is concerned however with the growth of Nashville over other cities in the state and nation. The determinant that most directly affects the relative growth of Nashville is how successful its policies are in establishing the most sustaining economic mix of housing, population, and business.

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[3]Robert Bendiner, The Politics of Schools (New York: Mentor and Plume Books, 1969), p. 176.

An inherent assumption within the model is that the environment outside the city limits is so large and broad that it will not be affected by what happens within Nashville. Nashville is viewed as a living system that communicates with the environment, but does not change it. People from the outside cross the boundary, entering and leaving the system without changing the outside environment because of its size, which is viewed as limitless. Naturally the environment will change over many years, but it will change in spite of Nashville, not because of it. As a result of this unidirectional flow of influence, the components within the system have a very different relationship than the components outside the system. The components outside the system that flow in (i.e. people, capital, etc.) cause the components within the system to interact over time in a series of feedback loops. The loops, however, remain within the system. They do not extend beyond the boundary and influence the environment. The unidirectional flow of influence between internal and external components is the best determinant of a system's boundary. In most other cities, the boundary that separates the city from the environment is a fuzzy line. As the city grows in area so does its influence on the surrounding area. In Nashville, however, because of the limiting surrounding topography, the boundary of influence is clearly established by the hills as well as the city's political boundaries.

Relative Attractiveness

The relative attractiveness of Nashville consciously or unconsciously influences the flow of people into or away from its boundaries by its relative appeal in relationship to the outside environment. Recently, Nashville has experienced a net immigration of people from the external environment, but this will continue only as long as those people feel that the opportunities in the city are more attractive than the environment from which they came. If they should begin to feel that another environment has more to offer to them, some of them may migrate out of the city. This relative attractiveness is not uncommon in cities and is frequently exhibited by the flight to the suburbs by the more affluent.

Opinions of attractiveness are not the same for all people, and not all people enjoy the same choice of opportunities of where to live, work, etc. Recognizing these differences, the model includes different attractiveness components that are based on actual attractiveness and perceived attractiveness for the different economic groups.

Examples of attractiveness components are different ratios, such as the underemployed/housing ratio (UHR), tax per capita ratio (TPCR), and the underemployed housing program rate (UHPR). All of these, work simultaneously and produce an attractiveness for migration multiplier, which, when joined with time delays that occur, produce the perceived attractiveness for migration multiplier (AMMP). Migration is based on the perceived attractiveness, and not the actual attractiveness. The basic idea of perceived relative attractiveness is true for all sectors. In some cases, the exchange within the model is the flow of people, in others it is the flow of goods and capital.

Components of the Model

The model is composed of three primary sectors as well as three secondary sectors. The primary sectors are illustrated in Figure 3.1 Three Primary Sectors: Industry, Housing, and Population. The secondary sectors are taxes, jobs and city development programs. Each of the three primary sectors are grouped into three categories that connote economic differences. The categories are:

Population

- Managerial/Professional
- Labor
- Underemployed

Housing

- Premium Housing
- Worker Housing
- Underemployed Housing

Business

- New Enterprise
- Mature Business
- Declining Industry

The definitions of these categories are self evident by their titles. (Specific definitions will be provided in the next chapter.) The principal difference between the categories is that they are generally based on economic groups. The basis for grouping population

NEC	New Enterprise Const.
NED	New Enterprise Demo.
MBD	Mature Business Decline
DID	Declining Industry Demo.
PHC	Premium Housing Const.
PHO	Premium Housing Obsol.
WHC	Worker Housing Const.
WHO	Worker Housing Obsol.
LCHP	Low Cost Housing Prog.
SHD	Slum Housing Demo.
MD	Mgt. Departures
MA	Mgt Arrivals
MPB	Mgt./Prof. Births
LTM	Labor To Mgt.
LB	Labor Births
LA	Labor Arrivals
LD	Labor Departures
LTU	Labor To Underemployed
UTL	Underemployed To Labor
UD	Underemployed Departures
UB	Underemployed Births
UA	Underemployed Arrivals

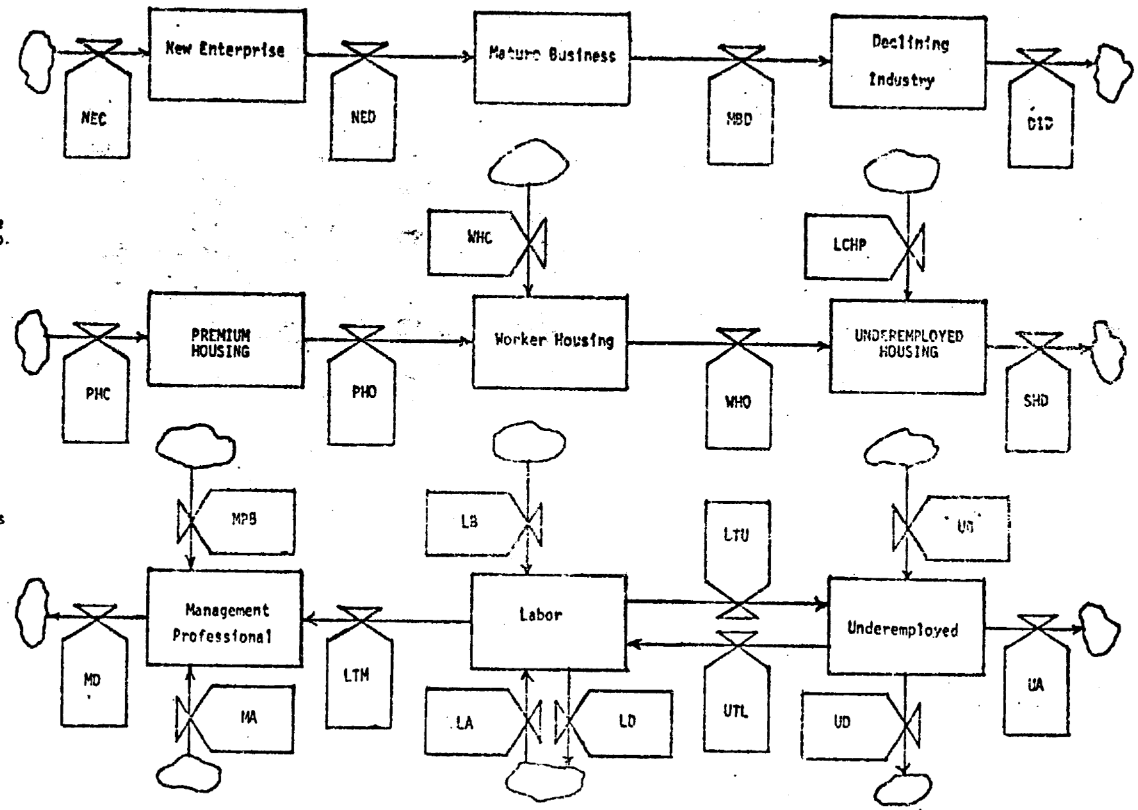

Figure 1.1 Three Primary Sectors: Industry, Housing and Population

into three economic categories is the annual family income. The model is constructed so that economic mobility exists if the conditions are appropriate. For example, if an appropriate amount of money has been spent on education and a shortage of managerial/professional (MP) persons exists, then the mobility from labor (L) to managerial professionals will increase. This same principle exists for mobility from underemployed (U) to labor.

The three groups for housing are determined by the age as well as the demand for the houses. Under normal demand conditions, housing units will be converted from the category of premium housing (PH) to worker housing (WH) as the units age. However, if there is a high demand for premium housing because little is being built, due to a shortage of money or labor, then the normal conversion of premium housing to worker housing due to aging will be reduced. Likewise, if an excessive supply of premium housing exists, the natural conversion process due to aging from the one category to another will be increased. This same conversion principle also exists for the conversion of worker housing (WH) to underemployed housing (UH).

The category "business" consists of industries that are grouped on the basis of economic viability, their age, as well as whether the number of persons employed in that category is increasing, decreasing or staying the same. The subcategory "new enterprise" (NE), for example, consists of new businesses that employ a growing number of persons. Mature business (MB) is older, less viable and employs a relatively constant number of persons. Declining industry (DI) consists of industries that are less viable, employ a declining number of persons, and may eventually die out.

Taxes are the basis for all public institutions and represent either taxes collected or taxes needed to support public institutions at a particular level of service. The current tax rate is determined by the tax rate perceived to be needed. This rate will usually differ from the actual tax rate needed due to time delays and different levels of perception and what is politically feasible. The tax rate has an important influence on encouraging or discouraging new enterprise or housing. If it goes too high, then new enterprise and housing construction will be discouraged. The population mix will also influence taxes needed. A large proportion of underemployed will place heavy burdens on the tax base while contributing little to support it. In time and unless restricted, the taxes needed to be collected will increase, placing pressure on the tax rate. This will discourage new enterprise, which is the best source of jobs for all economic classes. The point to be made is that in time, improper mixes of population tend to undermine the sources of jobs that the people need. One of the sources through which this may occur is by eroding the tax base.

Another consequence of an improper population mix is in the job sector. The job sector in the model computes mobility rates from one economic class to another, and the various job ratios for each different class. This in turn influences the construction multipliers for housing and business. If a period of growth exists and a scarcity of labor results, the construction multipliers for the future will be reduced. However, under these same circumstances, the demand for labor will increase the mobility from the underemployed to the labor class. Over time, this demand for labor will attract more labor and underemployed from the outside environment. Because of the delayed time perception of attractiveness, the demand for labor will be met long before the inflow of labor and underemployed stops. The consequence can be an overabundance of underemployed who place heavy burdens on the tax base which, in turn, discourages new construction. It is clear that one problem compounds others in a vicious circle.

The component city development programs was created in an attempt to correct urban problems that are characterized by such multiple positive feedback loops. This sector of the model is where urban policies are implemented and tested. Chapter 4 will be devoted to testing urban policies through city development programs to ascertain their success or failure. In that chapter the various different policies to be tested will be defined.

Criteria to Evaluate Nashville Model Policies

It was stated earlier that the objective of the model is to develop policies that enable Nashville to survive in its environment, therefore this will be the criteria upon which the policies will be evaluated. Survival is a relative question that must be compared to something, with the conclusion that one set of policies or policy is better than another. Thus, the objective will be to evolve the best set of policies or policy that creates the best possible environment -- this is to say the best mix of population, housing and industry. This will be measured by a set of indicators that will evaluate relative and absolute shifts within the three sectors of population, housing, and industry as well as the tax base that is needed. The best mix implies the least proportionate and absolute quantities of underemployed, underemployed housing, and declining industry, as well as the maximization of the proportionate and absolute quantities of managerial/professional, premium housing, and new enterprise. What results are the simultaneous objectives of minimizing one set of indicators while maximizing another. The objectives here differ from a zero-sum game because the overriding objective is for all residents of Nashville to step-up economically rather than to have one group gain at another group's expense -- as is common in the traditional zero-sum game.[4] Key variables in the model that help identify the proportionate shifts between population and business, as well as between population and housing are the job and housing ratios. These are subdivided into economic groups of underemployed job ratio (UR), labor job ratio (LR), management/professional job ratio (MR), underemployed housing ratio (UHR), labor housing ratio (LHR), and management/professional housing ratio (MHR).

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[4]Handy A. Taha, Operations Research, An Introduction (New York: The Macmillan Company, 1971) pp. 171-75.

It is realized that by attempting to improve the economic plight of all persons in Nashville, this will improve the overall attractiveness of Nashville, and possibly result in an influx of underemployed. This may pose a problem if the number of underemployed continually grow. The approach to this apparent contradiction will be to consider a policy a good policy if it indirectly minimizes the influx of underemployed. To be aware of this, the factors that influence the influx and exodus of underemployed will have to be included in the evaluation criteria. Variables that indicate this influx and exodus are the underemployed arrivals (UA), and the underemployed departures (UD). In order to see the success of upward mobility for the underemployed, the variable underemployed-to-labor-net (UTLN) will also be used as an indicator of the success of a policy.

Chapter II - Nashville Parameters

Introduction

The parameters in the model that describe Nashville are identified in this chapter. They are followed by a brief description of DYNAMO, the computer language in which the model is written. Forrester's generalized urban dynamics model and in many cases below both Forrester's parameters and the Nashville parameters are listed for comparative purposes.
Relationships between the structural elements are described in Chapter II. The structural elements of the model represent the cohesion that "glues" the model together. The parameters or coefficients represent the amount of glue or cohesion existing between the different elements.

The parameters are examined in three sections. The first is composed of variables that relate to land, such as the total area in Nashville and the density of housing and business units. The second set of parameters deals with housing and the population. The third set shows how the number of business and related variables are derived.

Land

Developable Land Area is the amount of land suitable for commercial or residential development. The number of acres of the type were determined by beginning with all the land within Nashville - Davidson County and subtracting out unsuitable land which constitutes almost a third. Most of the unsuitable land has a slope in excess of 20% or is in the flood plain of the Cumberland River.[5]

337,401	total area (acres)
-107,538	undevelopable land
229,863	total developable land (acres)

Since the total developable land is a constant, the equation begins with a C and is written:

C AREA = 229,863

The average amount of land per house (LPH) was determined by dividing the number of acres in residential use (78,885 acres)[6] by the total number of residential units (141,300).[7]

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[5] Planning Commission, Metropolitain Government of Nashville and Davidson County, Tennessee, Analyzing Suburban Development, p.37.

[6] Ibid.,p.7.

[7] Metropolitain Public Schools, Nashville, Tennessee, B.A.S.I.S., Building and School Improvement Study (Nashville: Metropolitan Public Schools, 1971), p.18.

Determining the Land Per Productive Unit (LPP) proved to be more difficult to determine, because the number of productive units had to first be determined. Without at this point going into the determination of the number of productive units (that will come later in this chapter), the LPP was calculated by dividing the number of acres in productive units (16,837)[8] by the number of productive units (49,455).

LPP = 16,837 acres/49,455 productive units = .344

The number of housing units and population size by economic class are closely related in the model. The determination of the number of housing units by economic class was done by first determining the number of families by class, then adjusting the total number of housing units in proportion to the number of families by class

To determine the number of families in each economic class, the economic classes first had to be defined. This subject itself could become the focus of another thesis or major paper, so without going into all the ramifications of what constitutes economic class, the following definition was chosen, based solely on annual income:

Economic Class	Annual Income Range
Underemployed	\$ 0 - \$ 4,999
Labor	\$ 5,000 - \$14,999
Management/Professional	\$15,000 - \$ more

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[8] Planning Commission, Metropolitan Government of Nashville and Davidson County, Tennessee, Analyzing Suburban Development, p. 7.

Once the economic classes have been defined based on annual income, the distribution of the number of families is determined by income class from 1970 census data.[9] The graph on the following page shows the distribution of the number of families related to their annual income on a logarithmic scale.

The 1970 census also provides data on the total number of housing units in Nashville. To determine the number of housing units within each economic class, the total number of units in Nashville were proportionally adjusted by the same distribution as the number of families. The resulting number of houses by economic class are listed below:

Premium Housing (PH) = 21,689

Worker Housing (WH) = 68,973

Underemployed Housing (UH) = 49,474

Having derived the number of families, the family sizes must be determined. Based on the 1970 census figures, the family sizes used in the model are:

Management - Professional Family Size (MPFS) = 3.4
Labor Family Size (LFS) = 3.05
Underemployed Family Size (UFS) = 3.3

These sizes are considerably smaller than the family sizes Jay Forrester put into his general Urban Dynamics Model.[10] Based on

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[9] 1970 Census, Nashville-Davidson County, Tennessee, Tables H-1, "Occupancy, Utilization, and Financial Characteristics of Housing Units: 1970" (Washington, D. C.: U. S. Printing Office).

[10] Jay W. Forrester, Urban Dynamics, p. 37.

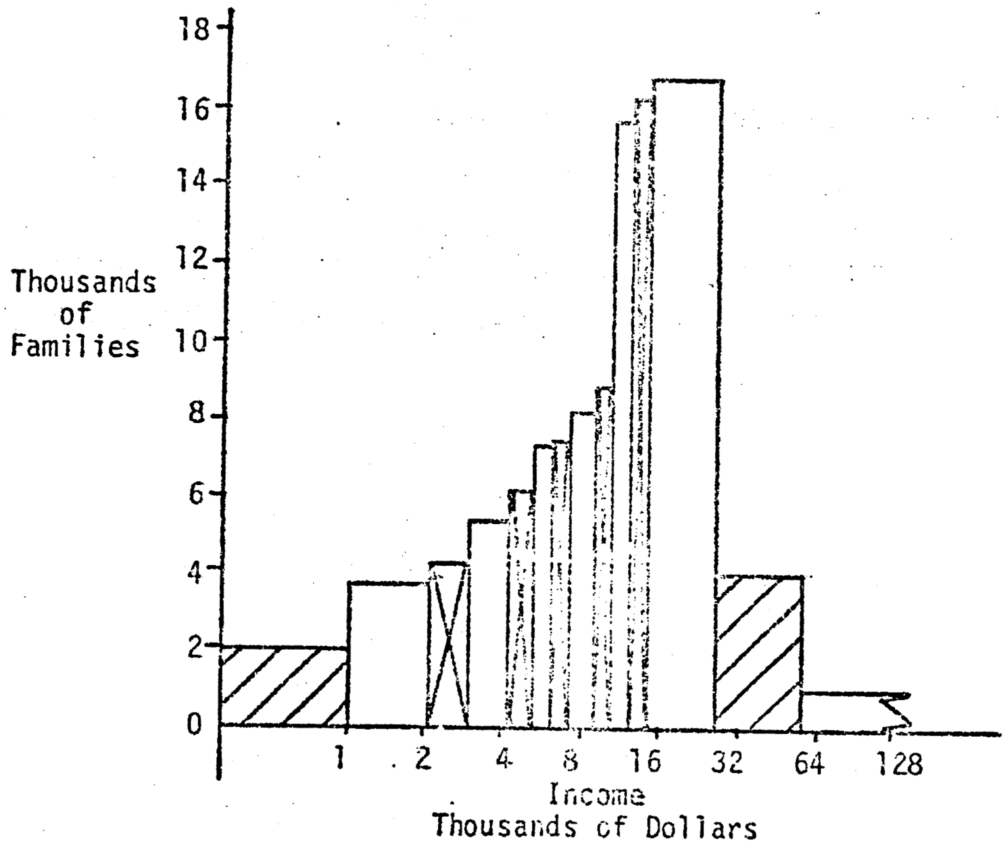

Figure 2.1 Family Income Distribution

experience gained at Community Management Corporation of Reston, Virginia, in evaluating family sizes, it is strongly felt that the sizes used in the Nashville model are reasonably accurate.

The number of persons living in each housing unit (different from family size) are revisions of Forrester's model. The persons per housing unit in the Nashville model were reduced from Forrester's as shown below:[11]

	Nashville Model	Forrester's Model
Premium Housing Population Density (PHPD)	3	3
Worker Housing Population Density (WHPD)	5	6
Underemployed Housing Population Density (UHPD)	7	12

Taxes

In order to evaluate the tax base from residential property, each house in the three economic classes is given an assessed value. The assessed value for each class is an extraction of data from the 1970 Census.[12] Below are the assessed values for each housing type used in the model:

Premium Housing Assessed Value (PHAV) = $30 thousand/unit
Worker Housing Assessed Value (WHAV) = $15 thousand/unit
Underemployed Housing Assessed Value (UHAV) = $5 thousand/unit

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[11] Ibid.

[12] <u>1970 Census, Nashville-Davidson County, Tennessee</u>, Tables P 1-8, "General Characteristics of the Population: 1970."

Implicit in the study of population are the birth and death rates. These two rates are most commonly joined together into one rate called the net birth rate (births - deaths). The birth rate in the model consists of a separate net birth rate for each of the three economic classes. The birth rates in the Nashville model were determined by first computing the overall rate of population increase less net in-migration; then in order to determine the net birth rate for each of the three economic classes, the overall rate was divided into the same proportions as Forrester's model.[13] The birth rates used in this model are contrasted below with Forrester's.

	Nashville Model	Forrester's Model
Management - Professional Birth Rate (MPBR)	.0113	.0075
Labor Birth Rate (LBR)	.0150	.0100
Underemployed Birth Rate (UBR)	.0226	.0150

(Note that the birth rate is constant and is generally 50% greater than Forrester's.)

An important part of evaluating the dynamics of an urban area are the burdens placed upon the public by the residents. Usually this is done by determining the per capita taxes and saying that at the existing level of services, it costs the existing per capita taxes to provide those services. This is fine as long as all people place the same per capita burden on public services, but they do not. It can be assumed that a person of lesser income will place a greater burden on public

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[13] Metropolitan Public Schools, loc. cit., pp. 1-3.

services than a person of greater income and that, as the composition of the population begins to shift and change, so will the cost of providing public services. In the model, the proportion of managerial - professional (MP) to labor (L) and to underemployed (U) all change over time as various different components interact; therefore, the total burdens placed on public services will also change. If the underemployed sector becomes a large portion of the total population, the burdens will be greater. Burdens by income group is built into the model so that proportional increases or decreases in income group size will change the total burdens placed on public services in the form of tax ratio needed (TRN). Because the per capita taxes collected in Nashville ($98.76) is not broken down into income groups, certain assumptions were necessary.[14]

It was first assumed that the per capita property taxes collected in 1967 were sufficient to sustain the existing level of services offered in 1967. Therefore, the taxes needed (TN) were assumed to be equal to the taxes collected (TC). Since data was not available illustrating the extra cost of providing public services to one group over another, the proportions derived from Forrester's model were used as coefficients of taxes needed so that a relative cost was established between income groups.[15] Using this set of coefficients plus the

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[14] Ibid., p. 97.

[15] Forrester, Urban Dynamics, p. 37.

proportion of population that each income group represents as another set of coefficients, the relationship between the income groups and their cost of services (taxes ratio needed) could be expressed in a series of equations.

Adding these equations and solving for X, the cost of services for each class is determined:

Income Class		Proportion of Population	Proportion of Taxes Needed
1.	Management - Professional	35%	$0.75 \times X_1 = .26X_1$
2.	Labor	38%	$1.0 \times X_2 = .38X_2$
3.	Underemployed	27%	$1.5 \times X_3 = .405X_3$
			$1.045X_i$

Where X_i = Per Capita Taxes Needed per class i, and \$98.76 = Per Capita Taxes Needed for all classes, therefore, $1.045X_i$ = \$98.76, and X_i = \$95.70, then X_1 = \$71.50, X_2 = \$95.70, X_3 = \$143.55

The taxes needed per income class are:

Tax per management person (TMP) = \$71.50/year
Tax per labor person (TLP) = \$95.70/year
Tax per underemployed person (TUP) = \$143.55
Tax assessment normal (TAN) = \$35/year/thousand dollars

The tax assessment normal (TAN) is the effective tax in the area outside of Nashville.[16] The tax assessment normal (TAN) is used for comparative purposes between Nashville and the area outside of Nashville.

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[16]Metropolitan Public Schools, loc. cit., p. 98.

Productive Units

The determination of the initial number of productive units for Nashville was difficult because a clear definition was not provided by Forrester stating exactly what a productive unit is. The name of each of the three classes of industry (New Enterprise, NE; Mature Business, MB; and Declining Industry, DI) imply the relative differences between the classes in terms of relative growth or decline; however, this does not define the absolute quantification of these three groups. After working with this mystical concept of productive units for many months, it was determined that their absolute values are based on an estimated dollar value (for tax purposes), and a number of workers per productive unit, housed in a defined land area. The assessed value and the number of workers per productive unit are defined below:[17]

Assessed Value Per Productive Unit

New Enterprise Assessed Value (NEAV) = $500,000
Mature Business Assessed Value (MBAV) = $300,000
Declining Industry Assessed Value (DIAV) = $100,000

Persons Needed Per Productive Unit

	Management - Professional	Labor
New Enterprise	NEM = 4	NEL = 20
Mature Business	MBM = 3	MBL = 15
Declining Industry	DIM = 2	DIL = 10

Notice that the underemployed population sector is not included in the persons needed per productive unit. This is because the economic

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17 Forrester, Urban Dynamics, p. 37.

groups undermployed are primarily employed in marginal jobs and become actively employed in the labor force only when the supply of labor becomes scarce. In order to determine the initial number of underemployed in the model, however, Forrester has estimated the ratio of underemployed for each of the three types of industry. That ratio is:

	Underemployed
New Enterprise	10
Mature Business	7.5
Declining Industry	5

The number of productive units used in the model was based on the number of persons employed in Nashville in 1970. The classification of productive units into the sectors of New Enterprise (NE), Mature Business (MB), and Declining Industry (DI) was done by evaluating the percent change of employment for each industry within Nashville. An increasing percentage of jobs placed the industry group into the New Enterprise category; little or no percentage change placed the industry into the Mature Business category; and a declining percentage change placed the industry group into the Declining Industry category. The industry groups in Nashville are defined below by category:[18]

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[18]Planning Commission, Metropolitan Government of Nashville and Davidson County, Tennessee, Analysis and Projection of Population and Employment Trends in Nashville-Davidson County (Nashville: Central Printing Office, March, 1969), pp. 39, 72 & 86.

New Enterprise	Number of Jobs	Percent of All Jobs
Manufacturing - Durable Goods	19,725	9.4
Wholesale Trade	10,800	5.2
Retail Trade	30,300	14.5
Service - Business and Repair	6,050	2.9
- Personal	19,450	9.3
- Professional and Related	23,200	11.0
Total New Enterprise	109.525	52.3

Mature Business		
Construction	11,800	5.6
Finance, Insurance, Real Estate	11,200	5.3
Service - Entertainment and Recreation	1,200	0.6
Government	27,200	13.0
Total Mature Business	51,400	24.5

Declining Industry		
Agriculture, Forestry Fisheries and Mining	1,400	0.7
Manufacturing - Nondurable Goods	29,575	14.1
Transportation, Communication, and Other Public Utilities	11,300	5.4
Total Declining Industry	42,275	20.2

The number of productive units were determined by dividing the number of jobs for each of the three categories by the total number of persons needed per productive unit. The resulting number of productive units for Nashville in 1970 are as follows:

New Enterprise (NE) = 3,221
Mature Business (MB) = 2,015
Declining Industry (DI) = 2,487

The initial number of "breadwinners" by economic class used to being the model is based on the product of the number of persons needed per productive unit and the number of productive units in each of the three economic classes, plus the number needed for construction. The number of breadwinners by economic class are listed below:

Management/Professional	(MP) =	33,903
Labor	(L) =	119,575
Underemployed	(U) =	213,176

Chapter III

Consequences of Urban Policies

Introduction

Using the generalized urban dynamics model and the parameters that describe Nashville, the Nashville urban dynamics model is used in this chapter to determine the consequences of ten urban policies. Chapter III begins with a description of model dynamics under "normal" conditions (normal conditions are defined as what happens in the model without introducing any new policies). This is followed by an illustration of how the model works, using the variable "new enterprise" as an example. Then the most substantive portion of this paper is presented. This is a description of the ten policies and the consequences of each policy. The following chapter is concluded with a choice of a "best" set of policies, based on the analysis of each policy individually.

"Normal" Model Dynamics

In order to understand how various urban policies affect the Nashville model, the dynamics of the model under "normal" conditions must be first understood. In Chapter 1 the primary and secondary components of the model were presented with examples of how some of the components respond and interact. The most important principle in understanding the dynamics of the model is that all variables (with the exception of constants) affect and are affected to one degree or another by all other variables. The variables differ in the degree that they affect each other and in time delays inherent in feedback loops (see Chapter 1 for an explanation of feedback loops).

In Chapter 1, Figure 2.1, the three principal components of business, housing and population are presented. The difficulty with that illustration is that it does not show the interrelations between the three components, only a summary of the relationships within each of the components. This interrelationship can be seen by examining the slopes of the various different curves. An example of this interrelationship can be seen in the curves of the variables new enterprise (NE), labor(L), and managerial/professional (MP) in Figure 3.1a "Normal" Model Conditions. In the time sequence between 1970 and 1990, the slopes of these curves are very similar. This is because as new enterprise (NE) grows, it requires more labor (L) and managerial/professional (MP) to work in these new enterprises.

The fourth figure in this sequence, Figure 3.1d, shows that in this same time sequence of 1970 - 1990, the rate of worker housing construction (WHC) grows in order to meet the demand for worker housing. As the demand for housing grows stronger, more worker housing is provided until suddenly the labor/housing ratio (LHR) falls

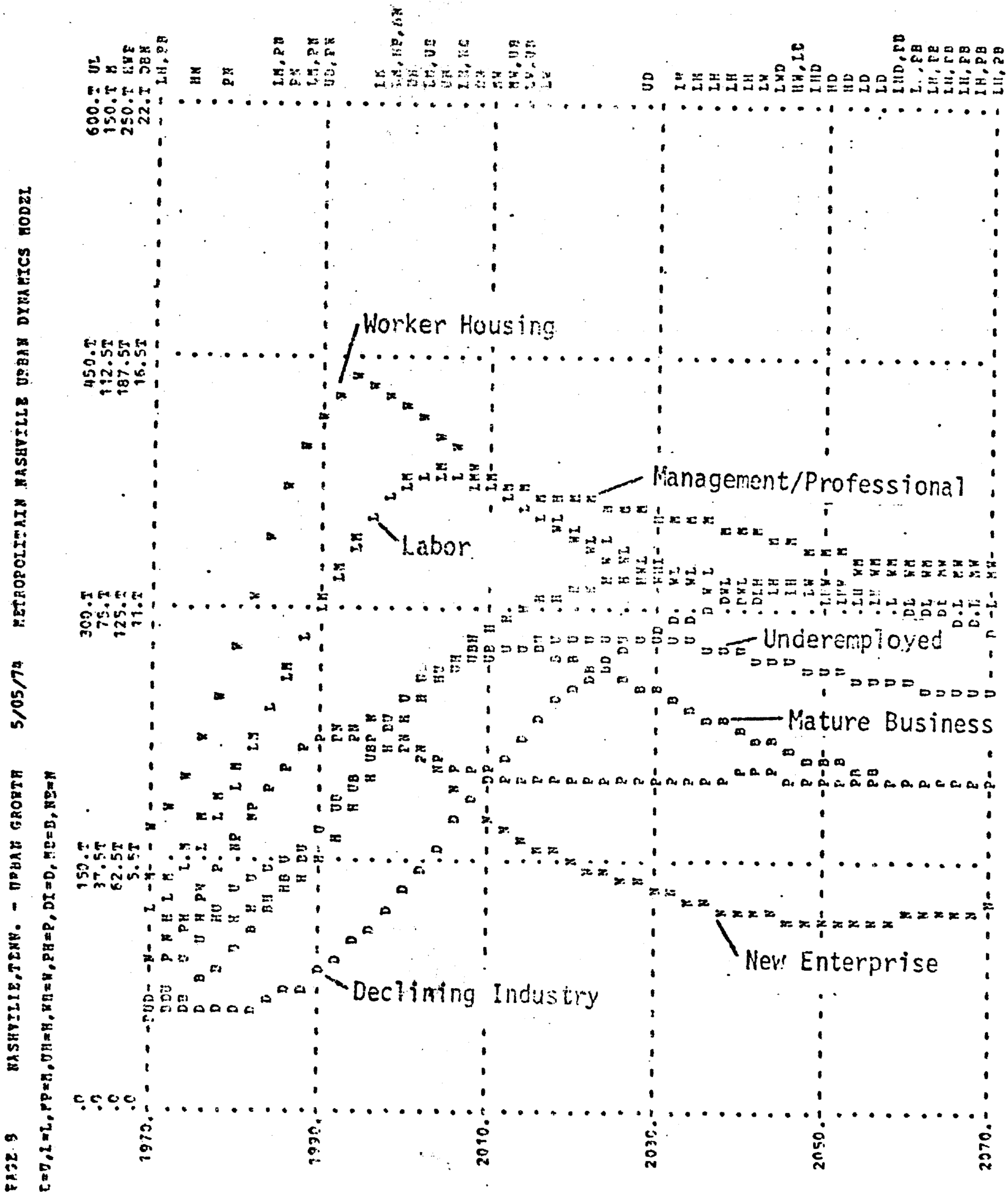

Figure 3.1 a "Normal" Model Conditions

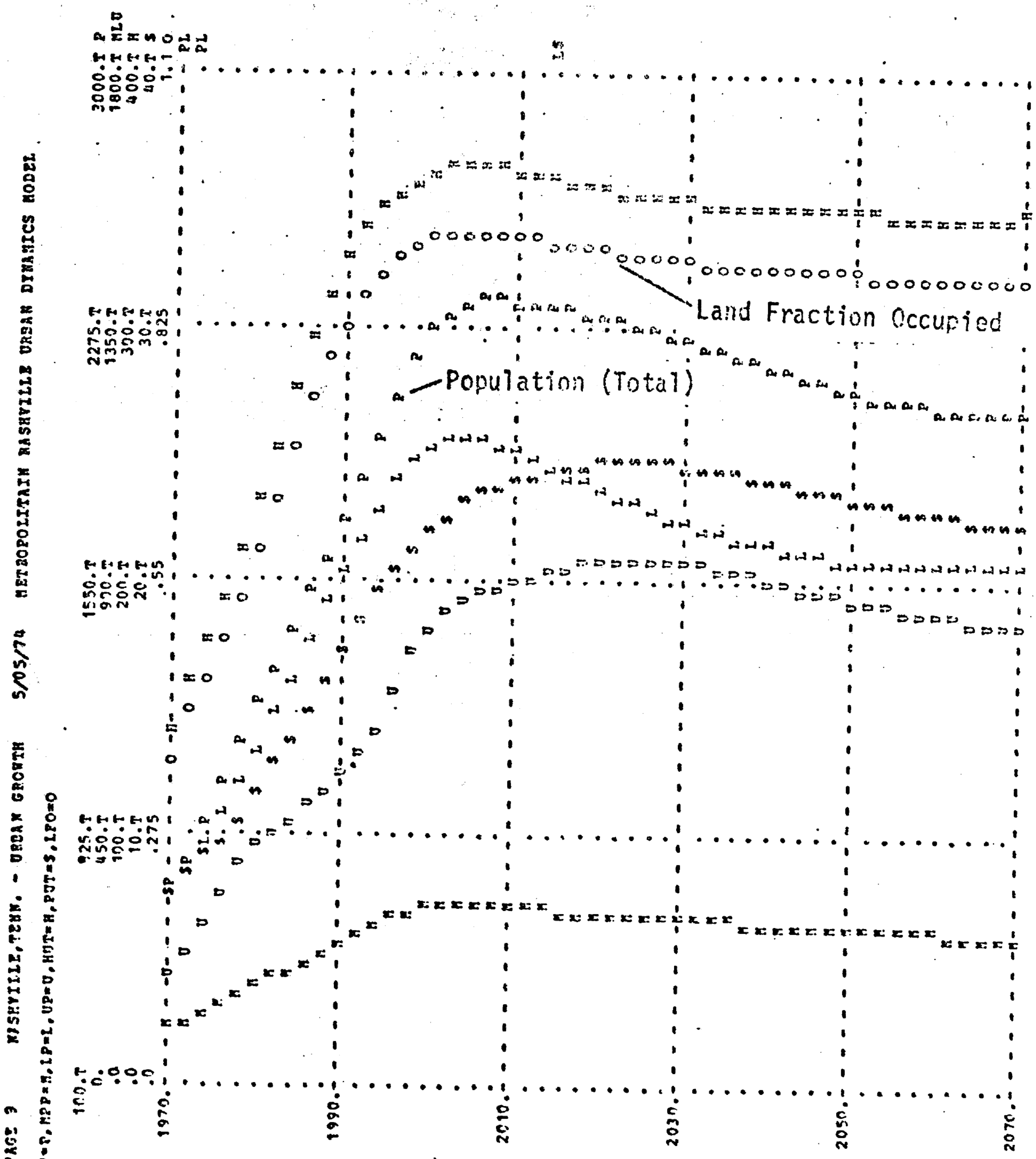

Figure 3.1 b "Normal" Model Conditions

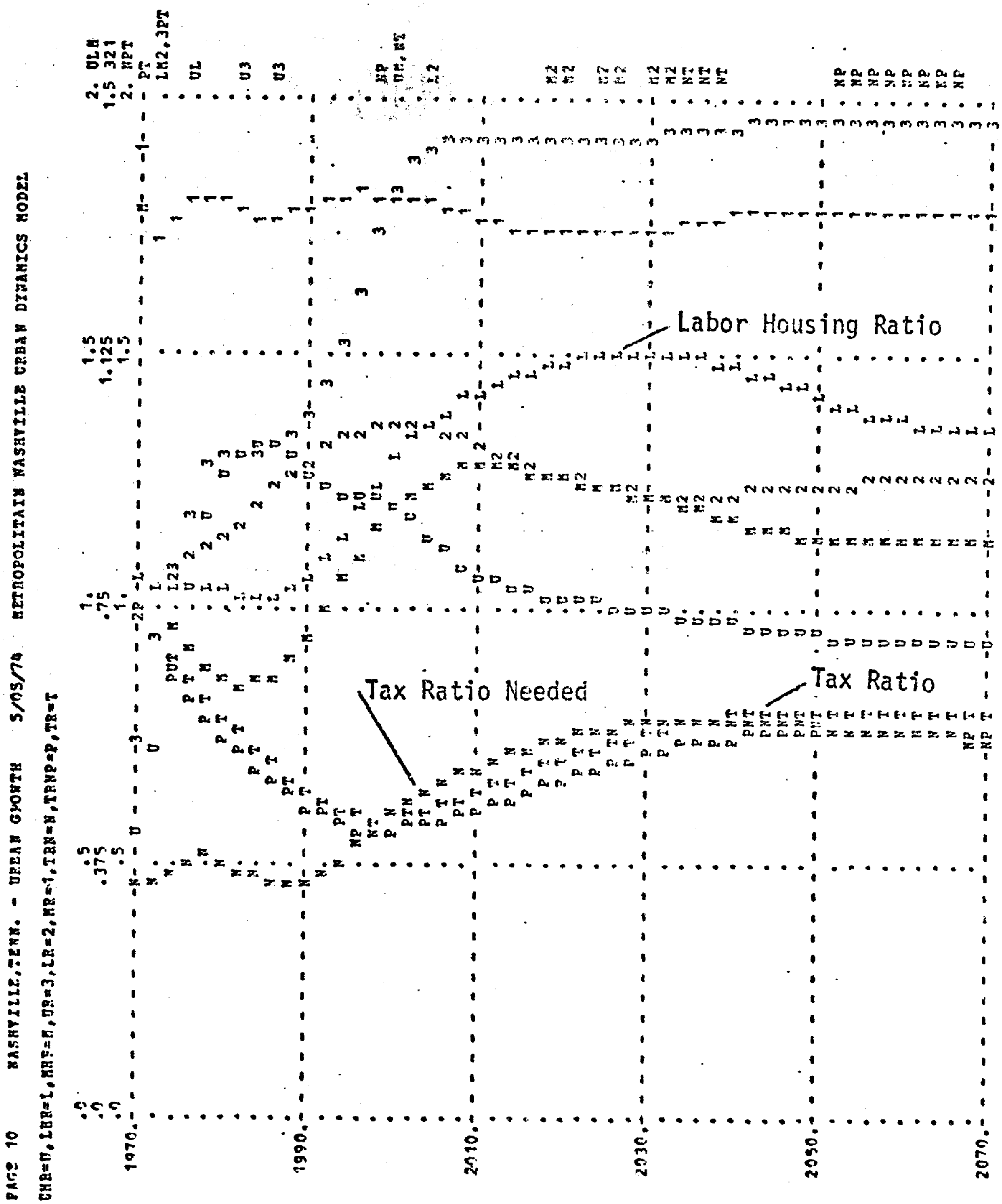

Figure 3.1 c "Normal" Model Conditions

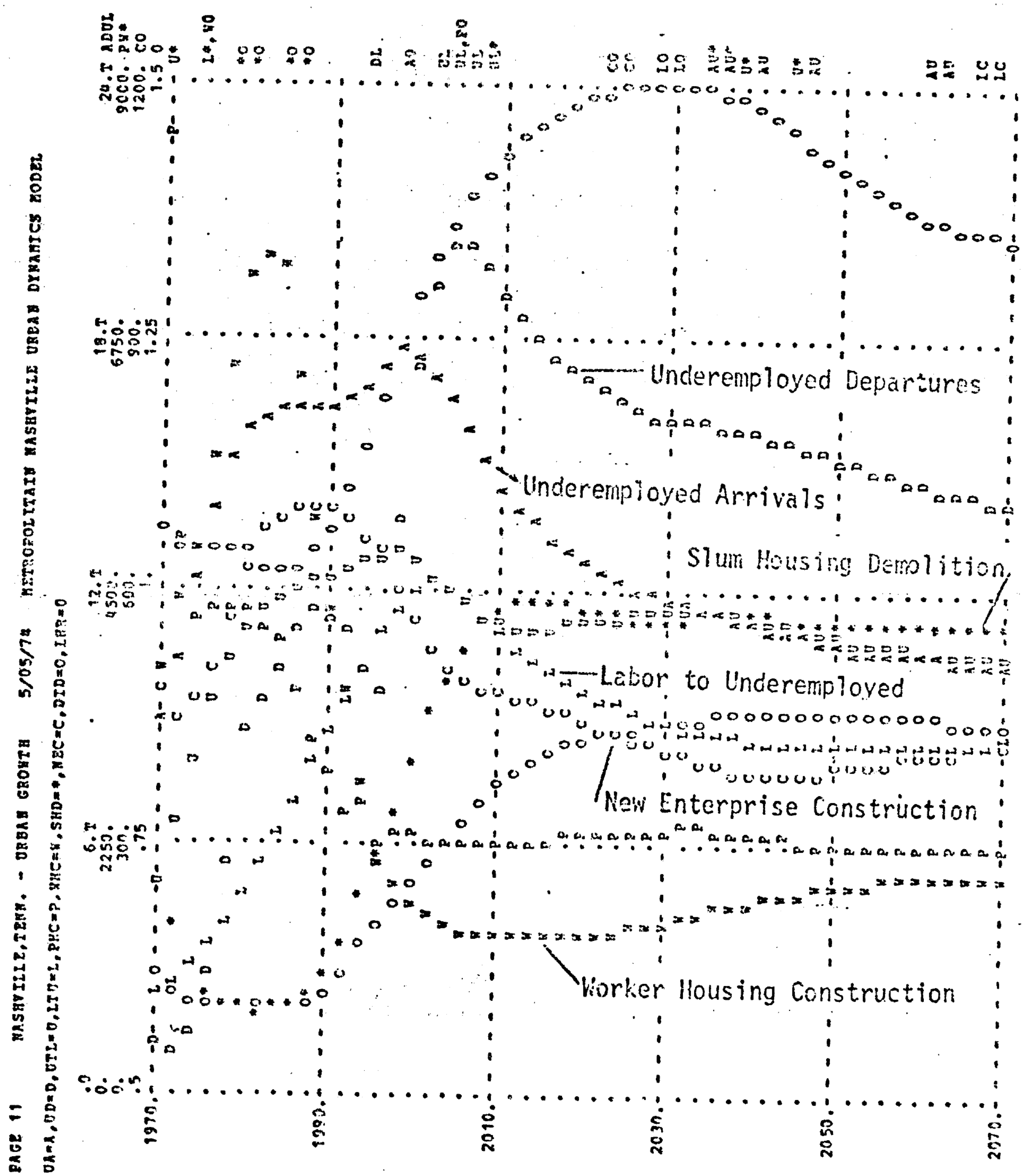

Figure 3.1 d "Normal" Model Conditions

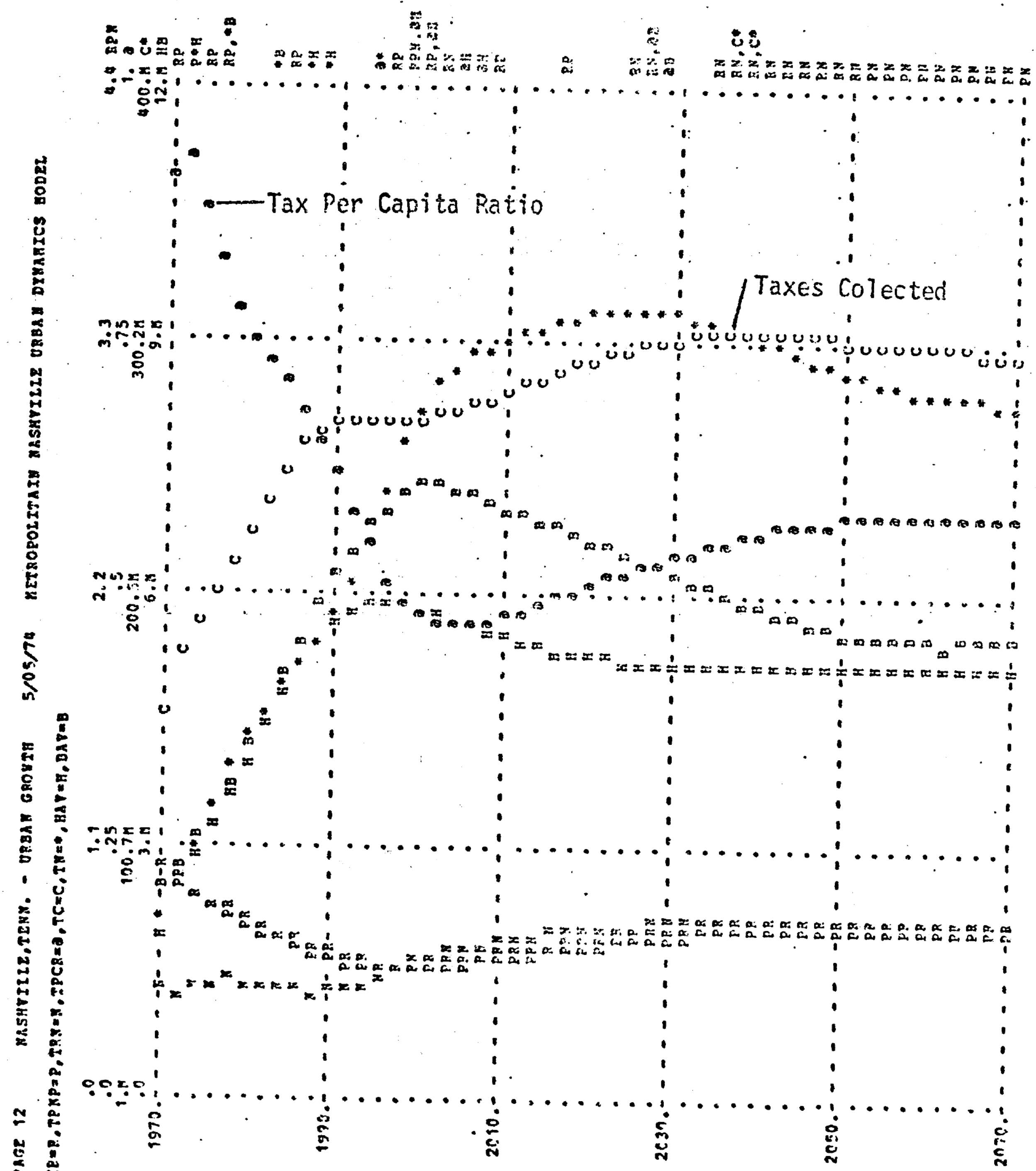

Figure 3.1 e "Normal" Model Conditions

below 1.01 (not shown in this figure) indicating an excess of worker housing being supplied, and the worker housing construction (WHC) rate immediately falls below its initial 1970 level. After this, the slope of the curve worker housing (WH) in Figure 3.1a begins to change and, in time, the total amount of worker housing (WH) declines.

In order to meet the demand for labor during this growth period, many underemployed move into the category of labor in order to fulfill this demand. This increased economic mobility from underemployed to labor is shown by the curve underemployed to labor (UTL) in Figure 3.1d. Later, after new enterprise has peaked in the year 2000, and begun to decline, less labor is needed and the underemployed to labor curve (UTL) declines.

All during this period of growth, labor shortage and upward economic mobility, individuals outside the boundary of Nashville, particularly underemployed, are attracted to Nashville. This is shown by the increase in the underemployed arrivals (UA) in Figure 3.1d. Underemployed arrivals are determined by the perceived level of attractiveness which results from the actual attractiveness experienced by the underemployed residents, but with a time delay. Because of this time delay, underemployed continue to arrive even after job and housing opportunities have become unfavorable. This arrival continues past the peak of new enterprise in the year 2000 and then levels off and begins a long decline four years later.

New Enterprise - An Example of Model Dynamics

During this discussion of the dynamics of the model under "normal" conditions, what happens as a result of the growth of new enterprise (NE) in Nashville has been shown. What will be explained here is why new enterprise grows, then goes into a decline, and levels off at a point slightly higher than when the simulation run began in the year 1970.

The most simple explanation for the growth and eventual decline of new enterprise is that the conditions within the model are ripe for the growth, then change, and later result in decline. To understand this, the influences on new enterprise will be explained in some detail.

The variables that make up new enterprise (NE) are expressed in the following formula and consist of:

L NE.K = NE.J + (DT)(NEC.JK - NED.JK)

NE - new enterprise;

DT - duration time of each period computed, 1 year is used;

NEC - new enterprise construction;

NED - new enterprise demolition;

L - indicates that this is a level equation.

New enterprise is determined by the amount of new enterprise in the past period J, plus the product of the duration time, times the new enterprise construction ratio in the time interval JK, less the new enterprise demolition ratio for the same time interval. The new enterprise demolition ratio determines the amount of new enterprise (NE) that becomes mature business. Mature business also has a similar ratio that turns mature business units into the declining industry category as the units age.

As a result of passing business units (referred to as productive units earlier) on to different categories, a series of peaks or chain of peaks result. Starting with new enterprise (NE), its curve peaks in 1998; then as a result of the new enterprise (NE) peak, mature business (MB) peaks in the year 2012 (see Figure 3.1a). As a result of the mature business (MB) peak, declining industry peaks in 2046. The point to be understood is the close interrelation between these three components, that in essence cause chain reactions. Since this chain begins with new enterprise, the success or failure of new enterprise has a strong influence on the success or failure of the rest of the business units and ultimately on all of Nashville.

To show how the components of new enterprise are affected by other variables in the model, two principal components are explained. The first component of new enterprise is new enterprise construction which is determined by:

R NEC.KL = (NECD.K)(LCR.K)

NEC - new enterprise construction;

NECD - new enterprise construction desired;

LCR - labor construction ratio;

R - indicates that this is a rate equation.

Labor construction ratio is the amount of labor available for construction. As the economy of Nashville grows, less construction labor is available to begin new construction. This shortage then restricts new construction as the existing construction is being built. The shortage will also affect the job ratio and make migration for jobs more attractive to people outside Nashville.

New enterprise construction desired is the second major component of new enterprise and is determined by the following equation:

A NECD.K = (NEDN)(NECF*NE.K + MBCF*MB.K + DICF*DI.K)(EM.K) + NECP.K

NECD - new enterprise construction desired

NECN - new enterprise construction normal (this is a constant equal to 5%)

NECF - new enterprise construction factor (a constant equal to 1)

NE - new enterprise

MBCF - mature business construction factor (a constant equal to .5)

MB - mature business

DICF - declining industry construction factor (a constant equal to .3)

DI - declining industry

EM - enterprise multiplier (a factor determined by the number of managerial/professional available to form new business units, the availability of land, the perceived availability of labor, the tax ratio, and new enterprise growth rate);

NECP - new enterprise construction program (if initiated).

This equation in essence says that the new enterprise construction desired (NECD) is the number of new enterprise productive units that will emerge as a result of each new enterprise productive unit, plus each 0.5 mature business productive units, plus each 0.3 declining industry productive units. When the product of this equation is joined with the labor construction ratio (LCR) the new number of productive units that are actually built is determined.

The foregoing discussion is an example of the interrelationship that exists between the components of new enterprise as well as between new enterprise and other components. These relationships also exist with other components of the urban dynamics model. The amount of housing, for example, is dependent on the age of housing and it, too, passes through cycles from premium housing to worker housing and, finally, to underemployed housing. Figure 3.1a shows premium housing (PH) peaking in 1996, then worker housing peaking in the year 2000, followed by underemployed housing (UH) peaking in 2024. Here again the "chain of peaks" or chain of reactions can be clearly seen.

In order to see other key variables in the model, Figure 3.1c, d, and e are presented. Later, when different urban policies are being analyzed, they will be compared with these graphs to illustrate the different consequences of each policy.

These are examples of consequences under "normal" circumstances, which means without introducing any new policies. But what happens within the Nashville model when policies are introduced to improve the outcome? This question will be answered in the next section.

Analysis of Policies

The primary objective of this thesis is to examine various different urban policies in the model to see which ones or combinations result in the best improved condition, above what was previously defined as the "normal" condition under existing policies. The policies to be examined come from various sources. Some were suggested by Forrester in his book Urban Dynamics.[19] Others were suggested as policies for analysis in various reports of the Nashville Metropolitan Planning Commission.[20] Still others were suggested by members of the author's thesis committee in a thesis committee meeting on August 20th, 1973.

All of the policies that follow were agreed in substance by the author's thesis committee and are presented here with only slight modification. The policies are:

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[19] Forrester, Urban Dynamics, Chapters 4 and 5.

[20] Planning Commission, Metropolitan Government of Nashville and Davidson County, Analyzing Suburban Development, pp. 8,17.

1. Increase in the Slope of the Tax Ratio.
2. Decrease in the Slope of the Tax Ratio.
3. Increase Housing Density by 10% above present density over a time period of 30 years.
4. Initiate a training program for 5% of the underemployed.
5. Receive $100 per capita of external financial aid to the Nashville government.
6. Initiate a job program for 5% of the underemployed.
7. Initiate a low cost housing construction program at the rate of 5% per year.
8. Initiate a slum demolition program of 5% above normal.
9. Initiate a new enterprise construction program of 5% above normal.
10. Restrict the construction of worker housing by 1 1/2% above normal.

Each of the above policies will be examined on an individual basis. It will state what the policy is, why it was chosen, how the Nashville model responds to that policy, and how that policy compares to normal conditions. After all ten policies have been examined, the better policies will be examined together to determine the "best" group of policies. The "best" policies will be joined together to see if they result in a better policy together.

When To Evaluate a Policy

In the course of evaluating the policies listed above, the question arises: at what point in time during the simulation should a policy be evaluated? Should it be the first few years after the policy is initiated? This would be desired by most politicians who must show immediate benefits from their policies in order to be re-elected. If a policy shows immediate benefits it does not necessarily mean that it will be beneficial in the long run. It may be that a policy that appears to produce very good initial consequences may be setting the circumstances that result in a "boom and bust" cycle. A case in point is where the economy does very well during a boom period only to overheat itself and result in the "bust" of inflation, shortages and high interest rates. A policy, then, should be evaluated after a longer time period. It should be evaluated after all the variables in the model have had a chance to interact and the model has reached a state of equilibrium. Equilibrium is reached in the model after 100 years, therefore the year 2070 is chosen as the point in time that the policies are evaluated.

Changes in the Tax Ratio

A common question raised in the process of managing a city is "what would happen if the tax rate were changed?" In order to answer this question, it must be understood that the model is constructed so that the tax ratio can change automatically within a specified range. What is done here is to change the slope of that range. To understand this, the means of determining the tax ratio in the model is explained.

The model is constructed so that there is a ratio between the taxes computed as being needed (based on the number of people in each economic class), and the taxes that are actually levied. This ratio is expressed as a table function so that the ratio is not a constant and changes as the tax needs increase or decrease. The taxes computed as being needed differ from the taxes that are actually levied because of the natural public reluctance and political infeasibility of raising taxes to the full rate to finance all city programs. This parameter is important in measuring the political impact by various economic groups who feel they have a vested interest in the tax rate.

By definition in the model, the underemployed contribute less and are more dependent on city programs than the managerial/professionals, who contribute more to the tax base and cost the city less. Because of these definitions, it is assumed that the underemployed prefer a tax rate that is higher and the managerial/professionals prefer a lower tax rate.

To see the consequences of these two points of view, the slope of the tax ratio curve is rotated approximately 5 degrees (around the point where TR = TRNP = 1.0), first counter clockwise, then clockwise. The result is that the slope of the tax ratio curve increases by the counter clockwise rotation, then decreases by the clockwise rotation. This rotation is shown in Figure 3.2 Tax Rate Slope Changes. The resulting changes in tax ratio tables (TRT) put into the model are shown below in contrast to the tax ratio in Forrester's model that is taken as the "normal" existing condition in the Nashville model:

Slope Increase T TRT - .1/.4/1/2/3.4/4/4.5

"Normal" Condition T TRT = .3/.5/1/1.8/2.8/3.6/4

Slope Decrease T TRT = .7/.8/1/1.7/2.4/3/3.4

These two points of view are the first two policies to be analyzed below.

1. Tax Rate Slope Increase By Rotation

The consequence of increasing the slope of the tax rate proved to be somewhat surprising. The surprise was that this policy actually resulted in a slight improvement in the overall condition of the model.

The explanation for this surprise is that because the economy remains healthy, the TR never goes above 1.0. With the rotation to change the slope of the curve, the TR curve below the point of TR = 1.0 is actually lower than it was before. At equilibrium, the tax ratio is .7603 as opposed to .8004 under "normal" conditions. This lower tax ratio encourages new enterprise and housing through the enterprisal multiplier (EM) noted earlier in this chapter.

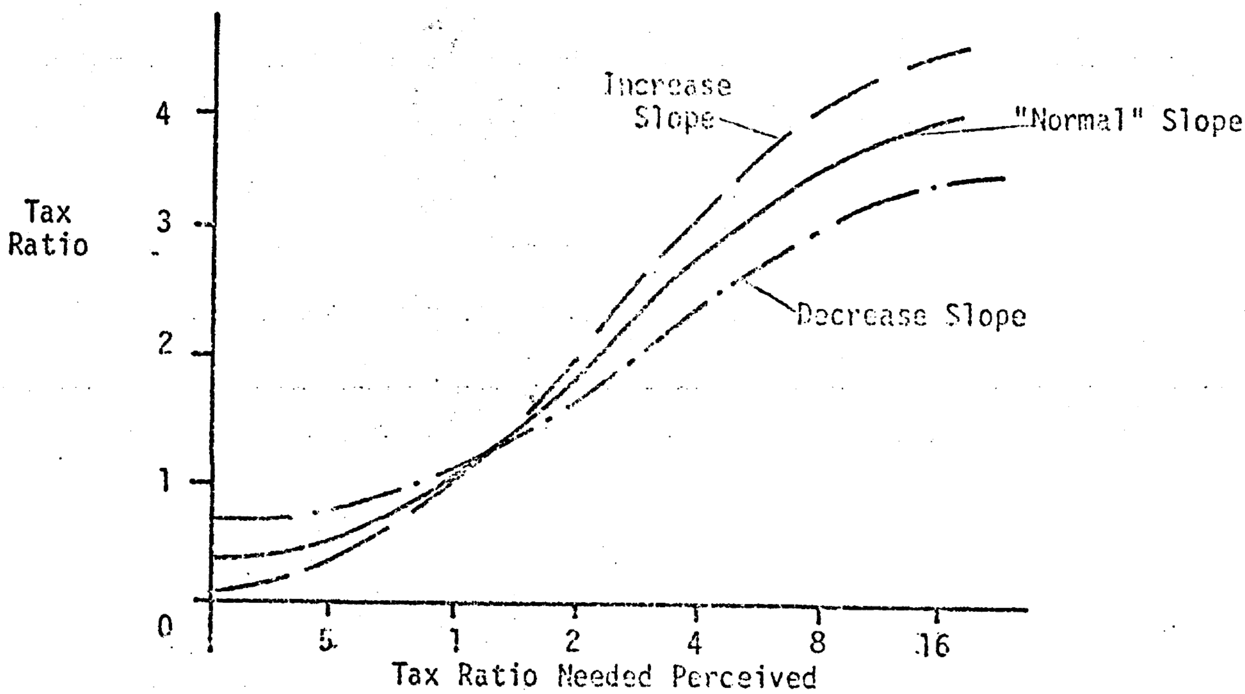

Figure 3.2 Tax Rate Slope Changes

A more detailed understanding can be seen by comparing certain key variables at equilibrium to those under "normal" conditions. Table 3.1, Consequences of Urban Policies at Equilibrium, shows the values of key variables for all policies at the year 2070. Throughout the analysis of all urban policies, reference will be made to this table comparing each policy to the "normal" condition.

Examining Table 3.1 shows that the policy of increasing the slope of the tax ratio by rotation brings only a slight improvement in the year 2070 over the "normal" condition. New Enterprise has risen by only 41 productive units or less than 1%. All the other key variables in Table 3.1 show the same response. They all increase by slight amounts that could not be considered significant. The only variable that should be noted is the underemployed to labor net (UTLN).

The UTLN shows a drop of 6% over the "normal" condition. The explanation for this comes directly from the changes in the tax ratio. Because the changed tax ratio collects less revenue, and almost the same population exists, the tax per capita ratio (TPCR) is lower. The lower TPCR (.554 vs .583 under "normal" conditions) means that less money is available to support public services such as education. The TPCR is a factor in the mobility from the underemployed category to the labor category. This is best illustrated by comparing Figure 3.1c to 3.3e, which compares the dynamics of these variables over time.

In summary, the consequences of rotating the tax ratio to produce a steeper slope did not significantly improve conditions in the

TABLE 3.1

CONSEQUENCES OF URBAN POLICIES AT EQUILIBRIUM

	Policy	NEW ENTERPRISE	MATURE BUSINESS	DECLINING INDUSTRY	PREMIUM HOUSING	WORKER HOUSING	UNDEREMPLOYED HOUSING	MANAGEMENT PROFESSIONAL	LABOR	UNDEREMPLOYED
	"Normal" Year 1970 "Normal" Year 2070	3,221 4,536	2,015 7,206	2,487 10,647	21,690 81,320	63,973 137,800	49,750 126,920	33,903 81,293	119,520 30[illegible],740	59,760 252,[illegible]
1.	Increase Tax Rate Slope % Change From "Normal"	4,577 1%	7,258 1%	10,649 0%	81,650 0%	137,600 0%	127,020 0%	81,729 0%	306,580 0%	253,090 0%
2.	Decrease Tax Rate Slope % Change From "Normal"	4,462 -2%	7,085 -2%	10,584 0%	80,460 0%	138,300 0%	126,610 0%	80,213 0%	304,030 0%	249,630 0%
3.	Increase Density % Change From "Normal"	5,040 11%	8,110 12%	11,913 12%	91,080 12%	150,900 9%	141,300 11%	91,010 12%	339,970 11%	283,980 12%
4.	Underemployed Job Training % Change From "Normal"	5,589 23%	9,031 25%	11,158 5%	86,530 6%	136,000 -1%	130,000 2%	93,729 15%	371,850 22%	[illegible] [illegible]
5.	External Financial Aid % Change From "Normal"	4,770 5%	7,698 7%	10,731 1%	83,700 3%	134,500 -2%	130,350 3%	86,143 6%	31[illegible],900 5%	270,210 7%
6.	Underemployed Job Program % Change From "Normal"	4,386 -3%	6,993 -3%	10,601 0%	79,840 -2%	135,200 -2%	130,460 3%	79,500 -2%	299,7[illegible]0 -2%	26[illegible],[illegible]30 [illegible]
7.	Low Cost Housing Program % Change From "Normal"	3,551 -22%	5,665 -21%	8,911 -16%	66,210 -18%	116,900 -15%	161,520 27%	65,372 -20%	248,770 -19%	246,090 -3%
8.	Slum Housing Demolition % Change From "Normal"	6,663 47%	10,708 49%	12,594 18%	103,630 27%	175,500 28%	70,838 -44%	110,770 36%	419,380 37%	194,740 -23%
9.	New Enterprise Construct. % Change From "Normal"	5,033 11%	8,294 15%	21,495 102%	95,700 18%	114,900 -17%	135,530 7%	109,590 35%	345,790 13%	339,940 35%
10.	Restrict Worker Housing Construct. % Change From "Normal"	4,437 -2%	7,254 1%	11,805 11%	88,270 9%	128,900 -6%	122,840 -3%	84,720 4%	305,550 0%	264,030 5%
	"Best"-Slum Demo., New Enterprise Construct., & Increase Density % Change From "Normal"	7,800 72%	12,702 76%	22,399 115%	125,680 53%	189,300 37%	74,891 -37%	146,320 80%	52[illegible] 72%	218,300 -14%

TABLE 3.1 (cont.)

CONSEQUENCES OF URBAN POLICIES AT EQUILIBRIUM

Policy	MGT./HOUSING RATIO	LABOR/HOUSING RATIO	UNDEREMPLOYED/HOUSING RATIO	MGT./JOB RATIO	LABOR/JOB RATIO	UNDEREMPLOYED/JOB RATIO	TAX RATIO	UNDEREMPLOYED TO LABOR NET	UNDEREMPLOYED ARRIV.-DEPART. NET
"Normal" Year 1970 "Normal" Year 2070	1.772 1.133	1.057 1.354	.566 .938	1.418 1.331	.728 .947	.548 1.473	1.0 .8004	2,767 2,014	7,874 -3,764
1. Increase Tax Rate Slope % Change From "Normal"	1.134	1.359	.942	1.332	.945	1.467	.7603	1,886 -6%	-3906 4%
2. Decrease Tax Rate Slope % Change From "Normal"	1.130	1.341	.930	1.331	.955	1.487	.9192	2,379 18%	-3,318 -12%
3. Increase Density % Change From "Normal"	1.133	1.374	.947	1.332	.941	1.470	.8054	2,538 25%	-4,095 9%
4. Underemployed Job Training % Change From "Normal"	1.228	1.668	1.004	1.306	.984	1.438	.7734	14,054 598%	7,727 305%
5. External Financial Aid % Change From "Normal"	1.166	1.452	.977	1.354	.953	1.522	.8205	5,297 153%	-943 -75%
6. Underemployed Job Program % Change From "Normal"	1.129	.1352	.966	1.331	.950	1.465	.8433	2,429 20%	-3,679 -2%
7. Low Cost Housing Program % Change From "Normal"	1.119	1.298	.718	1.333	.951	1.779	.8902	1,312 -35%	-4,365 16%
8. Slum Housing Demolition % Change From "Normal"	1.211	1.450	1.296	1.319	.946	.825	.4892	-480 -124%	-4,866 29%
9. New Enterprise Construct. % Change From "Normal"	1.298	1.884	1.182	1.245	.758	1.127	.8934	13,216 556%	4,943 231%
10. Restrict Worker Housing Construct. % Change From "Normal"	1.088	1.446	1.013	1.342	.919	1.448	.8199	3,366 67%	-2,910 -22%
"Best"-Slum Demo., New Enterprise Construct., & Increase Density % Change From "Normal"	1.319	1.694	1.374	1.271	.861	.830	.4705	2,353 7%	-2522 -33%

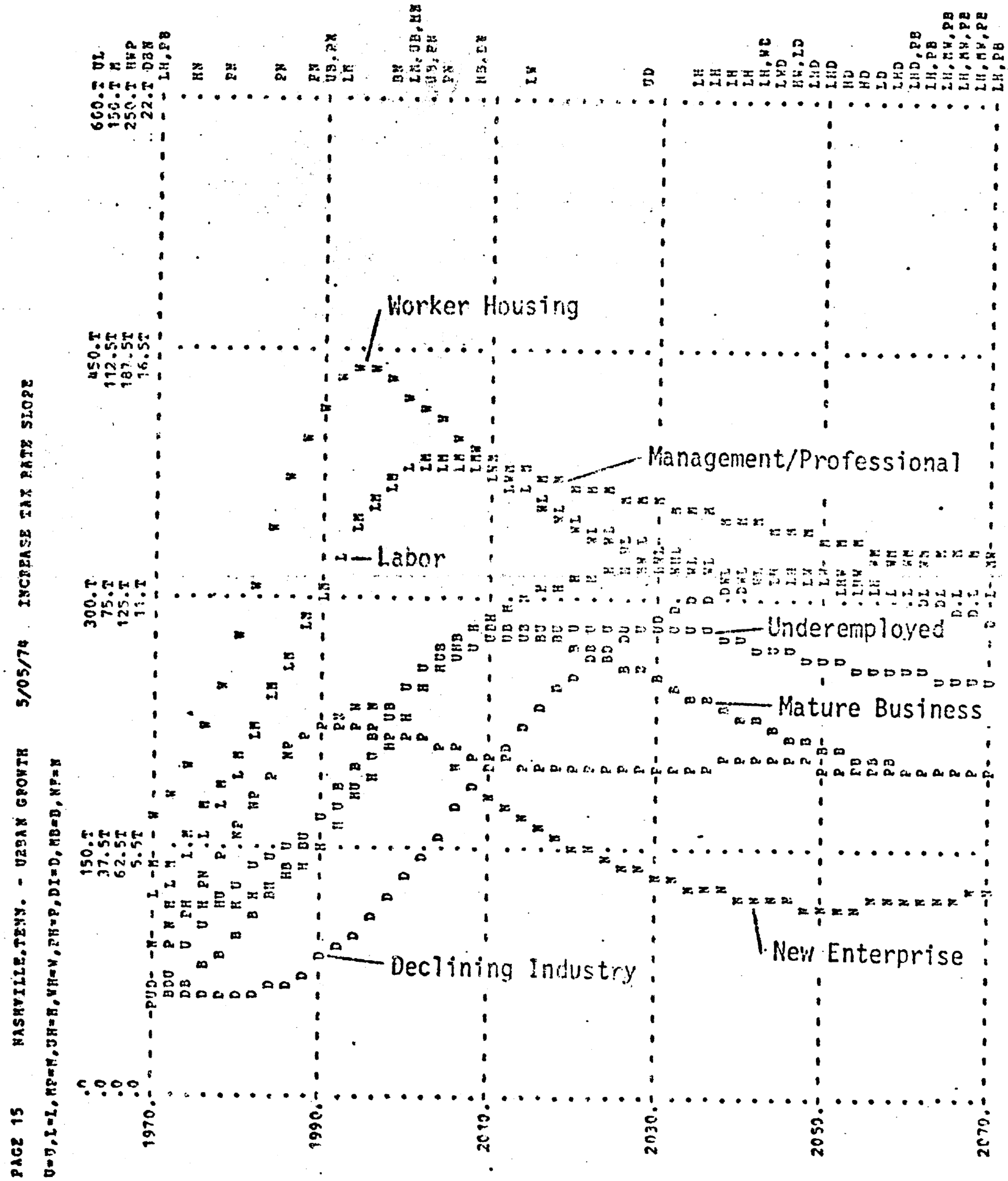

Figure 3.3 a Dynamics of Tax Rate Slope Increase

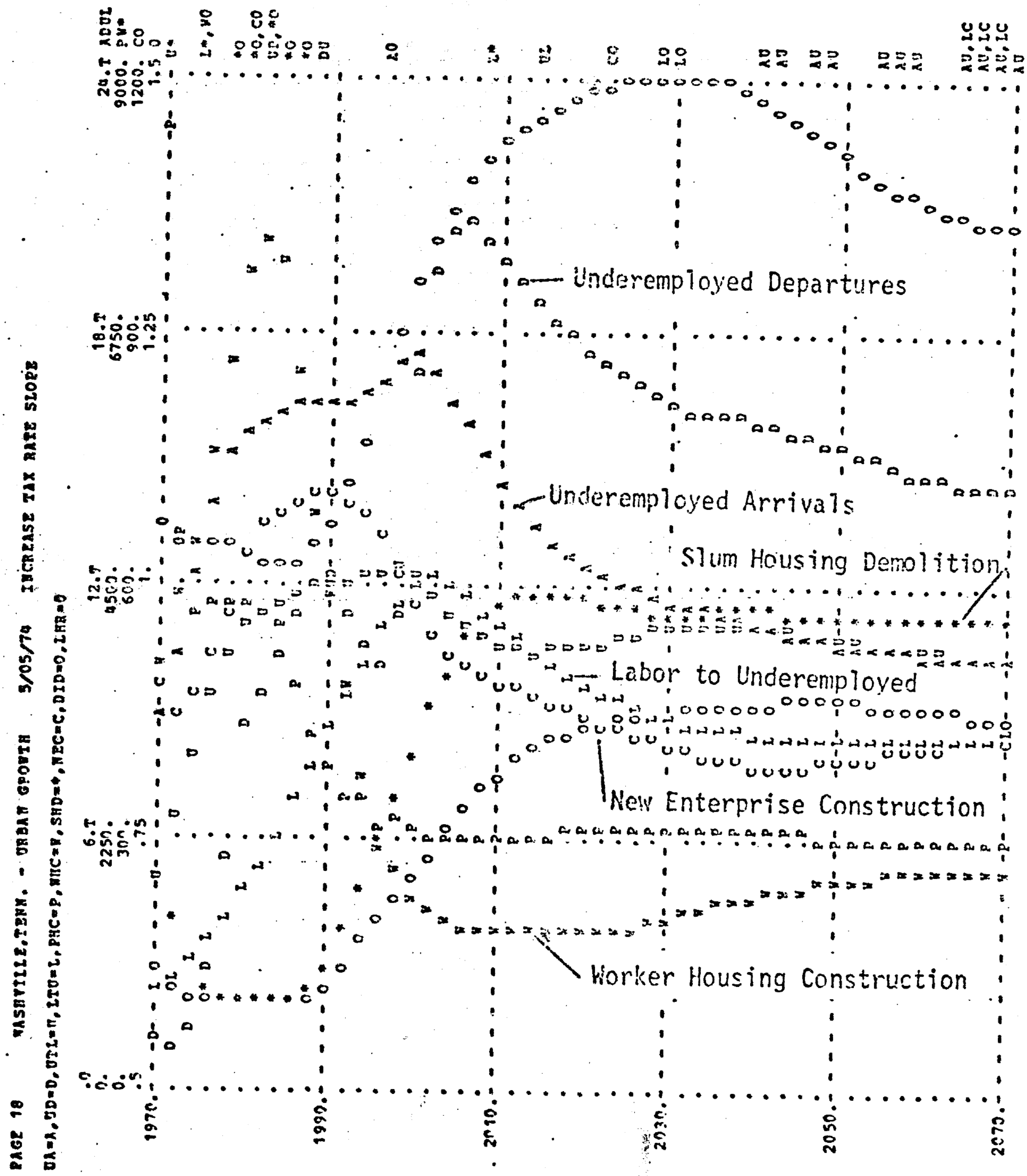

Figure 3.3 b Dynamics of Tax Rate Slope Increase

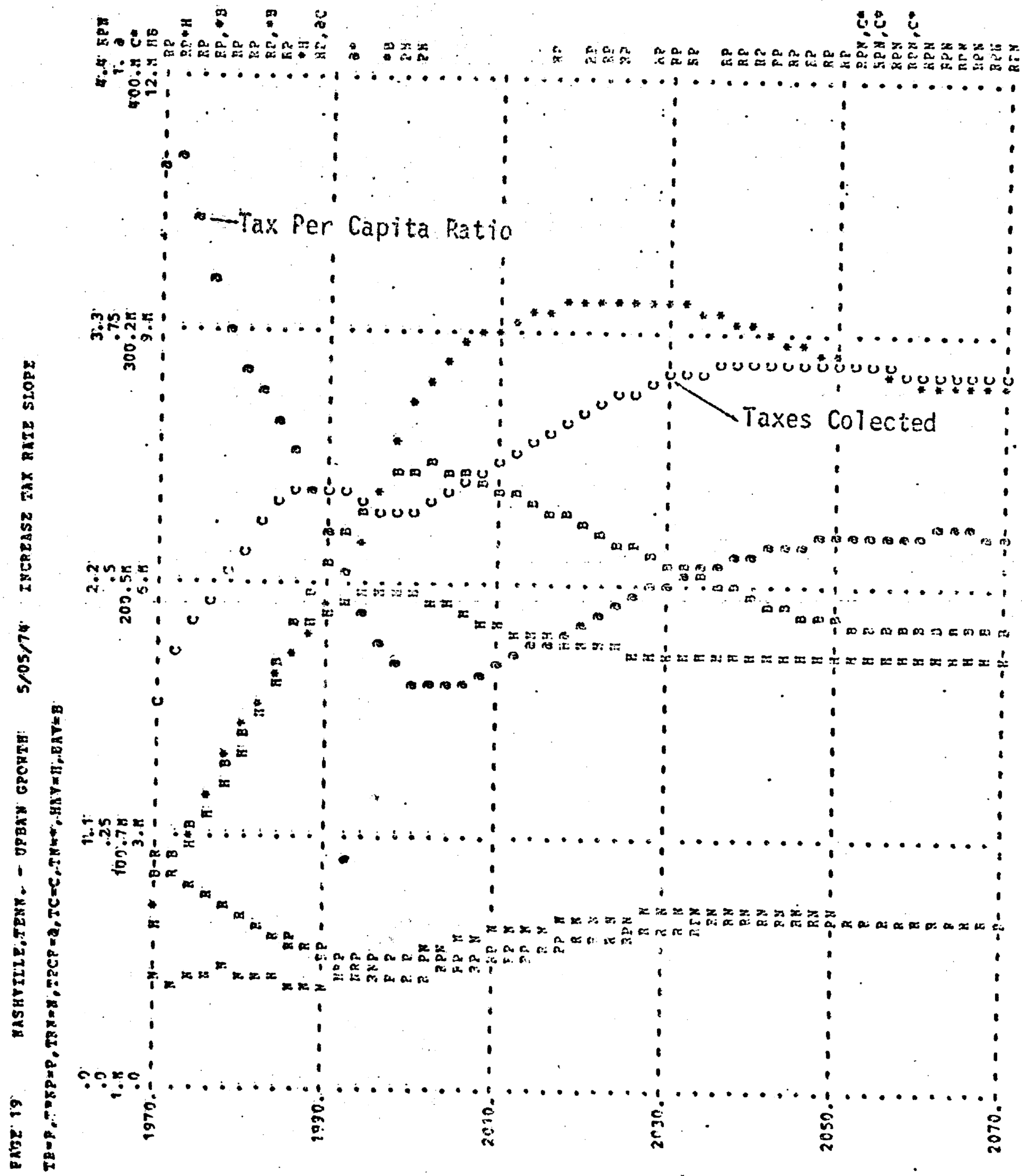

Figure 3.3 c Dynamics of Tax Rate Slope Increase

model. The only noticeable difference was a slight reduction in the mobility from underemployed to labor. Because this policy does not produce any significant positive consequences, it is not recommended as a policy to improve conditions in Nashville.

2. Tax Rate Slope Decrease By Rotation

The second policy of changing the slope of the tax ratio curve by rotation clockwise was expected to produce a tax ratio that was lower than under "normal" conditions. In reality, the same thing happened as with the first tax policy, except in the opposite direction. The net result was a higher tax ratio that discouraged the expansion of industry and housing. Figure 3.2 shows the clockwise rotation of the tax ratio resulting in a decreased slope.

By having a slightly higher tax ratio, all three sectors of industry were discouraged to the point where they were lower than under "normal" conditions. This can be seen on Table 3.1, Consequences of Urban Policies at Equilibrium. New enterprise (NE) decreases by 2% which causes the other two industrial sectors to decrease also. Housing and population remain the same as under "normal" conditions.

One variable to note here is the underemployed to labor net (UTLN). UTLN increases by 18% over the "normal" condition as a result of the higher TR. Again, the reason for this ties directly to tax per capita ratio (TPCR). Because the taxes collected (TC) are greater and the population is slightly less, the TPCR is higher

(.670 vs .583 under "normal" conditions). This permits more money to be spent on public services, such as education, that aid upward mobility from the underemployed category to the labor category. Figure 3.4c, Tax Rate Slope Decrease, shows the dynamic changes in the tax collections that jump off the graph as well as the tax per capita ratio (TPCR) that is higher than either the TPCR under "normal" conditions or under the first policy.

Two other variables to note are the underemployed job ratio (UR) and the labor job ratio (LR). They increase from a high 1.473 and .947 to a higher 1.487 and .955 respectively, which signifies a high rate of unemployment for these categories. Note that these are higher under this policy than any other policy.

In summary, the consequences of rotating the tax ratio to decrease the slope results in a worse condition than before. A significant change is the increase in the upward mobility of underemployed to labor. This increase in mobility opportunity however, is hampered by the highest rates of unemployment (personified by the high UR and LR ratios) of any policy. As a consequence, this policy of rotating the TR curve clockwise to decrease the slope makes the situation worse than before and is not recommended as a policy to improve the conditions in the model.

3. Increase Density By 10% Over 30 Years

The third policy examined through the Nashville model is the consequence of gradually increasing the overall density of all types

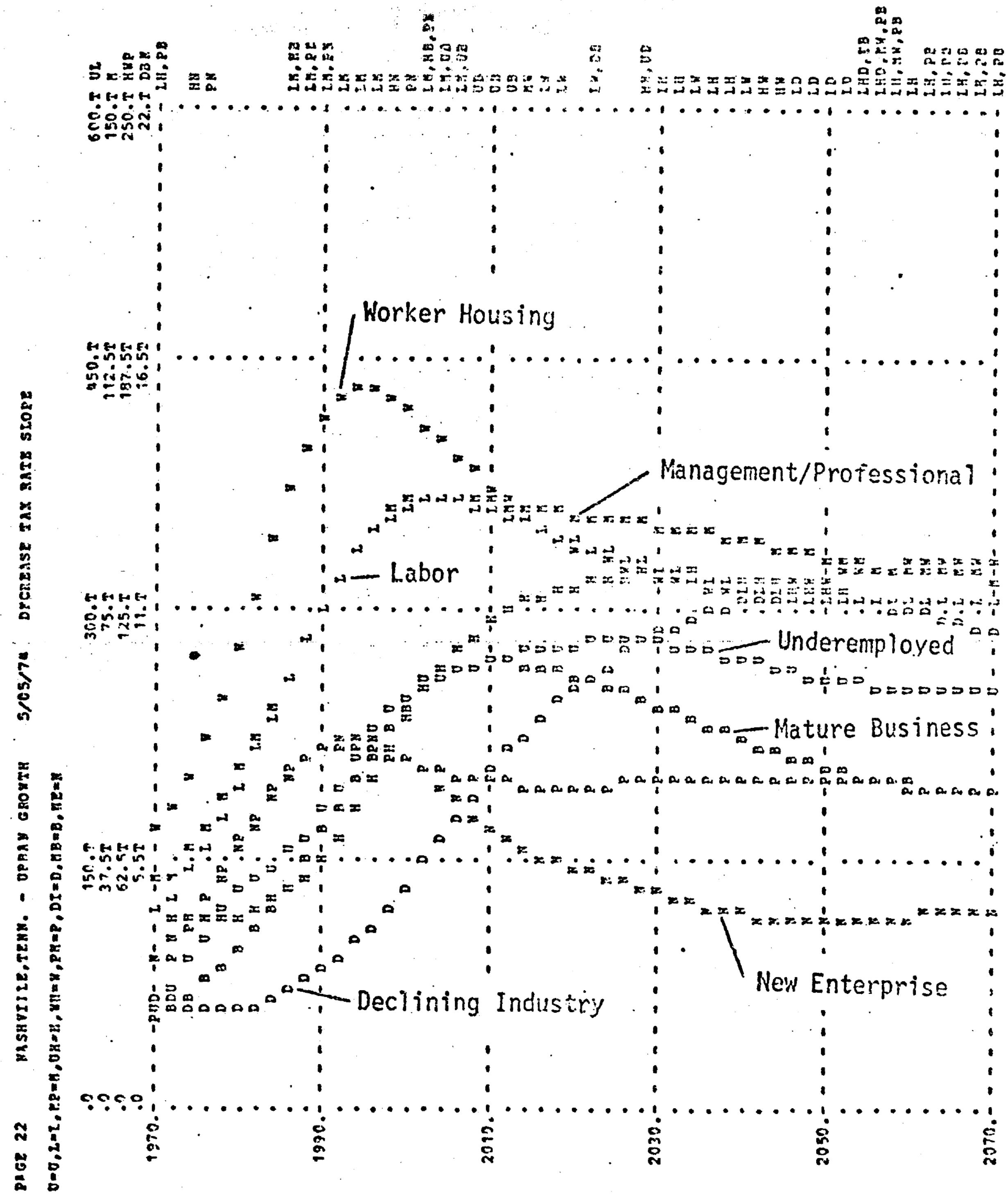

Figure 3.4 a Dynamics of Tax Rate Slope Decrease

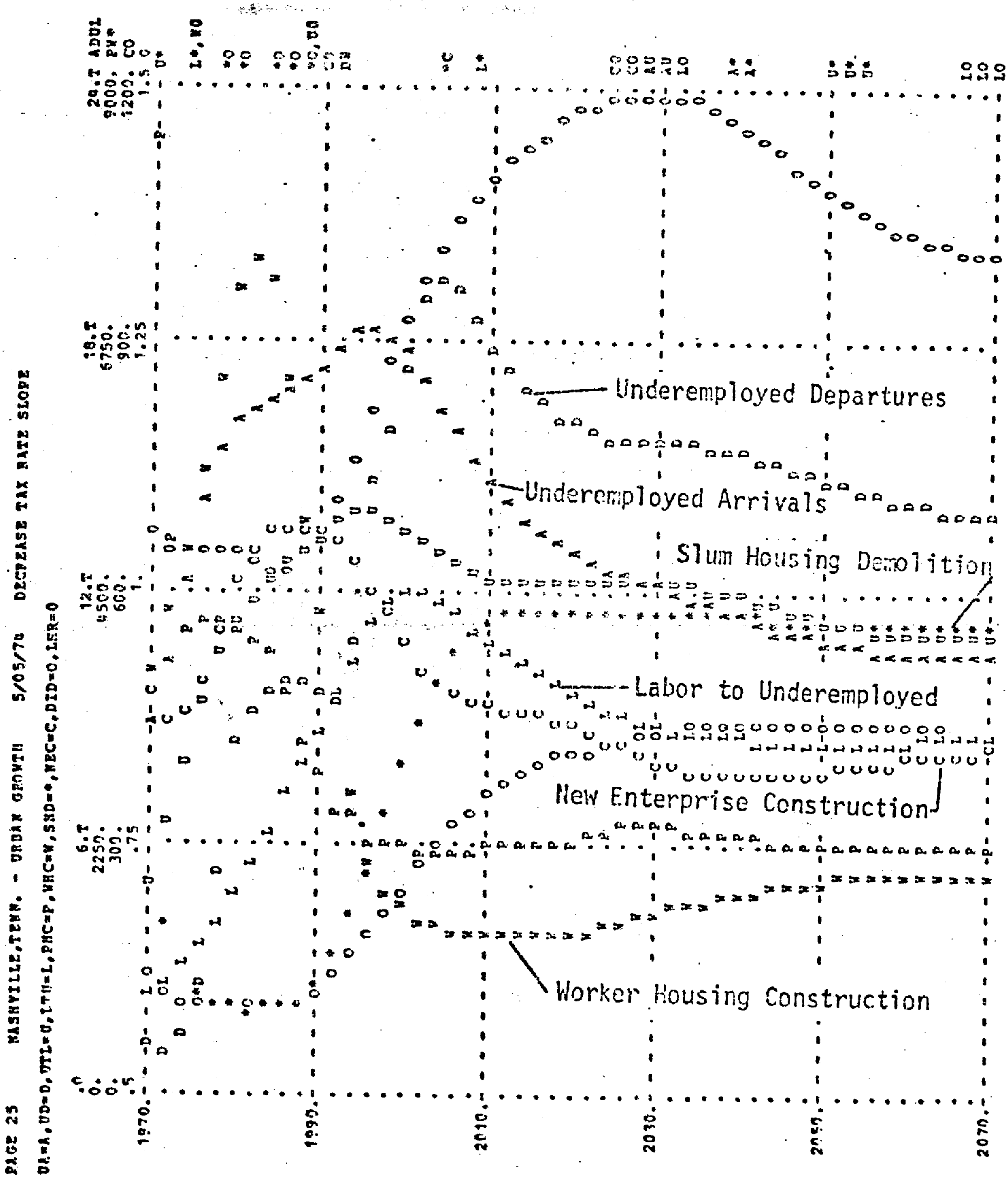

Figure 3.4 b Dynamics of Tax Rate Slope Decrease

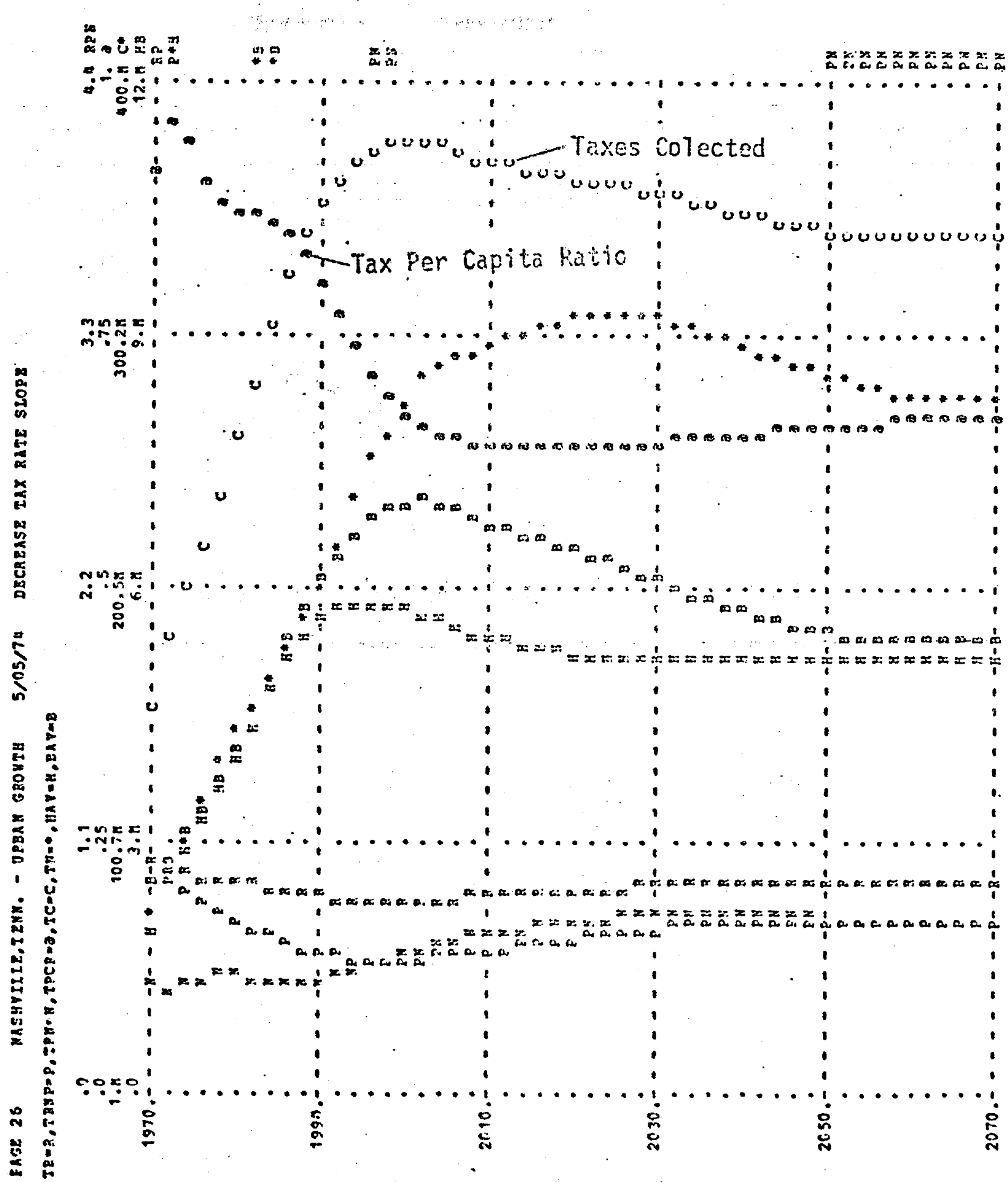

Figure 3.4 c Dynamics of Tax Rate Slope Decrease

of housing by 10%, over a period of 30 years. This was chosen because the question of density is being widely raised in many urban areas, and because the Nashville Metropolitan Planning Commission raised this question in their 1973 report, Analyzing Suburban Development as a policy that might be beneficial to Nashville.[21]

This policy is based on the assumption that the city would adopt a Land Per House Program (LPHP) that would gradually decrease the land per house from .5648 acres to .5084 acres. Thirty years was chosen as the transitional period from the original density to the 10% reduction because this is the average life of premium housing, and it would take thirty years to accomplish a 10% increase in overall density. The 10% increase in density is an arbitrary figure chosen to see what would happen from a defined increase.

The primary consequence of this policy is that more land would be available for other forms of development besides housing -- particularly industry. This can be seen in Table 3.1, Consequences of Urban Policies at Equilibrium, which shows an 11% to 12% increase in the number of productive units. Had the density of productive units also been increased, the number of productive units would have grown even greater. This was not done because of the obvious difficulties in increasing density of productive units.

Because of the increased number of productive units, a secondary effect is the increase in population by the same percentage. Even

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[21] Ibid.

though most jobs go to the management professional (MP) and labor (L) classes, the underemployed are attracted to the area because of the perceived availability of jobs. Figure 3.5a and 3.5b, Dynamics of Increased Density by 10% Over 30 Years, illustrates the dynamics of the model over time. Figure 3.5b illustrates the underemployed arrivals (UA). In the year 2000, UA exceeds the high point reached under "normal" conditions. This is what causes the increase in the number of underemployed.

Housing also increases, but by different percentages. Premium housing increases by the same 12% increase in population. Worker housing increases by only 9 1/2%, because the incentives are not as great as they are for PH. The underemployed housing (UH) increases by 11%. This greater increase in UH results from the longer period that it remains in that category.

The improved economic situation, plus a slightly higher tax rate, result in more mobility from the underemployed to labor category. As noted in the analysis of the first two policies, greater tax revenues per capita improve the mobility from the underemployed category to the labor category. This mobility is also helped by the expanding economy that needs more workers in the labor category. This mobility can be seen in Table 3.1, by the underemployed to labor net (UTLN) that shows a 26% increase.

Because of the favorable overall improvements shown in all sectors, the policy of increasing the density appears to be a good

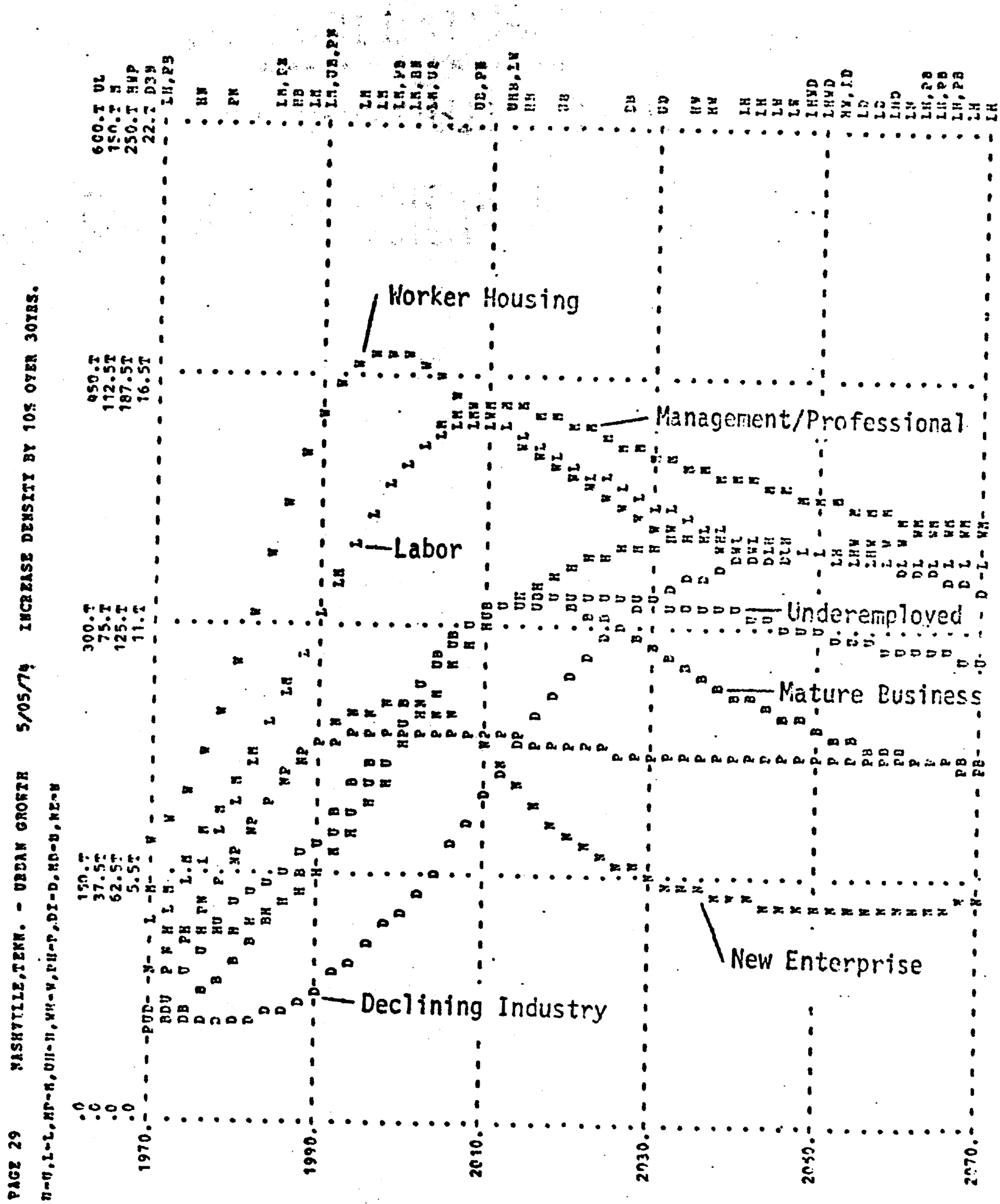

Figure 3.5 a Dynamics of Increased Density Over 30 Years

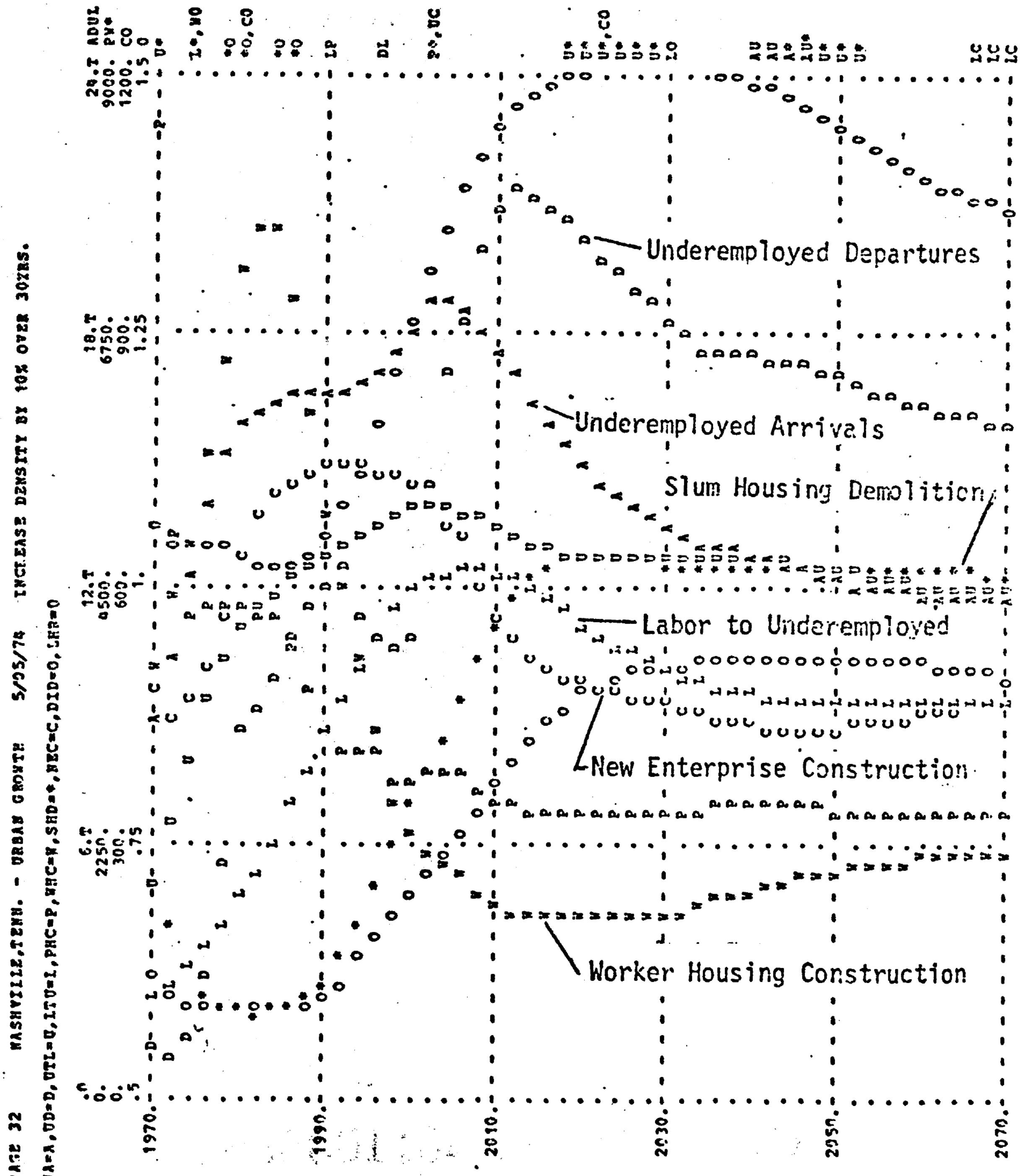

Figure 3.5 b Dynamics of Increased Density Over 30 Years

policy, and is recommended as a policy to be tested with other favorable policies. It is recognized that the components of the model do not measure all the possible effects that will result. Additional beneficial effects not shown are sure to be the reduced cost of providing most public services. But what will other consequences be? Higher concentrations of people can cause social problems not to be dealt with here. In terms of the effects of density, a general conclusion can be drawn from studies by Carl Norcross.[22] From reading his book, Townhouses and Condominiums, Residents Likes and Dislikes, one would conclude that it is not so much how dense an area is (within limits), but more important, how it is made dense. How an area is designed, then, becomes very important.

4. Job Training Program For 5% of the Underemployed

The fourth policy, initiating a job training program for 5% of the underemployed, simply assumes the movement of 5% of the underemployed each year into the labor category. This is assumed to be done without any additional expense to the city and it is assumed that the training program is successful enough for 5% of the underemployed to achieve this move. This training program begins in 1975, as do all of the policies being analyzed.

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[22] Dr. Carl Norcross, Townhouses and Condominiums, Residents Likes and Dislikes (Washington, D.C.: The Urban Land Institute, 1973), Chapter I.

This policy is chosen for analysis because it has been a fairly common program used by the Federal government in the past. (The Job Corps is an example of this type of program.) Recently, President Nixon signed a $1.8 billion bill, virtually ending most federal job training programs and putting the money into the hands of state and local governments.[23] This money could be used by Nashville to institute its own manpower training program similar to what is described here. As a consequence, this will serve as a glimpse of the possible effects of such a program.

The overall consequences of this policy are not overly impressive, even though they are an improvement in some areas over the "normal" conditions. The imbalanced results are shown on Table 3.1. Industry is the only sector that shows improvement. Housing remains almost unchanged and except for labor, the population sector grows very little.

The primary consequence of this policy is the attractiveness to the underemployed of the upward mobility to the labor category. This attractiveness results in a higher than normal influx of underemployed arrivals (UA) and a decline in the number of underemployed departures (UD), that can be seen in Figure 3.6b, Dynamics of A 5% Underemployed Job Training Program. Besides the increase in the underemployed to labor (UTL) that is intended, there is also an

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[23]"Nixon Signs Bill to Give States Manpower Funds", The Washington Post, Dec. 29, 1973, p. A1.

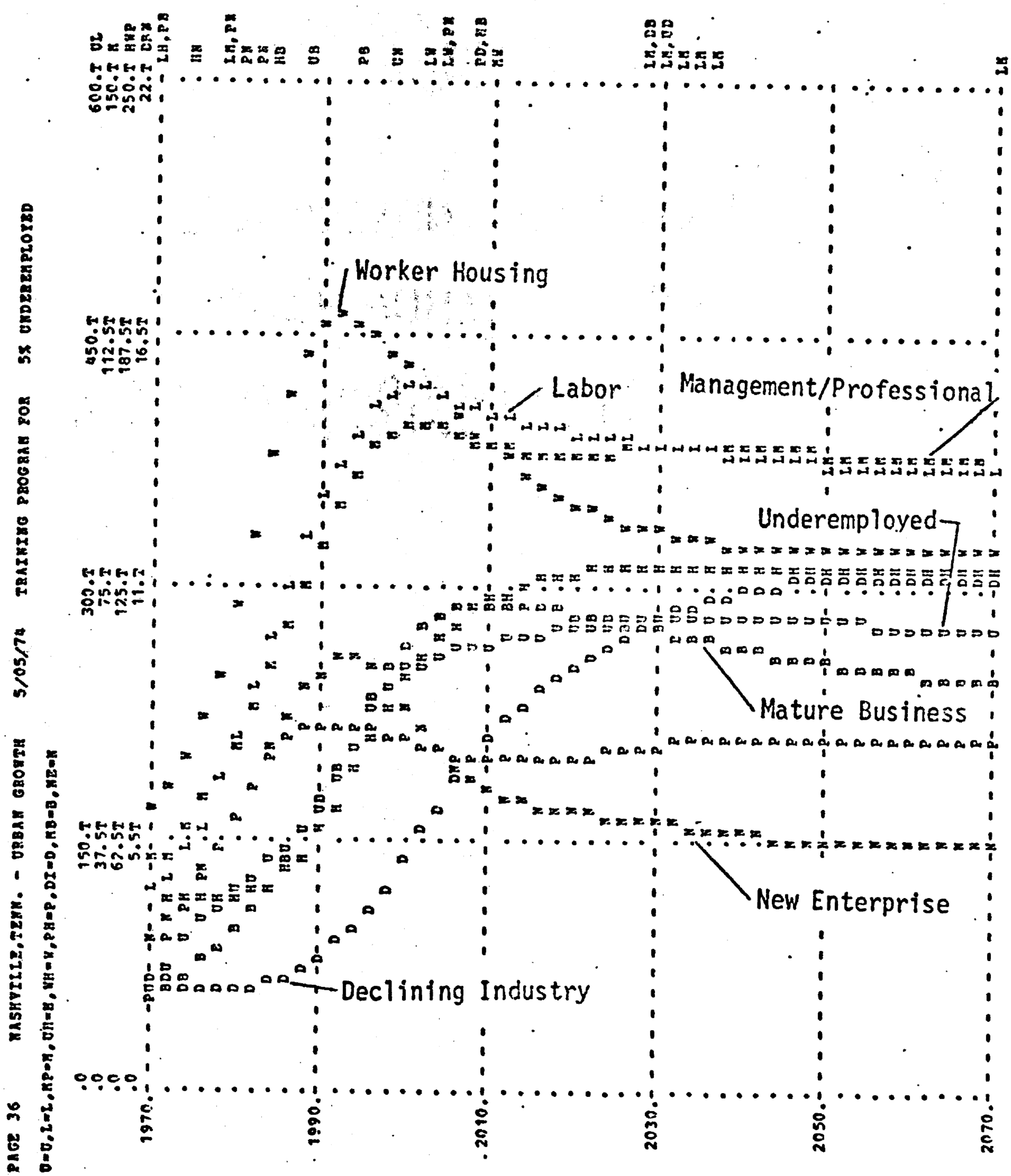

Figure 3.6 a Dynamics of a 5% Underemployed Job Training Program

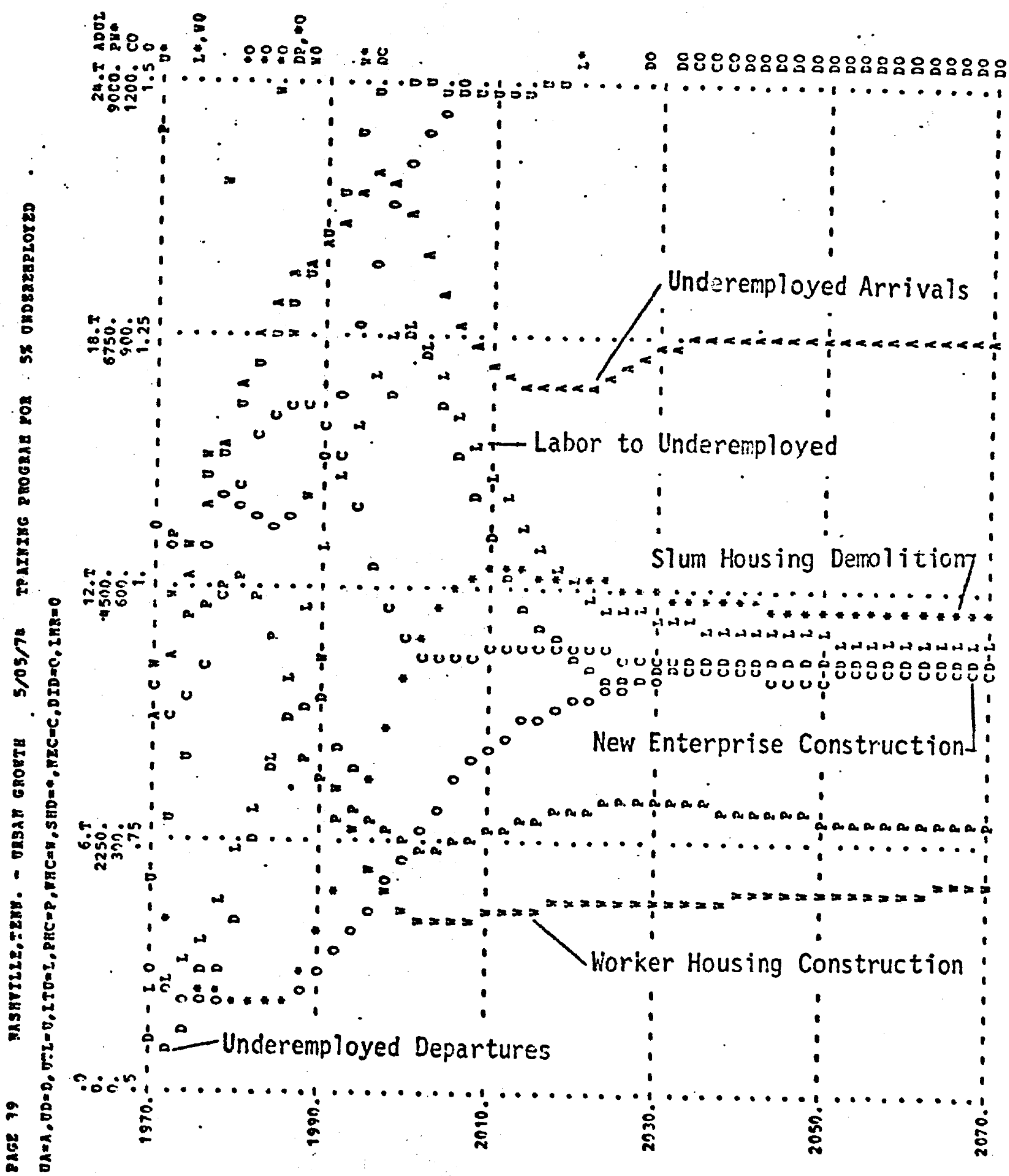

Figure 3.6 b Dynamics of a 5% Underemployed Job Training Program

increase in the number of labor to underemployed (LTU) by 2,390 above normal. This occurs because of the excessive sized labor group that is being created by the training program, and because jobs for them have not increased except by the secondary reactions in the system that can be seen by the increase in new enterprise (NE) and mature business (MB). Because of this overload, it is only natural that the flow of LTU increases.

The attractiveness that is created by the training program results in an over 300% increase in the number of underemployed arrivals over departure net (UADN). This means that the perceived level of attractiveness is very high. Even though this increase is high, it does not show the high number of departures of labor (20,830) or underemployed (10,200) that result from their dissatisfaction with the availability of employment. They come to the city, and may or may not be trained in the job training program. They find that jobs are scarce and then leave the city for areas of better employment.

The secondary consequence of this policy is for increases in the industrial categories of new enterprise (NE), and mature business (MB), but not declining industry (DI). The surplus of labor creates conditions that are good for new enterprise and mature business but not for declining industry. This is because under the improved conditions for NE and MB, there are greater incentives to dissolve marginal businesses that are part of DI and use the land, capital and labor for the creation of more profitable NE and MB.

This is illustrated by Table 3.1 that shows a 23% and 25% increase in new enterprise and mature business respectfully, but only a 5% increase in declining industry over "normal" conditions.

It has been mentioned that the population rises only slightly except in the labor category. The labor category increases not because of the training program; but because of the excessive number in this group, the labor job ratio (LR) increases to a high .941. The abundance of labor over jobs is personified by high unemployment. The managerial/professional group does not grow to the same extent as industry because the increase in industry is not accompanied by an increase in housing, therefore the area has limited attractiveness to the managerial/professionals.

Housing does not increase for two reasons: First, because the increase in population is not great enough to encourage its construction; and second, because in the competition for land, housing loses out to industry. Industry has the advantage of a surplus of labor that increases the incentive to build industry. As can be seen in Table 3.1, housing increases by only 6%, -1%, and 2% for premium housing (PH), worker housing (WH) and underemployed housing (UH), respectively. The housing ratios in Table 3.1 show the scarcity of housing for all three classes.

In summary, the consequences of this policy are not impressive because of the unbalanced growth that results. The city has become very attractive to the underemployed, because of the opportunities for upward mobility, but this creates an overlcad on the labor category that culminates in high unemployment. The net result is that many of these persons are later forced to leave because of a lack of jobs. This means that the city receives only partial benefit from the training program. It is not able to enjoy the full benefits of the program because the development of the city is limited to industry and not the sector of housing. This is a sign that development policies need to be balanced and in harmony with other policies that affect other sectors of the city. Because of the imbalanced growth that results from this policy, this policy is not recommended if initiated without any other policy that produces more balanced development.

5. External Financial Aid

The fifth policy to be examined is that of the city receiving financial aid from the state or Federal government to directly support existing welfare and public service programs. This is done by adding a tax per capita subsidy (TPCS) of $100 to the existing tax revenue. This $100 per person, directly increases the tax per capita ratio (TPCR), which in turn increases the public expenditure multiplier (PEM). The PEM in turn affects two things: 1.) the inward and outward migration of underemployed; and 2.) the educational multipliers for labor (LEM) and underemployed (UEM). These last two multipliers for education have a direct influence on upward mobility for the labor and underemployed groups.

Since this policy does not directly influence the creation or demolition of industry of housing, it is not surprising that the effects are not impressive in these two sectors. Table 3.1, Consequences of Urban Policies at Equilibrium, shows how little these two sectors change. Worker housing (WH) in fact shows a slight decrease of 2%. The third sector, population, also shows very little change. The only change that does occur is for the underemployed to increase slightly more than labor or managerial/professional. This subtle shift in population composition has a significant effect on the tax base.

The effect of the shift in population to more underemployed is felt by a change in the total assessed value of all housing and in the taxes needed to support public services. The assessed value of housing changes because more is occupied by the underemployed. The taxes needed to support public services increase because it has been assumed that the underemployed cost more to provide services for. Even with the additional income of $100 per capita, the abundance of underemployed forces the tax rate to increase by 3%. Therefore, the effort to increase public services and maintain the same tax rate has resulted in an increase in the tax rate.

The number of underemployed increases because the relative attractiveness has been increased by the PEM. Figure 3.7b shows the higher number of UA's and lower number of UD's that result.

In conclusion, the consequences of this policy are not impressive. In some cases they are detrimental. The key to successfully

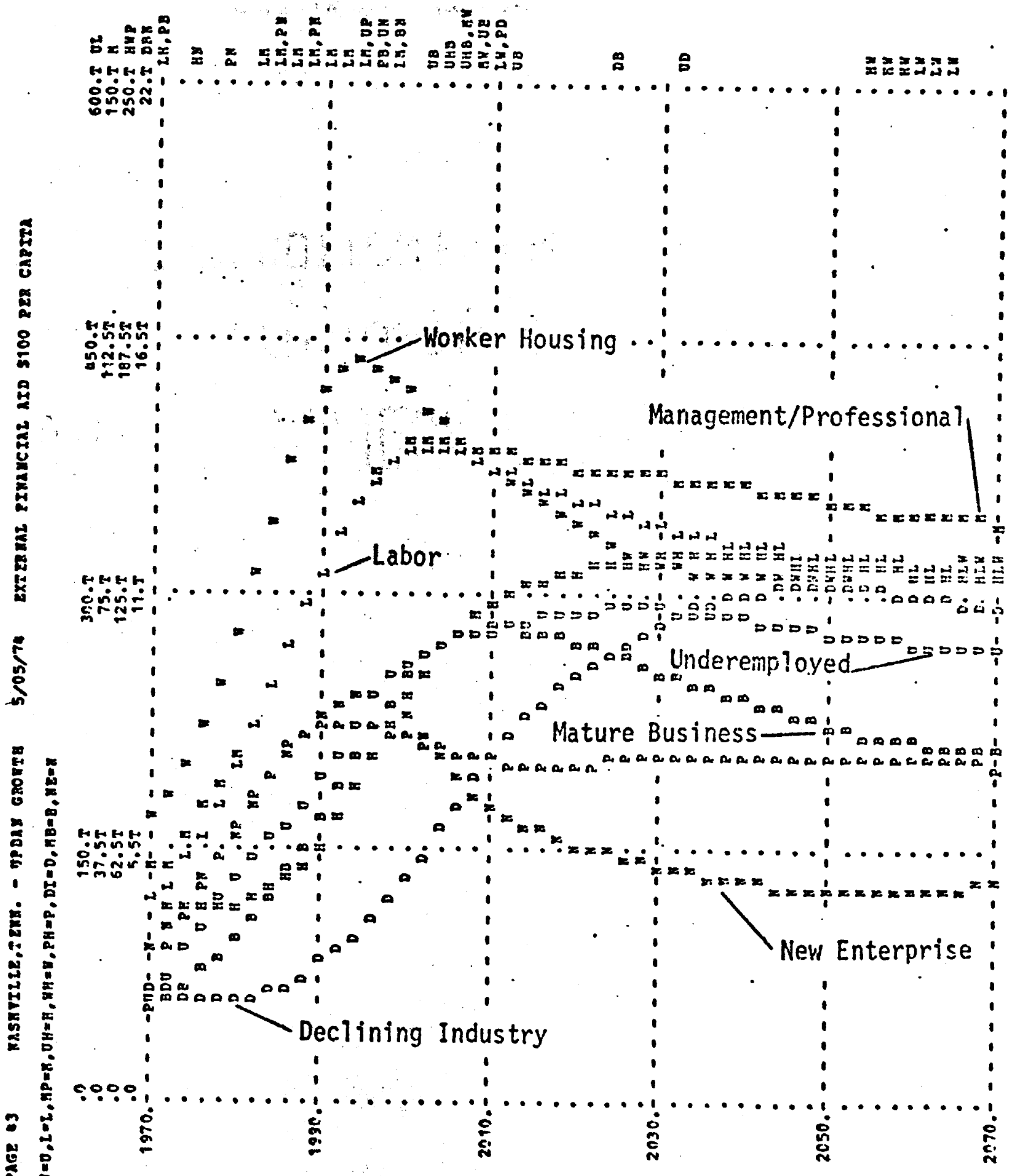

Figure 3.7 a Dynamics of External Financial Aid

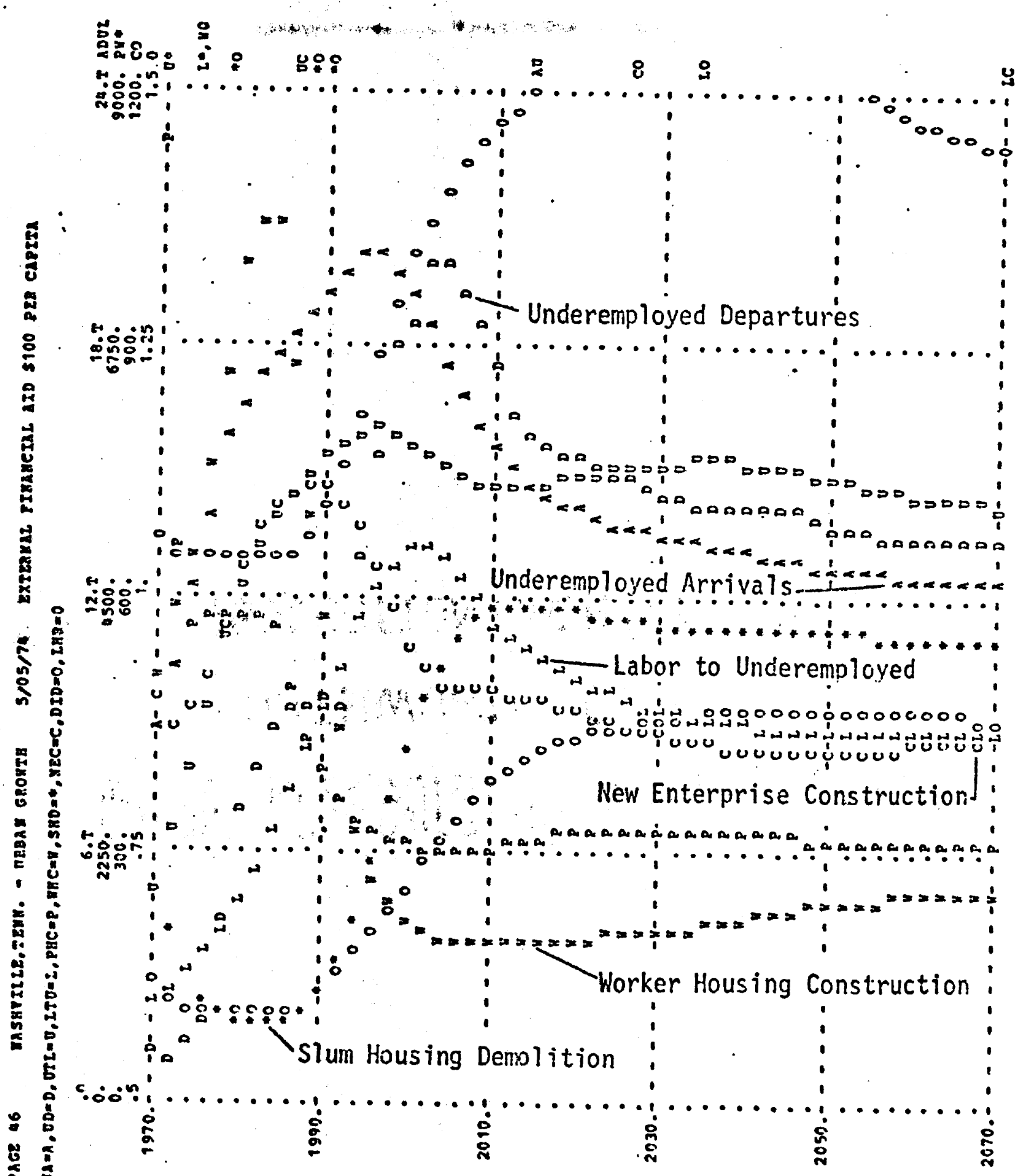

Figure 3.7 b Dynamics of External Financial Aid

utilizing a policy of this type is to use the outside funds to do more than simply give the citizens a free ride by hoping to have lower tax rates. The problem here with this type of policy is that it was not really used to do anything, other than pay for existing services. Had it been used to expand one of the sectors of housing or industry, it would have added a dimension that did not already exist. As it was, it simply made the area more attractive to underemployed outside the environment, and less attractive to those already in the city. Because of the poor consequences of this policy, it is not recommended as a means to improve Nashville.

6. Underemployed Job Program

The underemployed job program is the artificial creation of jobs for 5% of the underemployed. It is artificial from the point of view that the jobs are not part of existing industries, but created through public service jobs, such as the Public Works Administration of the 1930's. The jobs become part of the urban system by being added to the existing underemployed jobs (UJ). The job program is initiated in the model in the year 1975.

The immediate consequence of the program is for the underemployed job ratio (UR) to decrease because of the sudden surge of underemployed jobs. This increases the underemployed job multiplier, which in turn increases the attractiveness to the underemployed. Naturally, the underemployed arrivals (UA) increases. This causes the number of underemployed to increase, as Table 3.1 illustrates;

however the number of managerial/professionals and labor actually shows a slight decrease from what would happen under "normal" conditions. The reason for this decrease is in the industrial sector. For an illustration, see Figure 3.8a, b and c, Dynamics of Underemployed Job Program.

The industrial sector decreases slightly under the job program, indicating that this policy is actually making the economic situation, and thus the whole urban situation, worse than it was under the existing conditions. The reason for this decrease comes from the increase in underemployed, while the managerial/professional and labor decrease. This shift in population proportion causes the taxes needed to support the population to increase.

This increase in the taxes needed sets off a chain reaction that ultimately inhibits the industrial sector from "normal" growth through the enterprise multiplier (EM). The taxes needed (TN) cause the tax ratio to increase, which decreases the EM. The decrease in EM then discourages the creation of new enterprise, which means that mature business also decreases. Declining industry remains about the same.

The decrease in industry, managerial/professionals and labor causes a similar decrease in housing. Table 3.1 shows that only underemployed housing increases, and then by only 3%. This increases because of the decline in the overall economic situation that causes housing to deteriorate at a slightly higher rate and thus move more

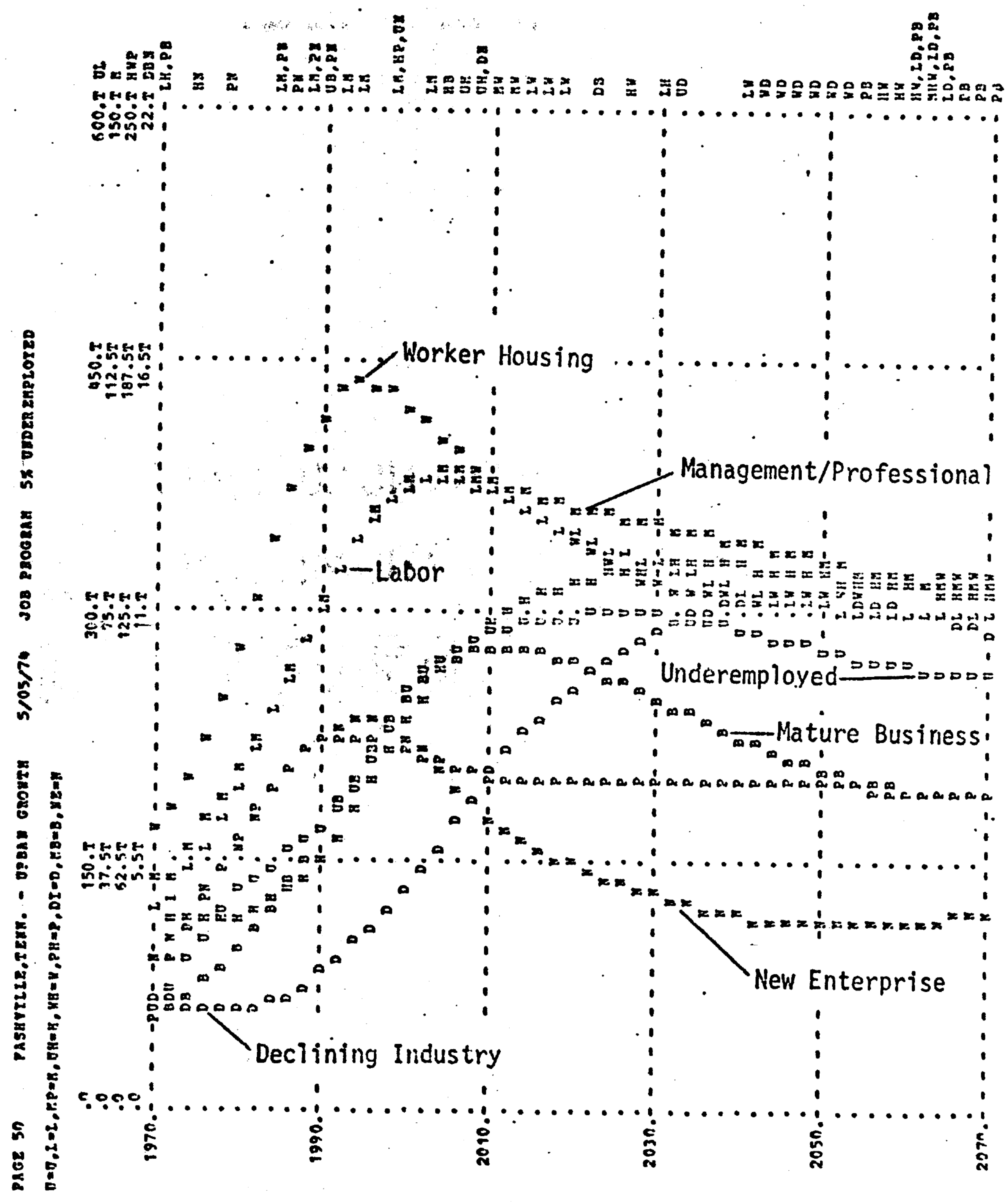

Figure 3.8 a Dynamics of Underemployed Job Program

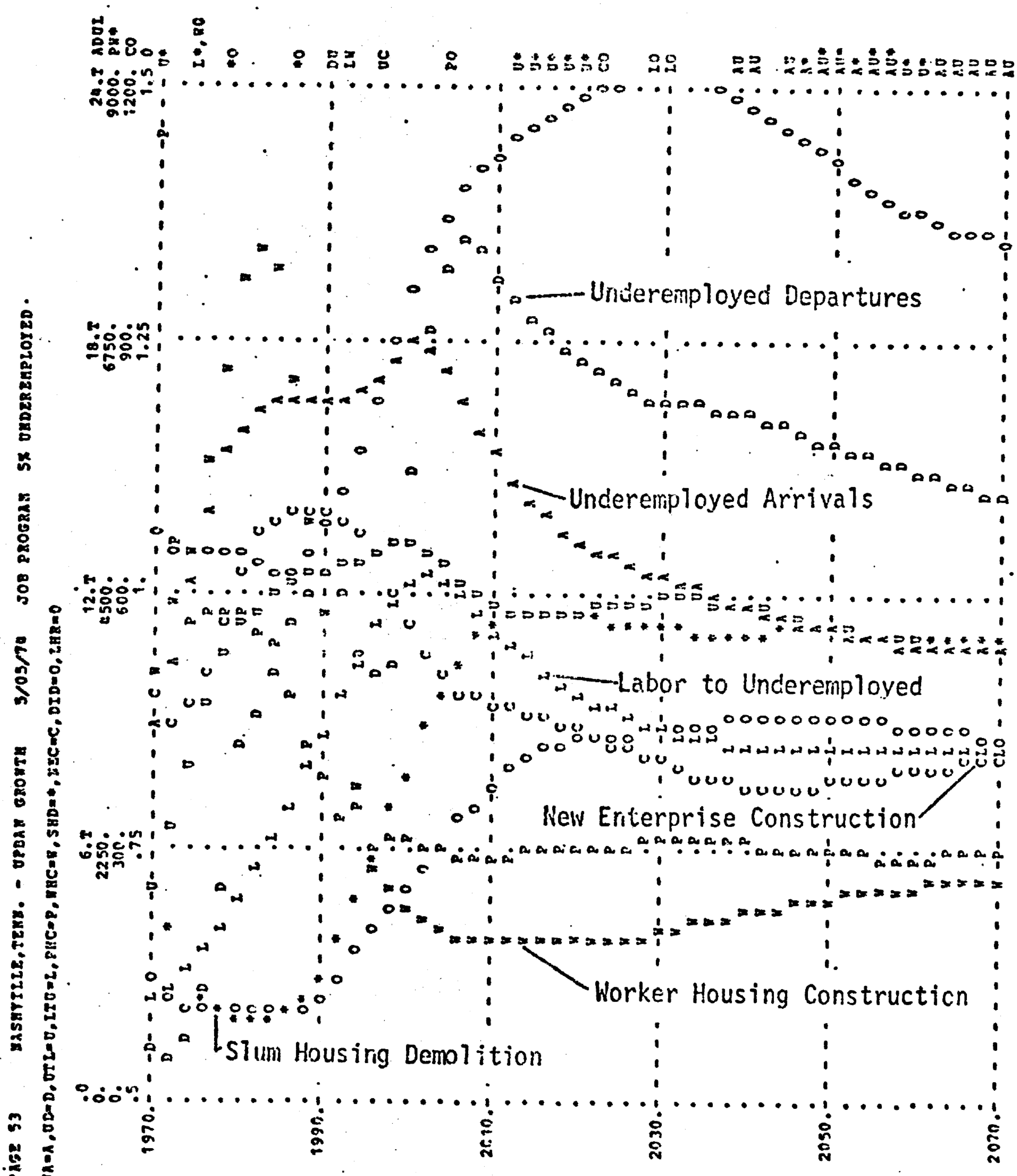

Figure 3.8 b Dynamics of Underemployed Job Program

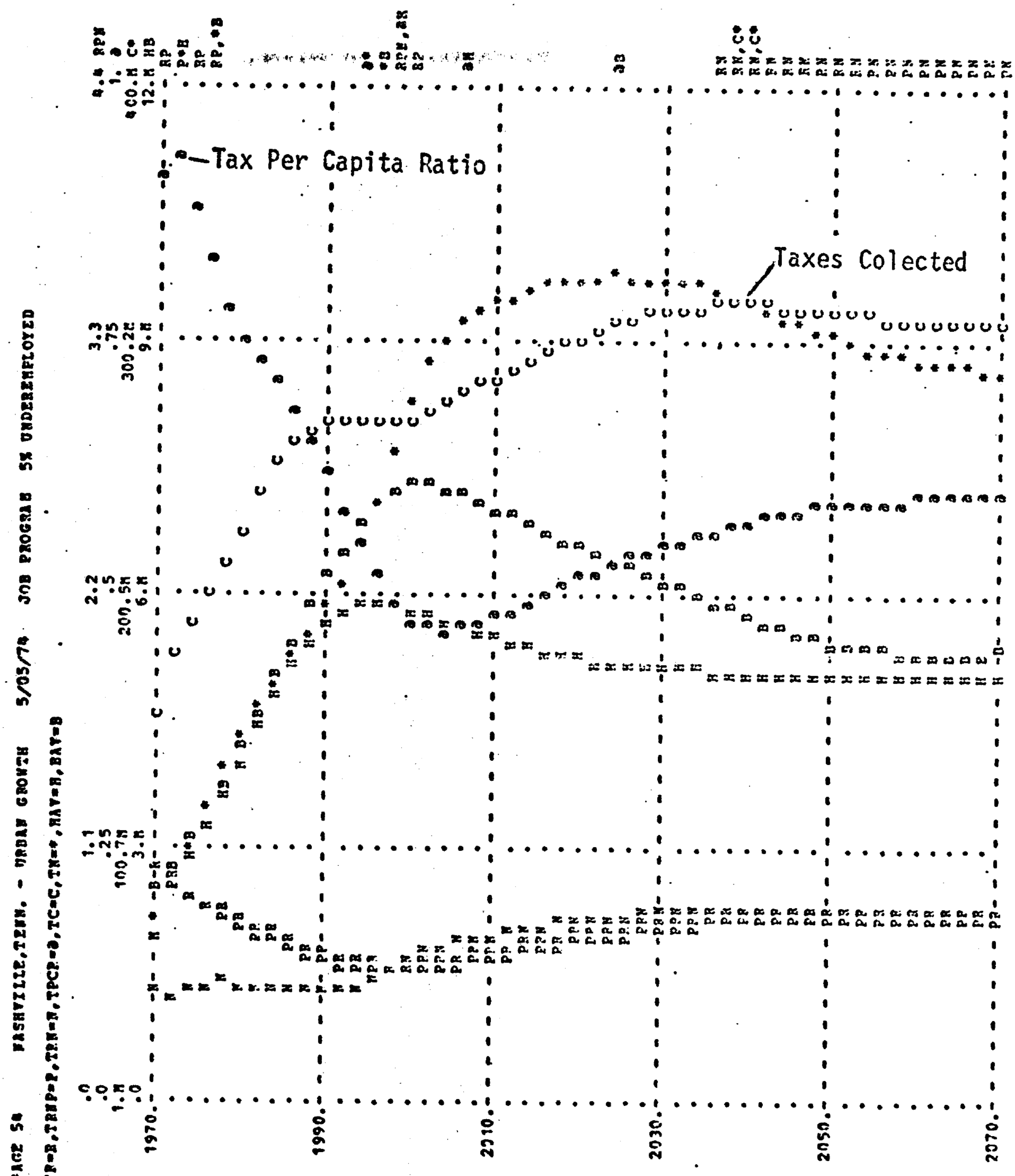

Figure 3.8 c Dynamics of Underemployed Job Program

quickly into the underemployed housing category. This change can be seen in Figure 3.8a, b and c, Dynamics of Underemployed Job Program.

In conclusion, the consequences of the job training program make the situation worse than it was under "normal" conditions. Industry and housing decline and the population shifts to require higher tax revenue. As a result of these conclusions, this policy is not recommended as a means to improve the urban environment in the Nashville model.

7. Low Cost Housing Program

The low cost housing program is intended to provide housing to the underemployed in addition to the existing underemployed housing (UH). The amount of housing constructed is 5% of the existing UH, beginning in 1975. The funding for the program comes from outside the city, therefore it costs the city nothing. It employs labor from the construction force to build the housing.

The program was chosen for examination because it was very commonly used in the 1960's in the form of urban renewal to try to replace slum housing. Urban renewal has lost its popularity as a solution to slum housing because of the social problems that result. The consequences of this low cost housing policy show other consequences that are more detrimental to all of the city than social problems.

The immediate consequence of the low cost housing is a decrease in the underemployed housing ratio (UHR) that results from the sudden increase in housing for the underemployed. This gradually increases the attractiveness perceived by the underemployed, which causes an increase in the underemployed arrivals (UA). The increase in the UA causes an increase in the proportion of underemployed. This shift can be seen by Table 3.1 where all population sectors decrease significantly except the underemployed. MP decreases by -20% and L decreases by -19% but the U decreases by only -3%. This relative proportionate increase in the underemployed (U) causes more taxes to be needed, which eventually increases the tax ratio to .8789, as opposed to .7011 under "normal" conditions. This increase in the tax ratio tends to discourage new industry and is expressed in the model as a decrease in the enterprise multiplier (EM). As has been mentioned in the analysis of other policies, the EM is one of the determinants of new enterprise, which decreases as the EM decreases.

Another factor that causes the EM to decrease is the land fraction occupied (LFO). The LFO is the fraction of the land that is occupied by housing and industry. In the Nashville model, the amount of land available for development is limited to 229,863 acres. As this land area fills up, development is more difficult and expensive. As the LFO increases, the EM is decreased from the additional underemployed housing. This, and the increase in taxes, cause industry to plunge lower than with any other policy -- almost back to what they were in 1970.

Because of these disastrous results, the policy of trying to aid the underemployed by providing more housing proves to be the worse policy initiated. Therefore, it is not recommended as a policy to improve the urban environment of Nashville. An illustration of the disastrous consequences of this policy is shown in Figure 3.9a and b, Dynamics of Low Cost Housing Program.

8. Slum Housing Demolition

The analysis of a slum housing demolition policy is performed by initiating a slum housing demolition program in 1975 that demolishes 5% of the underemployed housing in addition to the slum demolition by normal dynamics in the city. It is assumed that this is accomplished by indirect methods rather than having the city administer the demolition. Methods that might be used are to make changes in tax and zoning laws. This policy has been chosen for analysis in order to compare it to the previous policy of providing low cost housing. The previous policy proved to be such a disaster, and to point the city in such a wrong direction, that taking the opposite policy of destroying the worst underemployed housing may prove to improve the situation rather than make it worse. As will be shown here, adopting the policy of slum demolition does in fact turn the city around and improve the urban environment for all sectors of the model.

The initial consequence of adopting the policy of slum demolition is for the supply of underemployed housing to decrease and, with time, the perceived supply of underemployed housing (UH) also

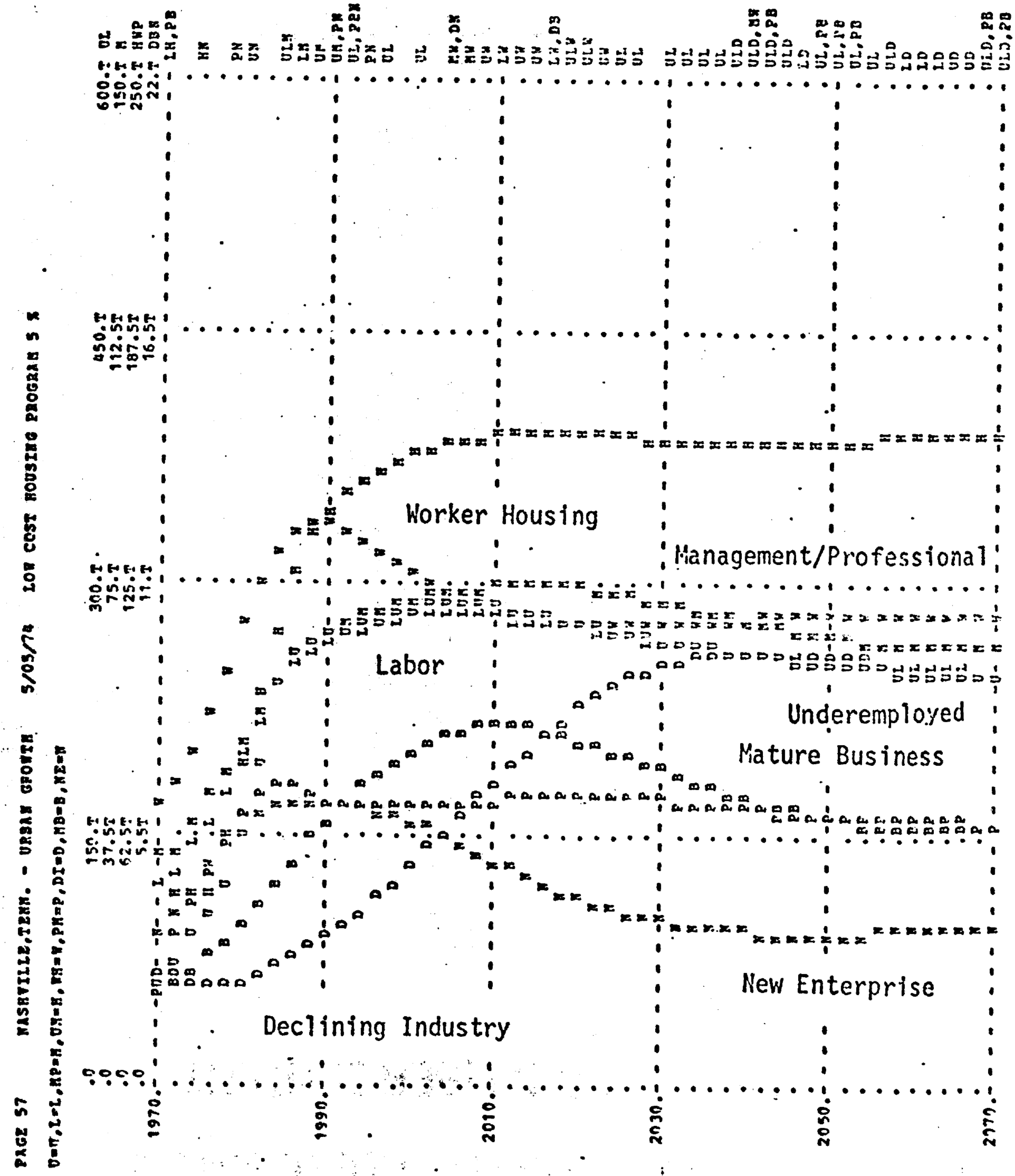

Figure 3.9 a Dynamics of Low Cost Housing Program

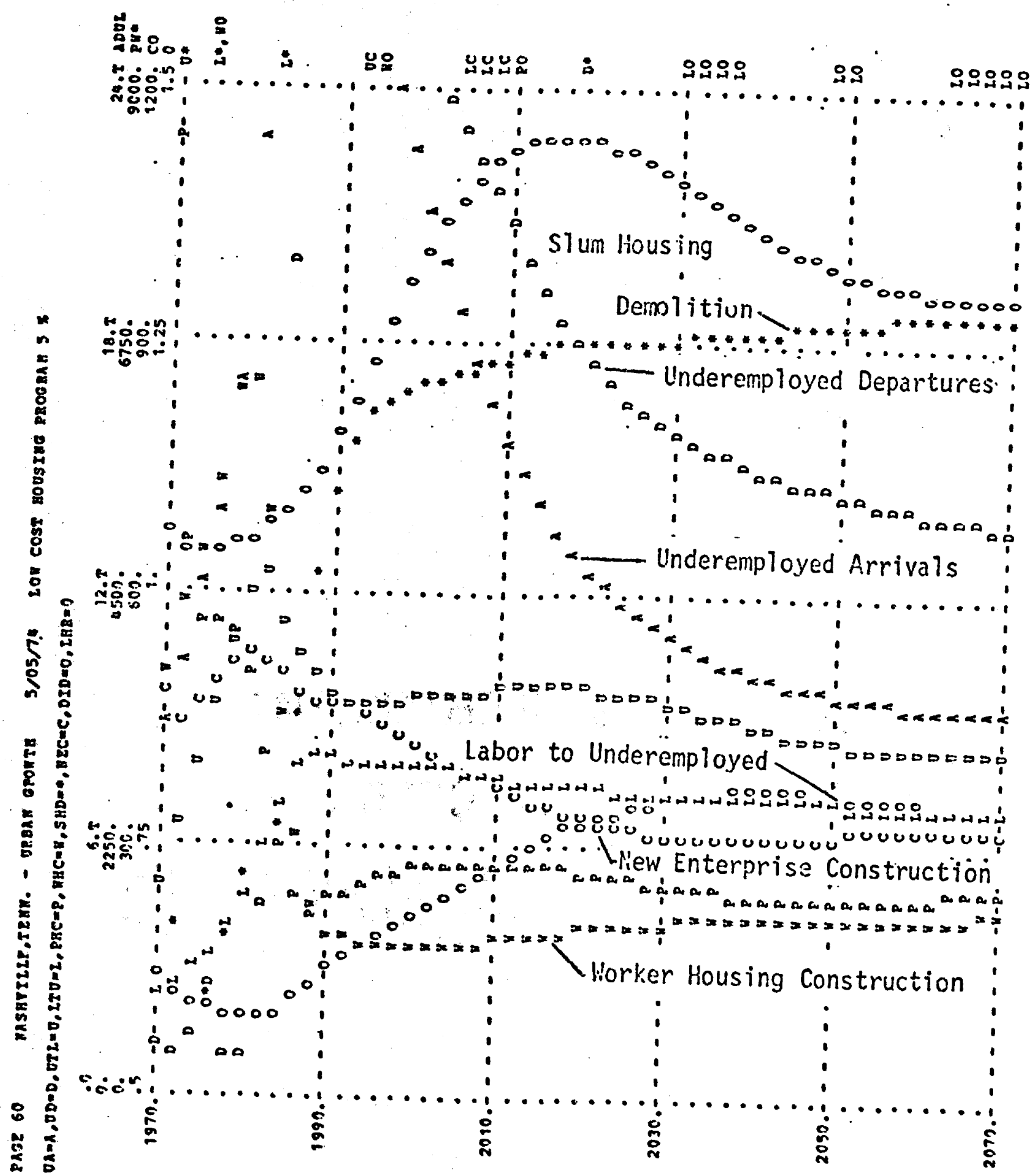

Figure 3.9 b Dynamics of Low Cost Housing Program

begins to decline. With the perceived supply of UH declining, the attractiveness to the underemployed declines beginning in 1980. As as result of these declines, the number of underemployed does not increase as much as it did under "normal" conditions. This can best be seen by comparing the growth of the underemployed under "normal" conditions in Figure 3.1a and under the policy of slum demolition in Figure 1.10a. Notice, in particular, the difference in the slope of the underemployed and the underemployed housing (UH). They are not as steep as under "normal" conditions. This more gradual increase the underemployed causes a reduction in the proportion of underemployed. This means that the taxes needed (TN) to provide public services is less therefore the tax ratio is less.

As was pointed out in the analysis of the low cost housing program, the tax ratio has a direct impact on the enterprise multiplier (EM). By having lower taxes, the EM increases, which causes new enterprise to increase. By having fewer UH, more land is available for new industry and housing. The more land available can be seen in Figure 3.10b by the slightly lower land fraction occupied (LFO). The lower LFO also has a favorable impact on the EM. This, joined by the lower tax ratio, produces a very good environment for new enterprise (NE). In fact, NE increases by 47%, mature business (MB) by 49%, and declining industry (DI) by 18%, which is a greater increase than with any other policy.

The increased activity in the industrial sector encourages premium housing, which increases by 27%, and as a result of this

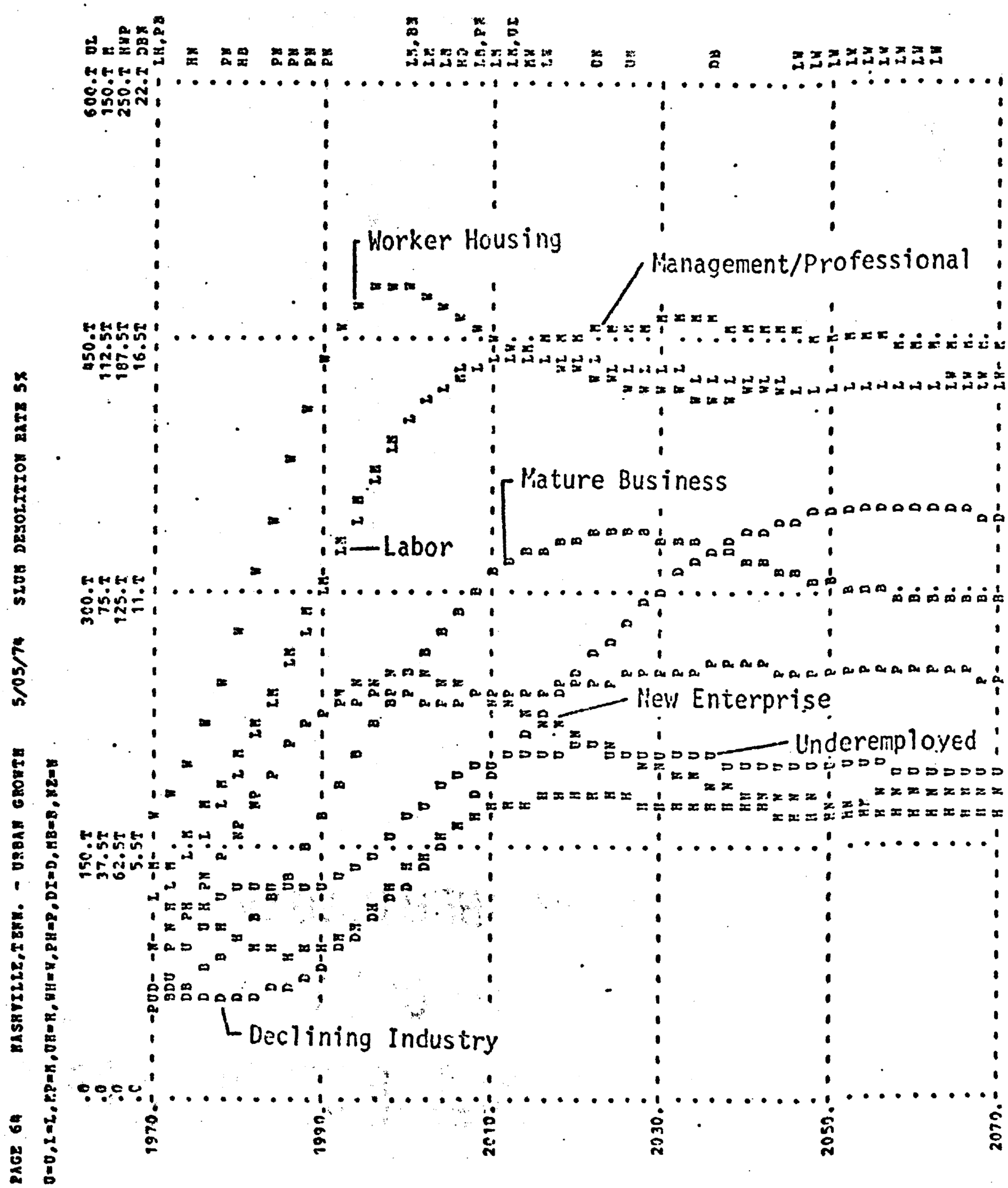

Figure 3.10 a Dynamics of Slum Housing Demolition

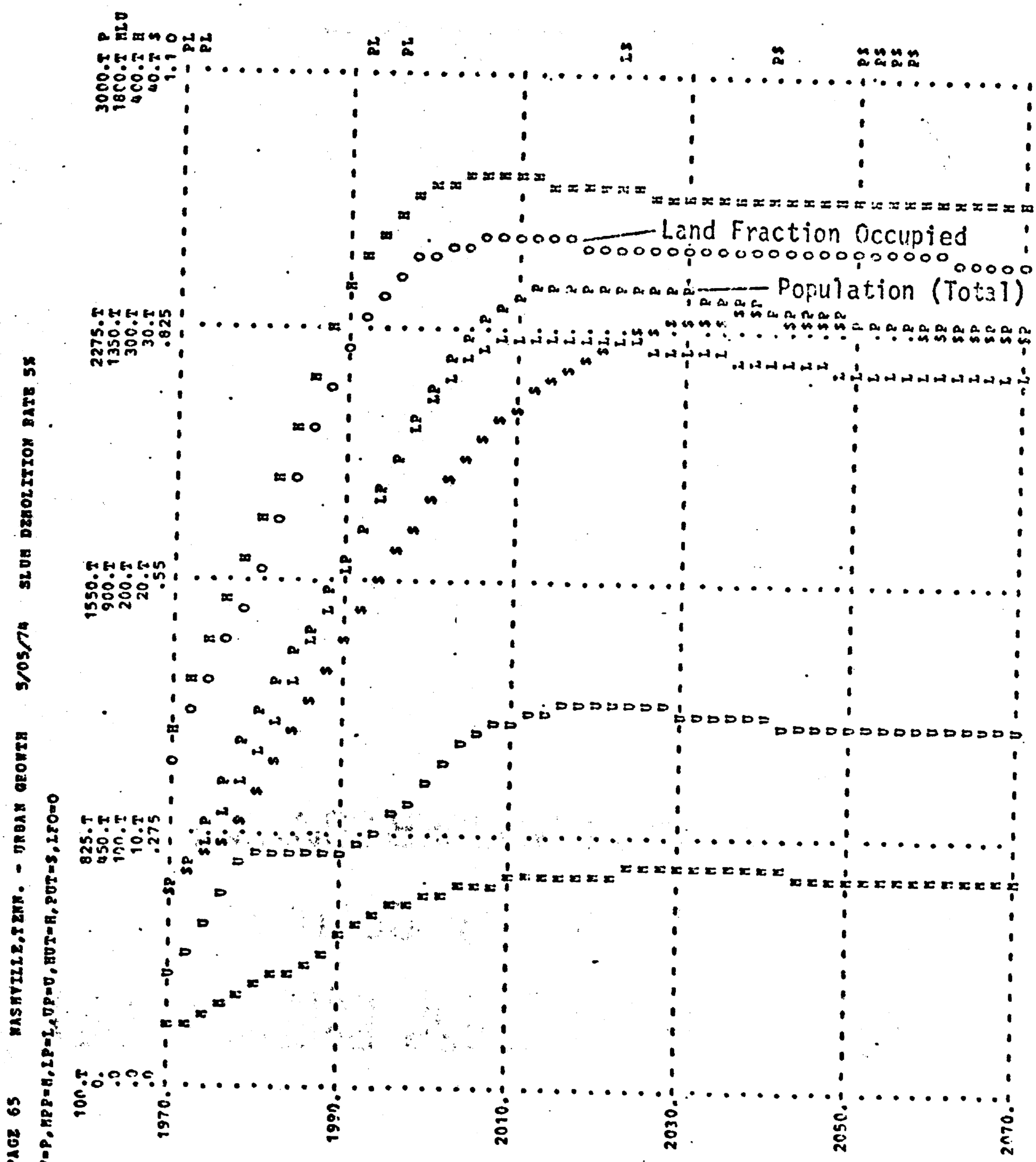

Figure 3.10 b Dynamics of Slum Housing Demolition

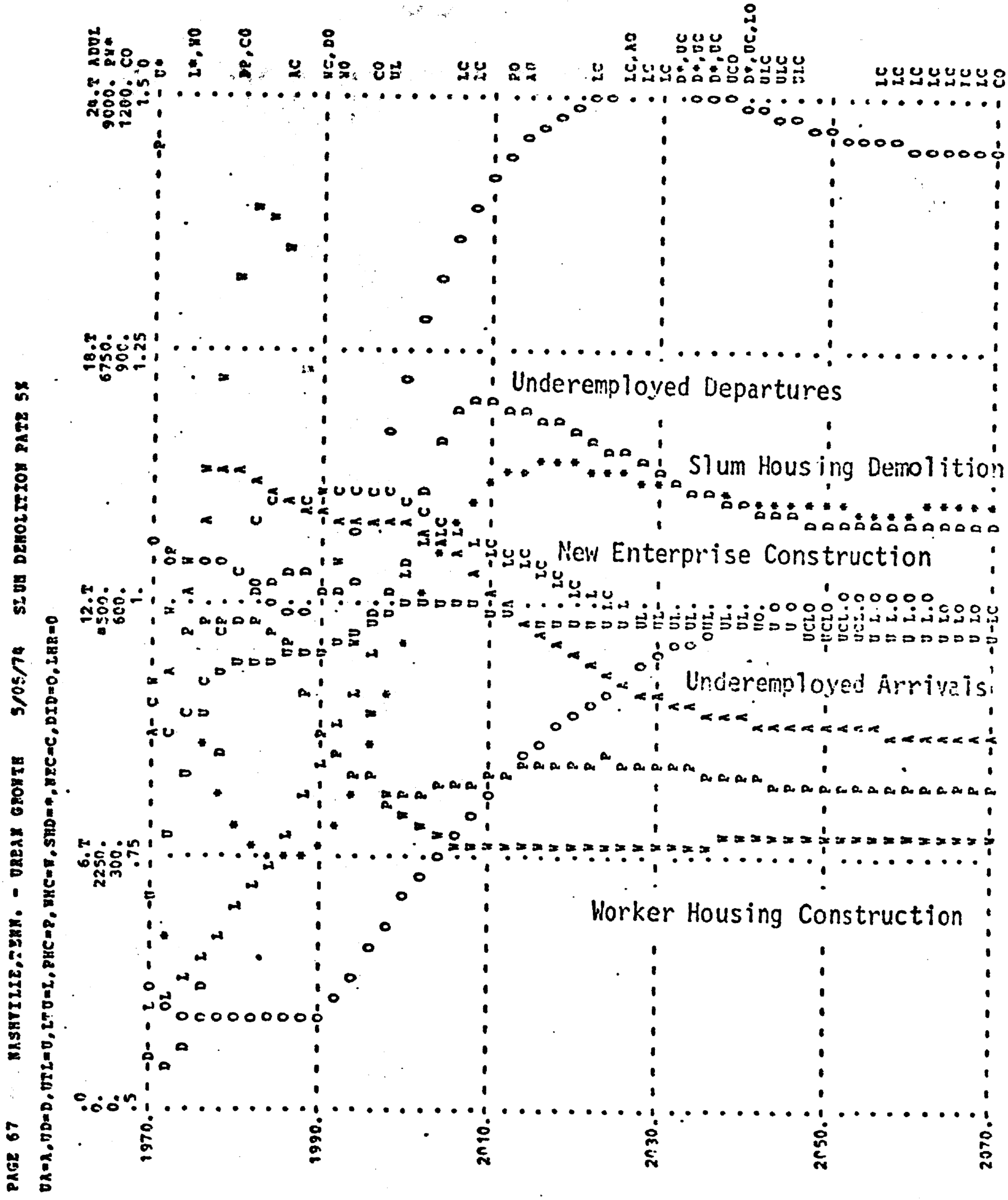

Figure 3.10 c Dynamics of Slum Housing Demolition

increase, worker housing also shows a similar increase of 28%. But because of the slum demolition program, underemployed housing decreases by 44% in the year 2070.

But an increase in industry and premium and worker housing is not the only way in which the health of a city is measured. Jobs for all sectors of population are an important measure -- perhaps more important than housing or industrial growth. Looking at the job ratios on Table 3.1 shows that the ratios (MR, LR, and UR) are slightly less and, most important, the UR has decreased by a dramatic 44%. This decrease, particularly for the underemployed, shows a sharp reduction in unemployment. The housing ratio for the underemployed, on the other hand, has also changed substantially -- but of course in the other direction -- because of the slum demolition program. The UHR on Table 3.1 has increased to 1.296, which is apparently needed in order to keep the attractiveness down for the underemployed and to permit the growth of industry, which provides a high level of jobs for the underemployed as well as for the other population groups.

Based on the assumption that, if forced into a decision between housing or jobs for the underemployed (which it appears that we are), it is better to have jobs and a shortage of housing than to be without jobs and have a surplus of housing.

From the evaluation of the consequences of this policy, it is obvious that the consequences here are beneficial to all sectors of the city and is therefore considered to be a good policy to recommend.

9. New Enterprise Construction Program

A new enterprise construction program has been established under the assumption that the city can present inducements that will result in a 5% increase in new enterprise (NE) construction. The policy was chosen to see what will happen to NE and the rest of the sectors in the model by directly adding NE, rather than indirectly encouraging NE as was done in the slum demolition policy just examined.

The initial consequence of the program is an increase in the new enterprise desired (NED). A key variable that influences the NED is the enterprise multiplier (EM). When this familar variable is low value, the NED is low, meaning that less NED results and less NE exists. The EM is a significant variable and, as will be shown, has an important influence on the level of industry.

As a consequence of this policy, industry does grow greater than what would have under "normal" conditions. But it does not grow to the extent that it did under the slum demolition policy. As is shown under this policy in Table 3.1, Consequences of Urban Policies at Equilibrium, new enterprise (NE) does grow by 11%, mature business (MB) by 15%, and declining industry (DI) by a surprising 102%. The first question that naturally comes to mind is "why does DI grow by 102% when the other two sectors of industry grow by only 11% and 15%?" The answer is found in the enterprise multiplier (EM), which is one of the variables that determines the amount of DI.

The amount of declining industry (DI) that exists is determined by the amount of mature business demolition (MBD) and the amount of declining industry demolition (DID). The mature business demolition is not really demolished, but passes from the mature business category to the declining industry category. The flow of productive units from the mature business category to the declining industry category is determined by the enterprise multiplier (EM). When the EM is high, the downward flow of productive units is slow; when it is low, the flow is greater. Under this policy, the enterprise multiplier is low -- particularly because of increased taxes and the higher percentage of land that is occupied. As a result, more declining industry accumulates because there is less incentive to replace it with new industry or housing. The increase in taxes and land fraction occupied result from shifts in the population and increases in the housing sectors respectively.

The low enterprise multiplier results from shifts in the population sector. Because of jobs perceived to exist, underemployed are attracted to the area, therefore the taxes needed to sustain them rise. The increase in the population sectors can be seen on Table 3.1, where the managerial/professionals increase by 35%, the labor group by only 13%, and the underemployed by 35%.

The increase in the land fraction occupied results from the increase in the proportion of housing vs industry. Under the new enterprise construction program, both industry and housing increase, but in respect to the amount of land that they occupy, housing takes up most of the land. Each housing unit takes up .5648 acres of land and with 346,100 housing units in the year 2070, a total of 195,546 acres of land are taken up with housing. This is opposed to 11,980 acres of land taken up with industry, where each productive unit is .344 acres and there are 34,820 productive units in the year 2070. This dominance of housing in the percentage of land causes the LFO to increase and thus inhibit the expansion of industry that was intended.

Looking more closely at the impact of this policy on the housing sector shows some interesting consequences. Most particularly, worker housing (WH) shows a decrease while the other two sectors show increases. Specifically, Table 3.1 shows changes of 18%, -17%, and 7% for PH, WH, and UH respectively. This results because WH declines in quantity faster than new worker housing is added. This happens for four reasons: 1.) a shortage of premium housing reduces the flow of premium housing to worker housing because, with the shortage, the housing is maintained for a longer life; 2.) the land multiplier which encourages housing is reduced because the land fraction occupied is over 90%; 3.) the labor to underemployed ratio (LUR) is not high enough to induce more housing to be constructed; and 4.) the tax ratio has become too high to induce additional worker housing. All of these result in a decreased supply of worker housing. See Figure 3.11a, b and c, Dynamics of New Enterprise Construction, for an illustration of changes under this policy.

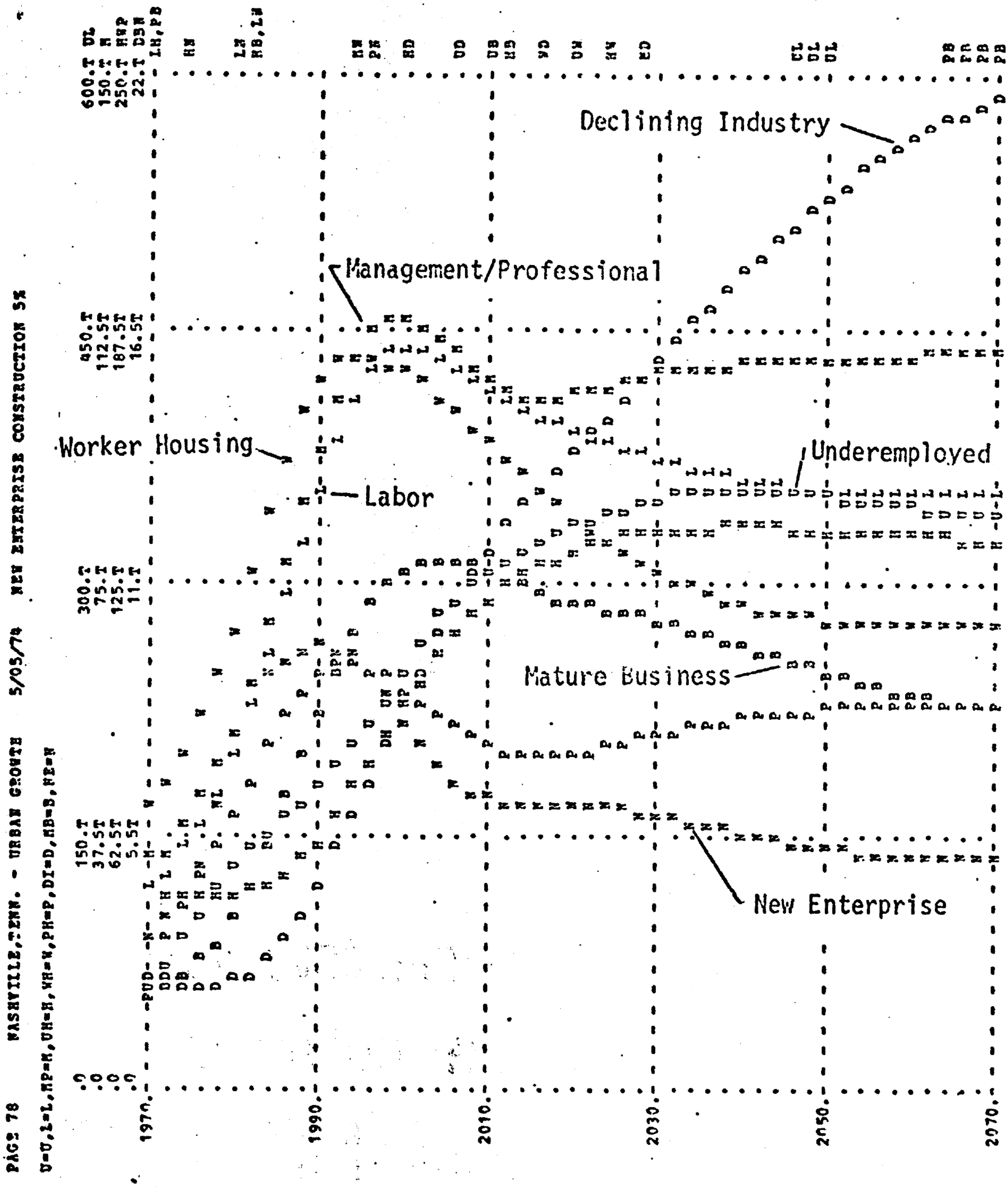

Figure 3.11 a Dynamics of New Enterprise Construction Program

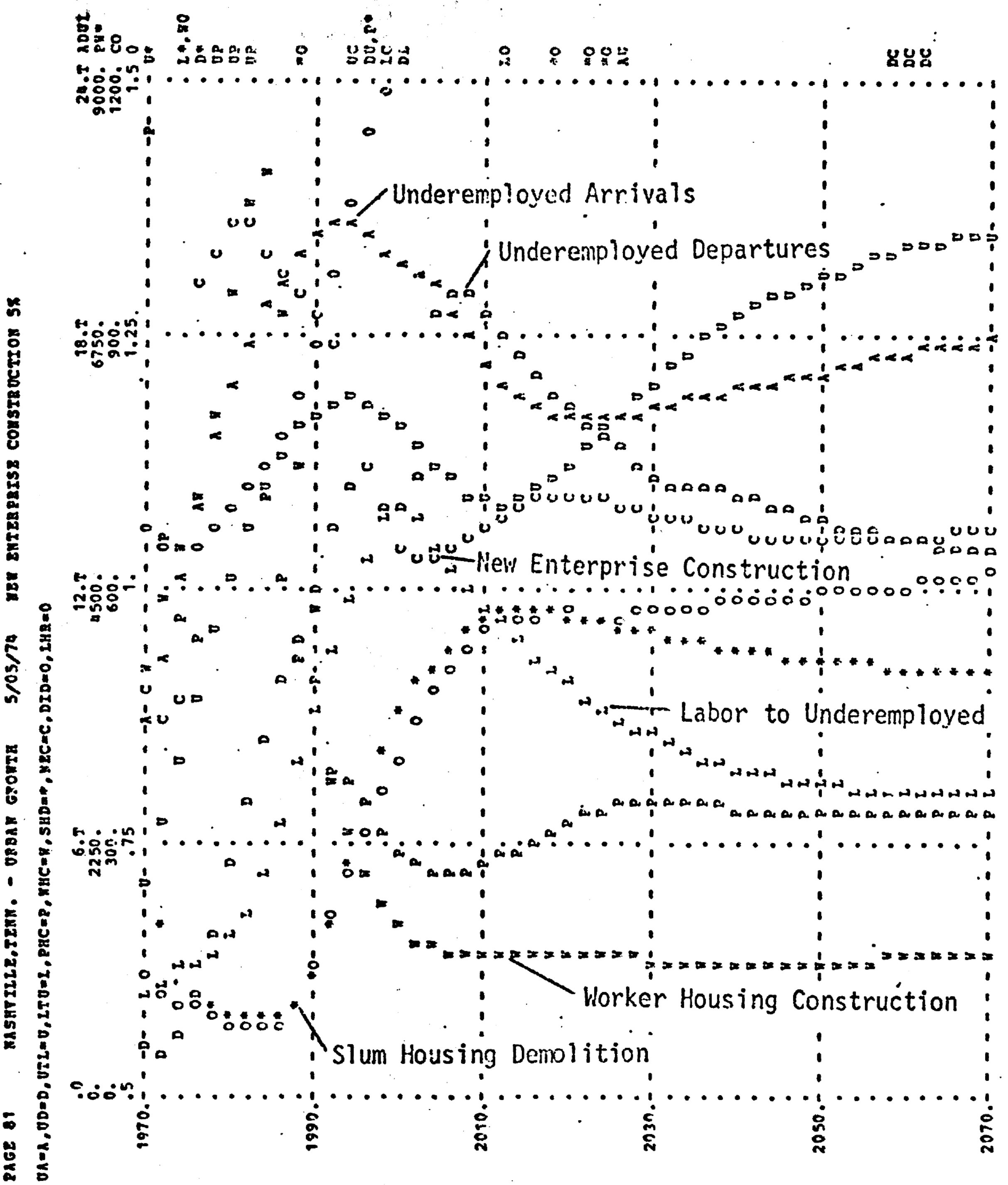

Figure 3.11 b Dynamics of New Enterprise Construction Program

NASHVILLE,TENN. - URBAN GROWTH 5/05/74 NEW ENTERPRISE CONSTRUCTION 5%

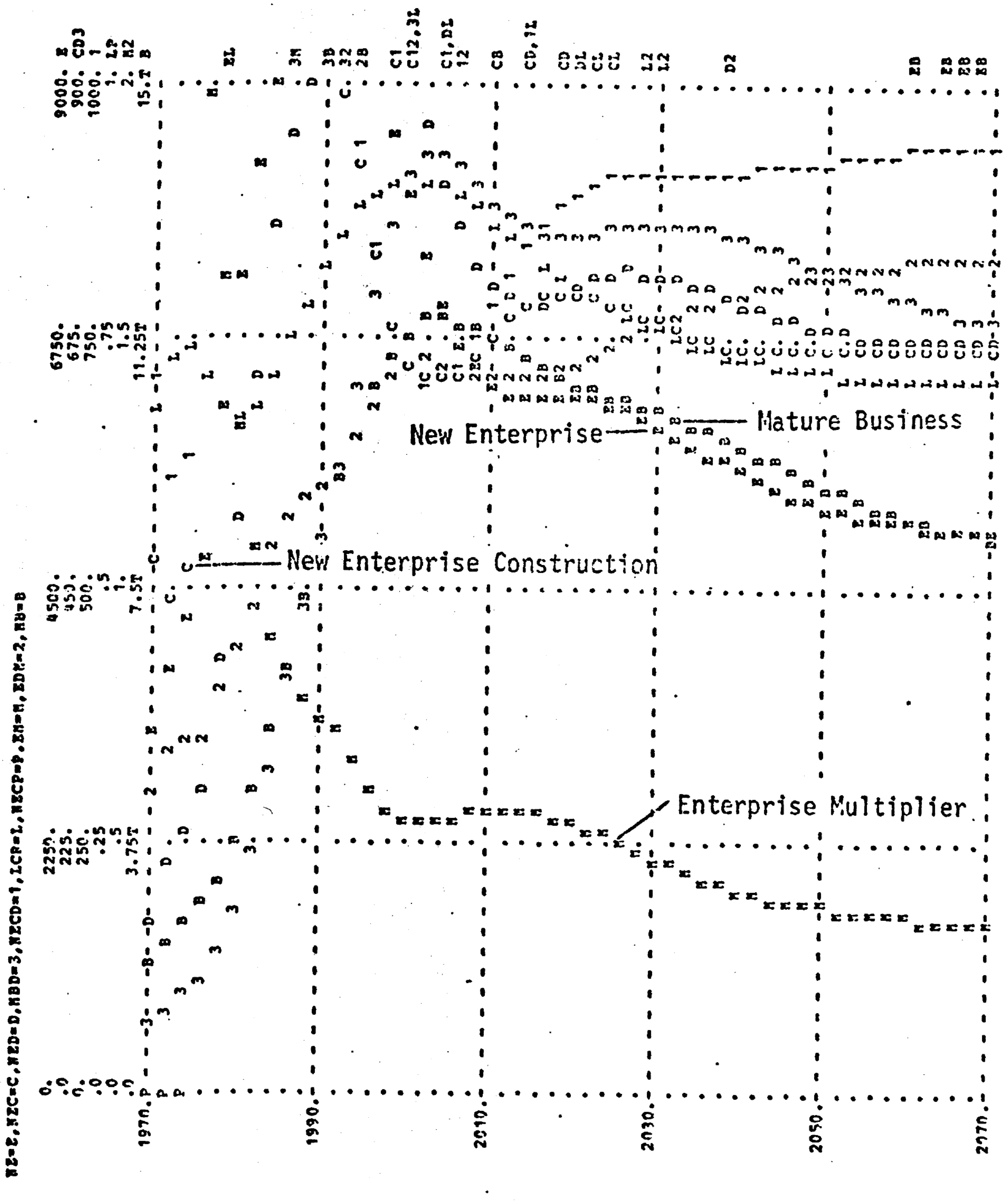

Figure 3.11 c Dynamics of New Enterprise Construction Program

The question might be raised "If all these factors are working against the growth of worker housing, why do premium and underemployed housing grow?" The answer is that the inducements to build premium housing are greater than for worker housing, and that the life before demolition for underemployed housing is longer than the other two categories, therefore there is a tendency for underemployed housing to accumulate.

Looking at the overall consequences of the new enterprise construction policy shows that the results are mixed. For some sectors, the consequences are improvements, while for others they are not. What is needed is a more balanced outcome that would improve all sectors, not just a few.

Generally, it appears that the policy is not more effective because it was forced to happen, rather than allowed to happen naturally. Contrasting it to the slum demolition policy, where new enterprise was a byproduct and grew greater than under this policy, leads to the conclusion that a direct inducement is not always as effective as an indirect inducement. This happens because a direct inducement tries to force a response out of the system, when in fact the conditions have not been set for the desired consequences to happen naturally. The solution to producing a favorable response is to find the variables that dominate the others such as the enterprise multiplier (EM), then see how that variable might be influenced. By finding and altering the influences of the dominant variables, the desired action will be able to proceed more smoothly through a natural course of least resistance. Just as water flows down the course of least resistance to friction and gravity, so do actions in this model.

Because the majority of consequences of this policy are favorable, it is recommended as a policy to improve the urban environment. This is the type of policy, however, that would probably be most successful when enacted with another policy to give it more balanced consequences.

10. Restrict Worker Housing Construction

The last policy to be analyzed is what happens when the construction of worker housing is reduced by 1 1/2% of the normal rate, beginning in 1975. This policy was chosen to be analyzed as a possible means to improve the urban environment because of the success that resulted from the slum demolition program.

The initial consequence of this policy is the reduction of worker housing construction (WHC) that reduces the amount of worker housing available. As has been seen in the previous analysis of policies, the introduction of a change in one of the principal sectors produces changes throughout the rest of the system. In this case, the change in the supply of worker housing first decreases the flow of housing from worker housing to underemployed housing. The resulting shortage of underemployed housing reduces the attractiveness of the city to the underemployed, therefore the number of underemployed arrivals (UA) declines below what happens under "normal" conditions. All this changes the composition of the population and produces favorable conditions for growth of new enterprise in the early years of the simulation.

The favorable conditions that result from the change in the population composition are in the form of lower taxes and more land available for industrial development -- both contribute to a higher enterprise multiplier (EM). (A description of the enterprise multiplier appears in the analysis of both slum demolition and new enterprise construction.) The higher enterprise multiplier produces a sharp increase in new enterprise that causes a high demand for labor. The demand for labor induces labor to fill the jobs, which in turn puts strong pressure on the supply of worker housing which has been reduced. The pressure on housing becomes so great that it overrides the restriction placed on worker housing construction produced by this policy. Responding to the pressure for more housing, the supply of housing jumps up to a level greater than before the policy was introduced. With the need for labor being met, new enterprise continues to increase and gradually make the area more attractive to the underemployed because of the abundance of jobs and the increase in underemployed housing that results from the increase in worker housing.

The final consequence of the large increase in new enterprise and resulting underemployed arrivals is that the population shifts back to an over supply of underemployed, which raises the tax rate back up again, and finally reduces the enterprise multiplier. The enterprise multiplier is also reduced because the land fraction occupied (LFO) begins to reach 90%. The decline in the EM causes new enterprise construction to decline and new enterprise to stabilize at a point slightly below where it would have been under "normal" conditions. The fluctuations that have been described here can be clearly seen in Figures 3.12a and 3.12c.

The condition of the model can be interpreted by looking at the key variables in Table 3.1, Consequences of Urban Policies at Equilibrium. The final outcome in the model is very similar to the outcome under "normal" conditions, but as was just described, the primary variables go through a lot of fluctuating before reaching this point. Some of the fluctuations produced early in the simulation were good, but they were not balanced enough to be sustained into equilibrium. In order for this policy to be considered beneficial to the urban environment, it needs to be balanced with another group of policies that will sustain its benefits produced in earlier years of simulation. Therefore this policy is recommended only with that reservation.

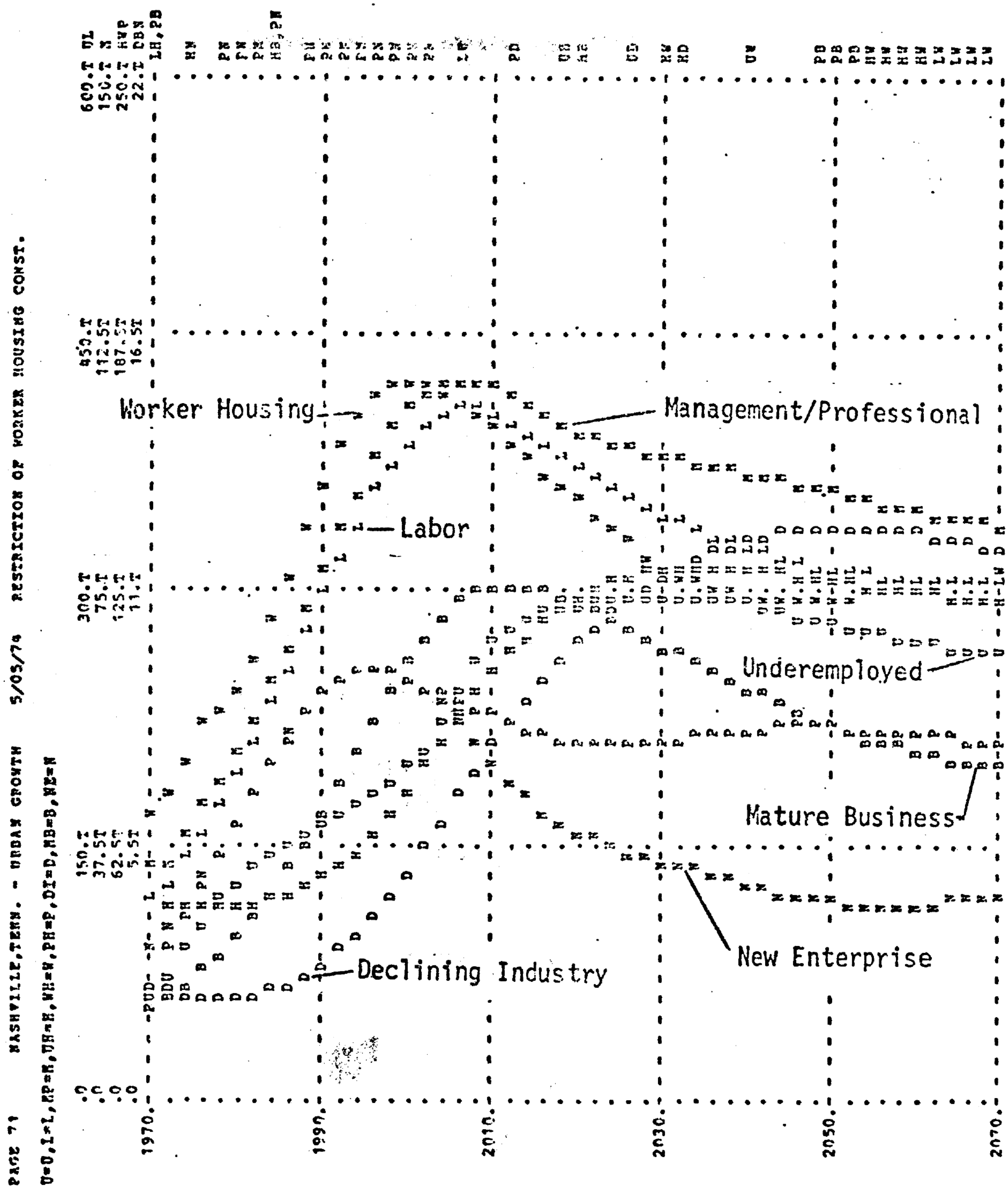

Figure 3.12 a Dynamics of Restricted Worker Housing Construction

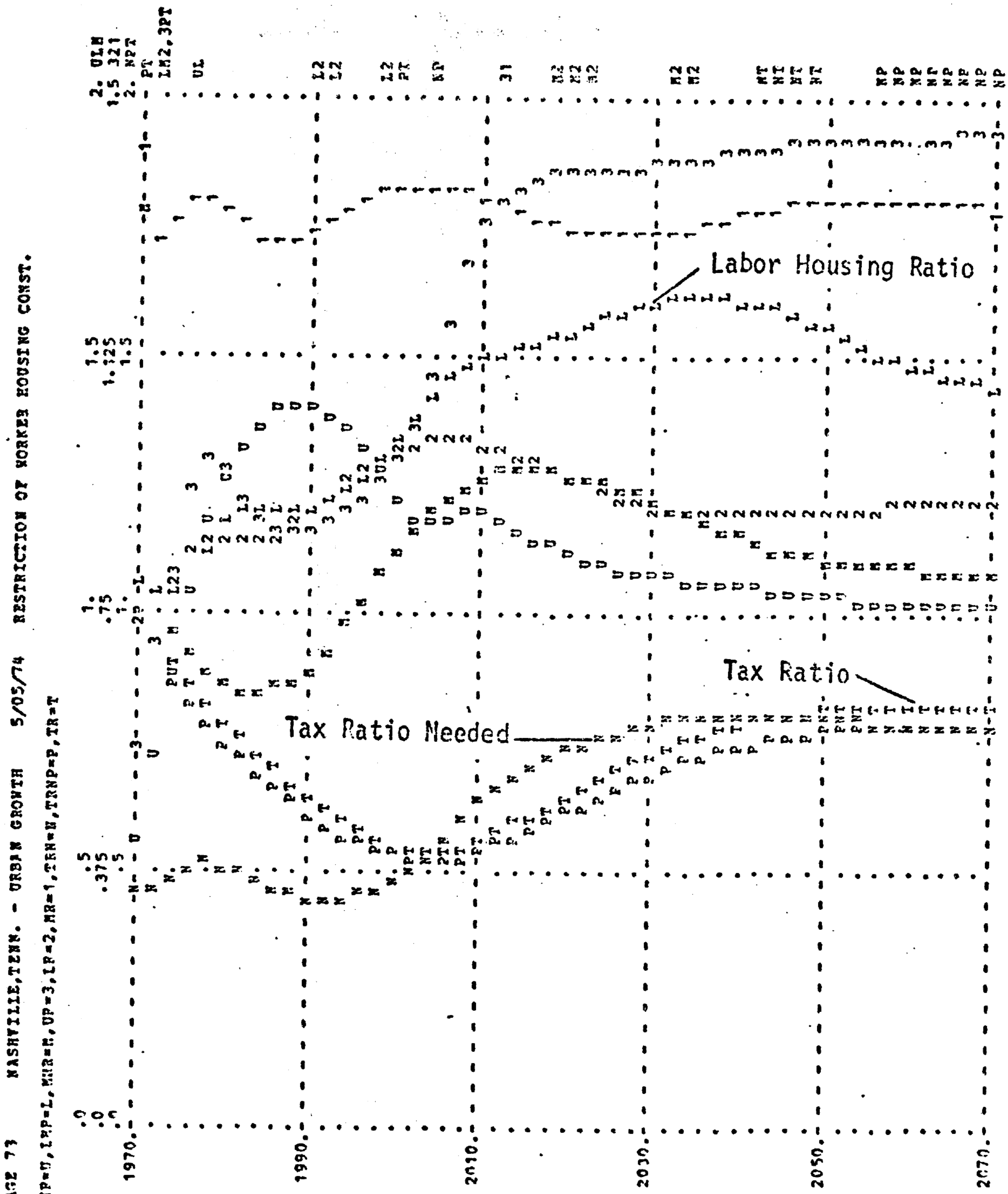

Figure 3.12 b Dynamics of Restricted Worker Housing Construction

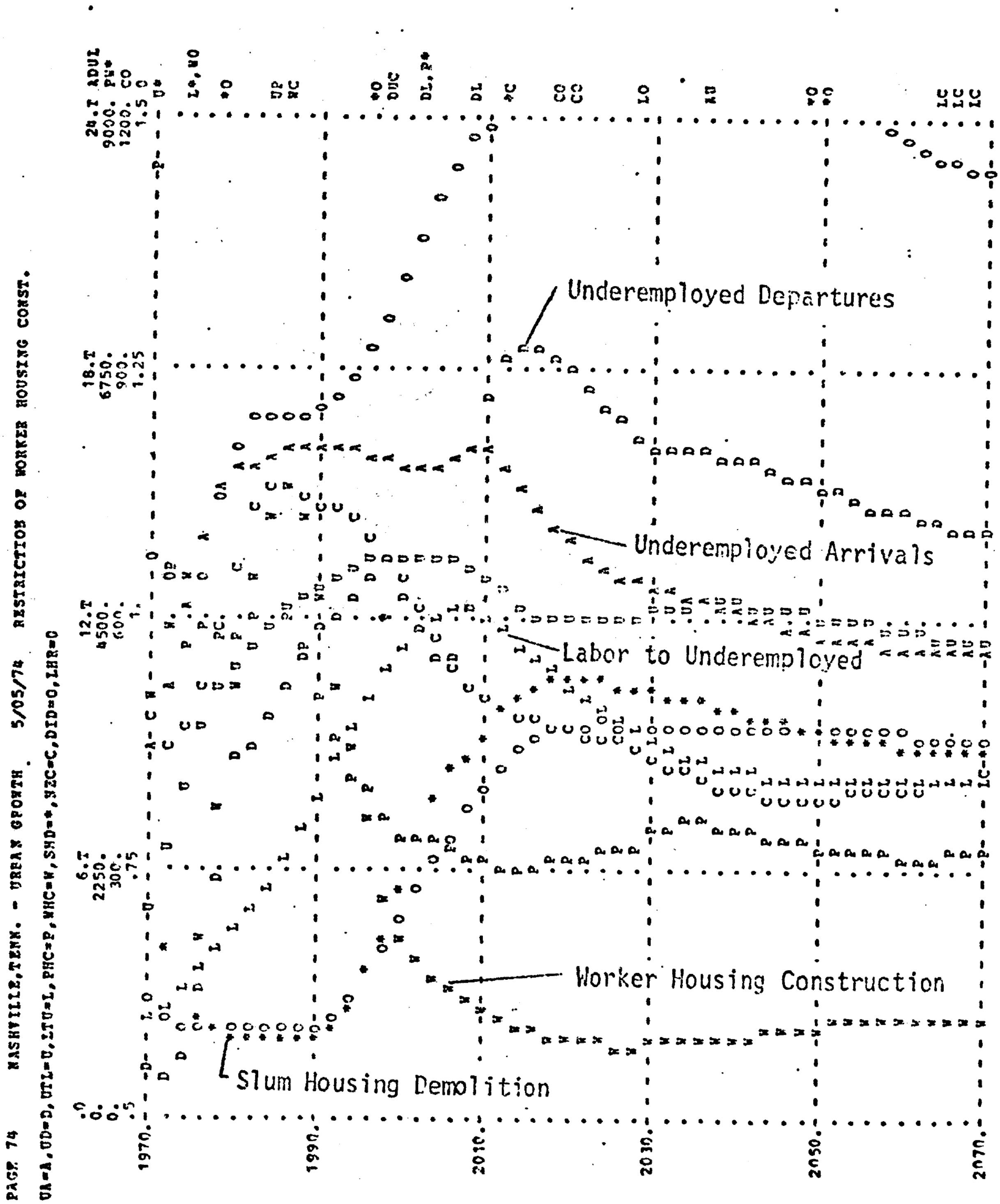

Figure 3.12 c Dynamics of Restricted Worker Housing Construction

Chapter IV

The Choice of a "Best Policy"

The choice of a "best policy" for the Nashville urban dynamics model is difficult because the identification of goals and objectives of the model (which are the basis for evaluating a policy) were not part of this analysis. It was stated in chapter I, however, that the criteria on which to evaluate the different policies would be a set of indicators identified in that chapter. Those indicators have been used as a basis for evaluating the 10 policies examined above.

The task of choosing a "best policy" or set of policies becomes difficult when relative value judgements are made that this indicator is more important than that indicator. What results is the subjective determination that an indicator of a particular sector is more important than an indicator of another sector. Fortunately, the choice of value judgements is not a totally subjective decision.

Analysis of different policies shows that the policy intended to improve a particular sector will not result in improvement without a balanced policy where the other sectors are also improved. For example, the supply of housing for the underemployed was intended to be improved by Policy 7, Low Cost Housing Program. It was found that, as a result of this policy, the situation actually got worse rather than better, as was shown by the underemployed housing ratio (UHR). It was found that the means to improve the UHR was to produce an improved economic environment. This resulted in an improved UHR, as well as in an improvement in the job ratios for underemployed, labor, and managerial/professional. This leads to the simultaneous improvement of all the indicators, rather than the improvement of one over another.

The group of policies that have been determined as being the best for the Nashville urban dynamics model are drawn from the 10 policies examined above. They are the three policies of: Slum Housing Demolition of 5% of the underemployed housing, a 5% increase in New Enterprise Construction, and a 10% Increase in Density Over a Thirty Year Period.

The consequences of this combination policy are quite impressive, as is shown in Table 3.1, Consequences of Urban Policies at Equilibrium. Industry shows a dramatic increase of 72% for new enterprise, 76% for mature business, and a 115% increase for declining industry. Total population shows a large increase as well as a shift to more managerial/professional and labor. Managerial/professional increases by 80%, labor by 72%, while underemployed <u>decreases</u> by 14% from what would have happened under "normal" conditions. Housing follows the population increase as well as shift. Premium housing increases by 53%, and worker housing by 37%, with underemployed housing decreasing by 37%. Because of this shift in population, the tax ratio goes down to a low .4705, which encourages industry. With the housing ratio being higher than with the other 10 policies examined above, the underemployed arrivals minus departures net is still a net outflow, but it is 22% less than under "normal" conditions because of the job ratio being lower than ever before.

To illustrate the dramatic improvement of conditions in the model under this group of "best" policies, a graph is presented below contrasting the results under "normal" conditions with the "best" policy. This graph, Figure 4.1, Consequences of "Normal" and "Best" Policies, shows key variables such as new enterprise (NE), and the various job and housing ratios. This graph is followed by Figure 4.2a, b, c, d and e, Dynamics of Slum Demolition, New Enterprise and Increased Density.

The "best" set of policies includes an increase in new enterprise construction. This is not saying that more industry is necessarily better. Combinations of other policies can produce larger quantities of industry, but these policies produce the lowest overall job ratios for all three sectors of population (MP, L, and U), as well as producing low housing ratios. These policies do not produce the lowest housing ratios, but they are lower than most, when tested separately or in combination with other policies. The choice of these policies is saying that jobs are more important than housing. This is based on the very simple observation that jobs are a greater necessity than housing, although both are very important. Housing

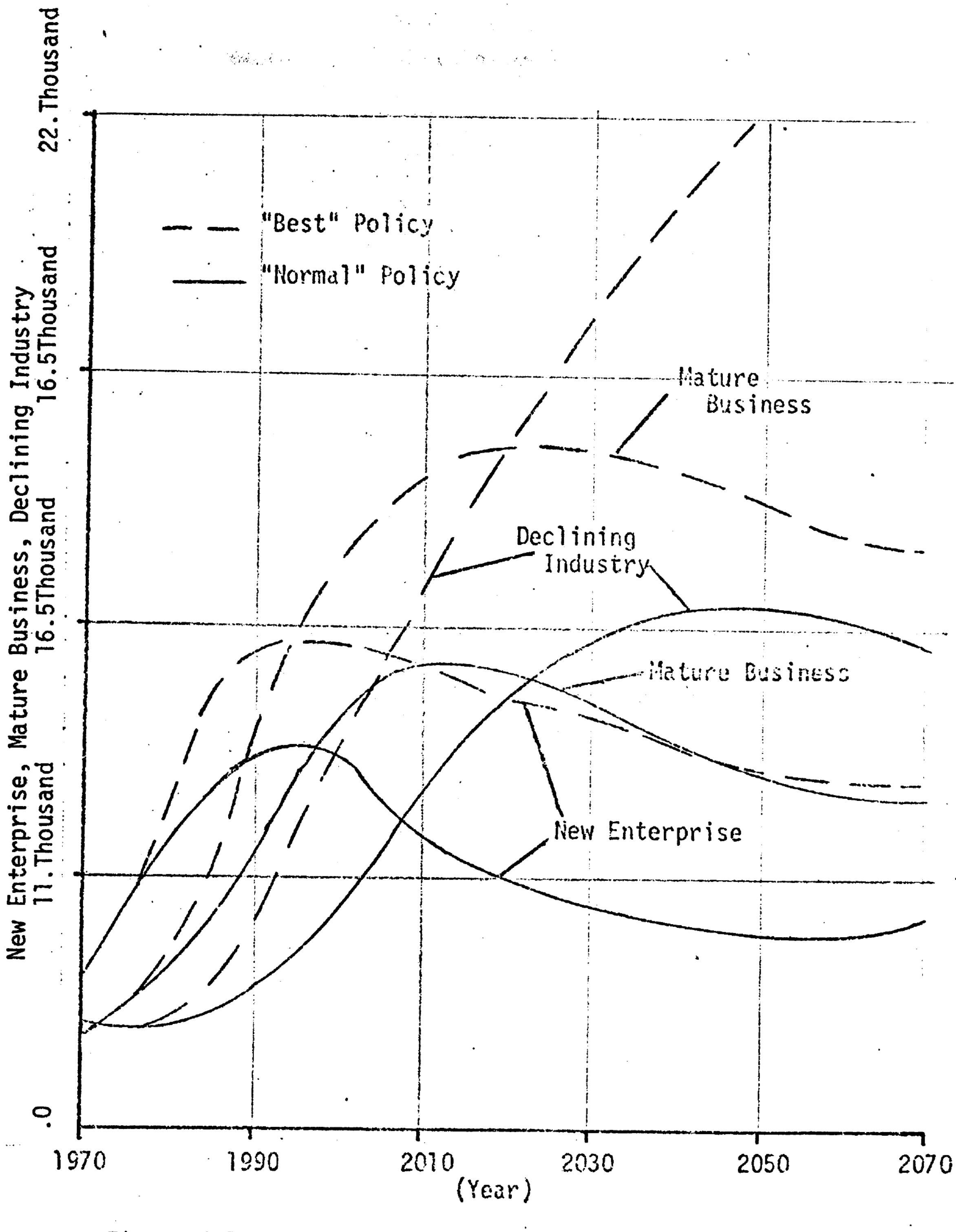

Figure 4.1 a Consequences of "Normal" and "Best" Policies

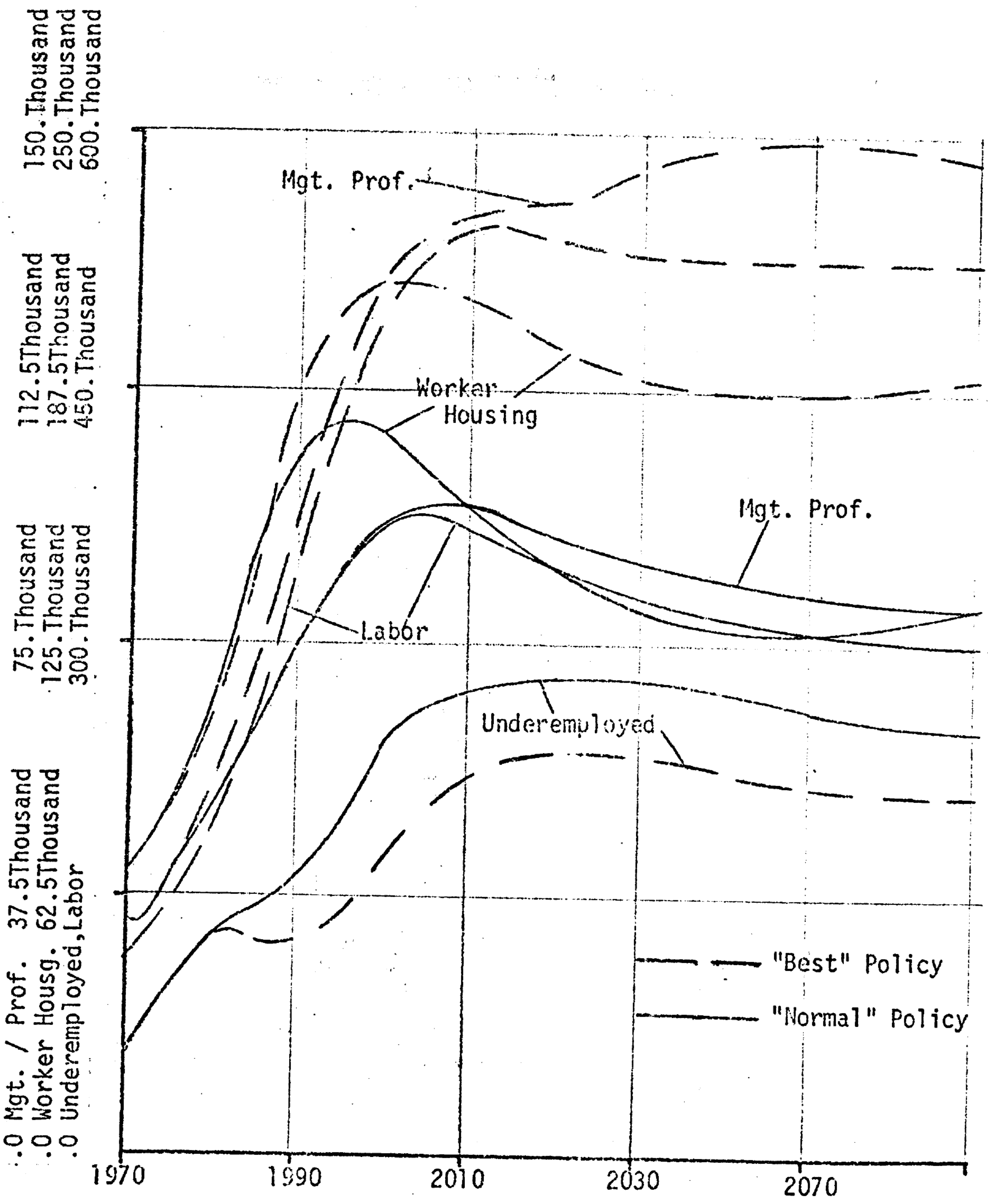

Figure 4.1 b Consequences of "Normal" and "Best" Policies

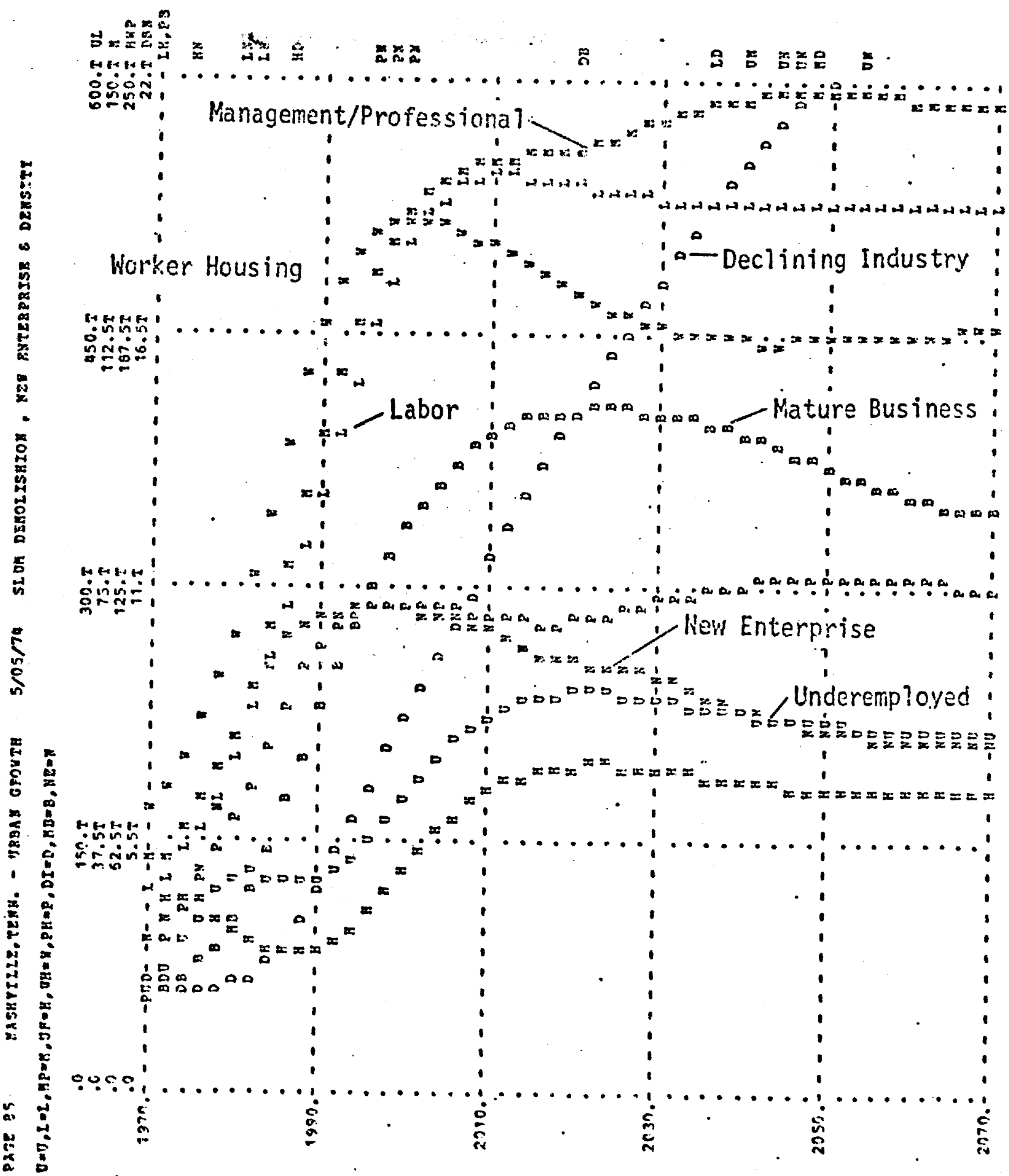

Figure 4.2 a Dynamics of Slum Demolition, New Enterprise and Increased Density

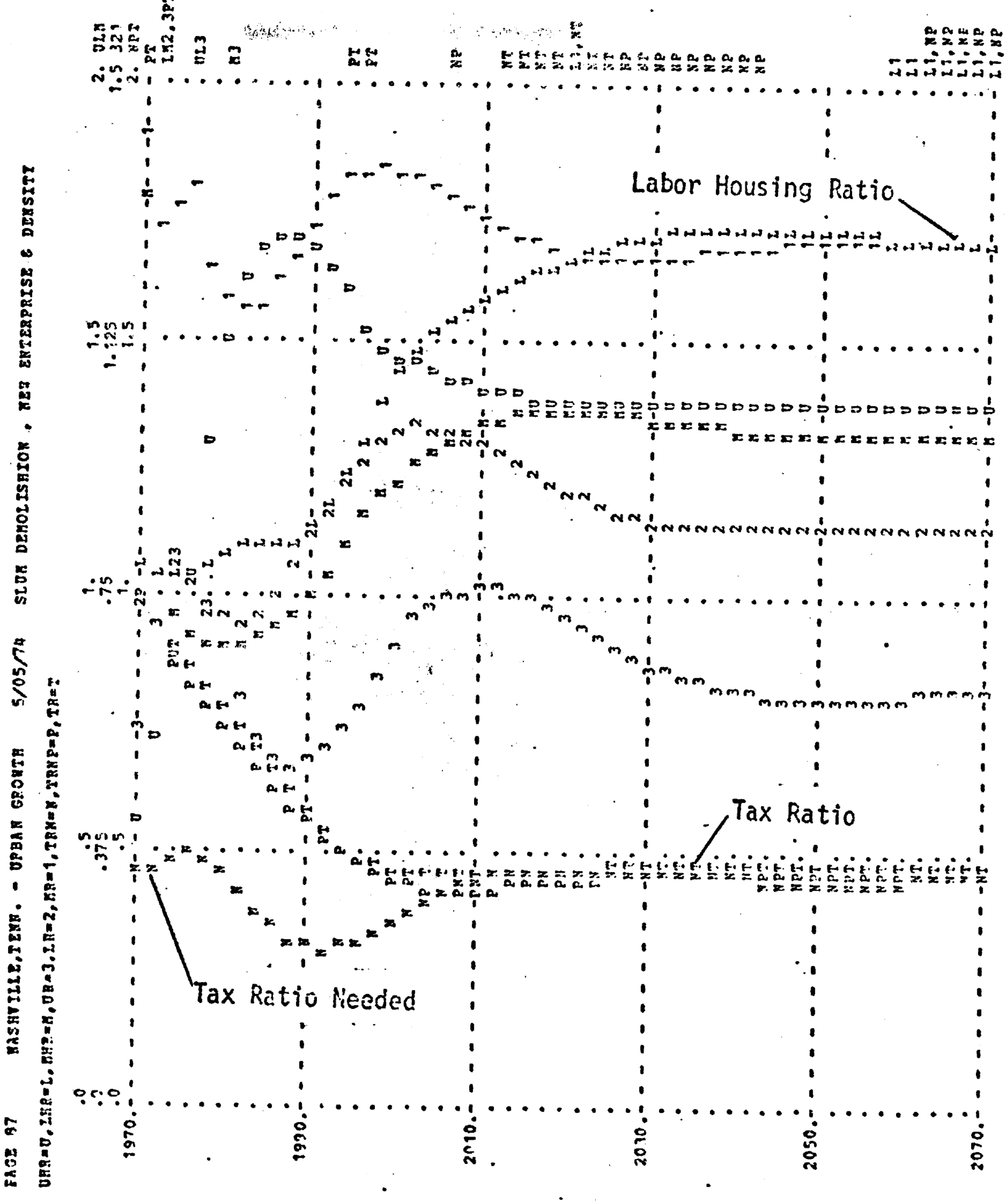

Figure 4.2 b Dynamics of Slum Demolition, New Enterprise and Increased Density

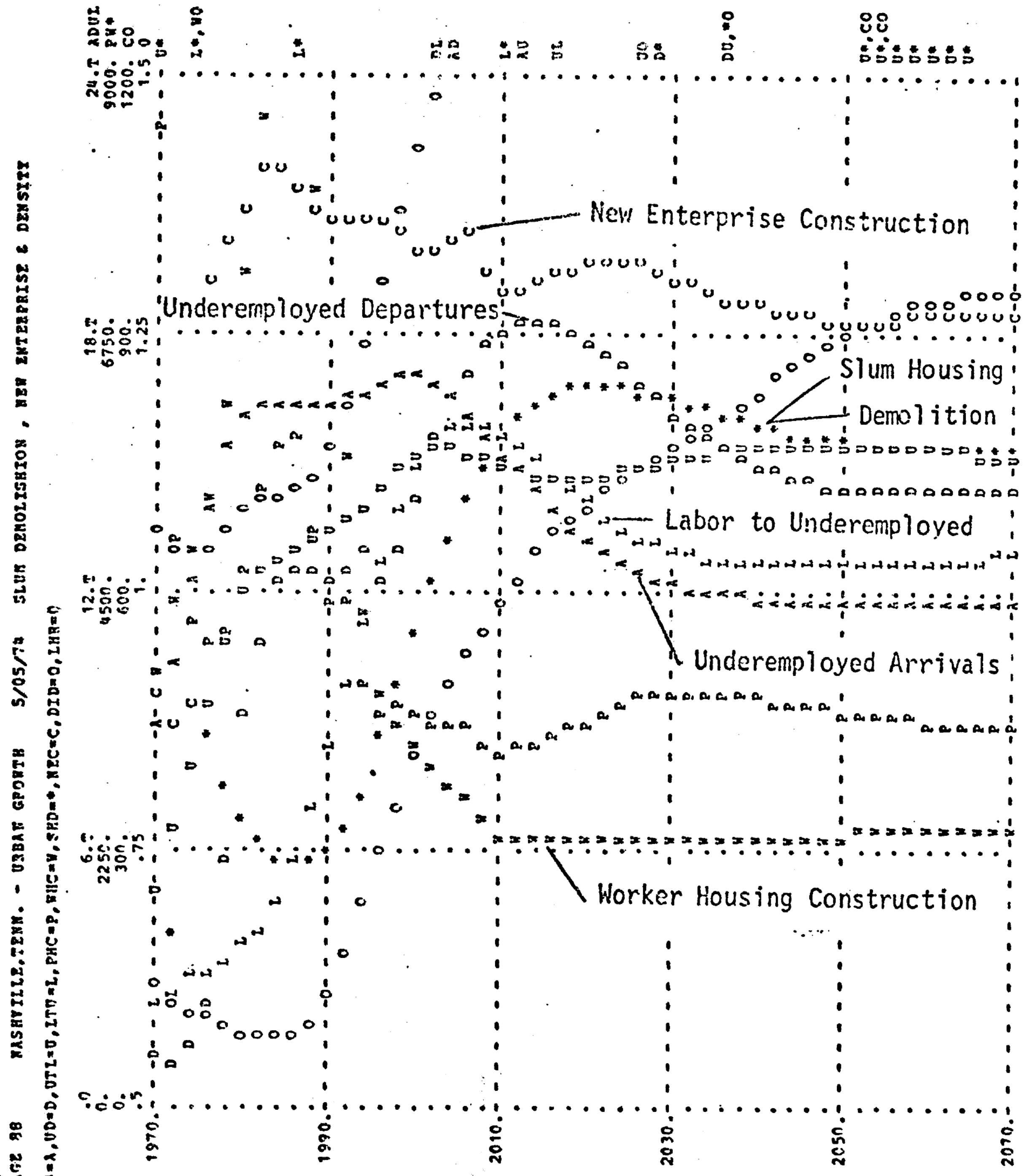

Figure 4.2 c Dynamics of Slum Demolition, New Enterprise and Increased Density

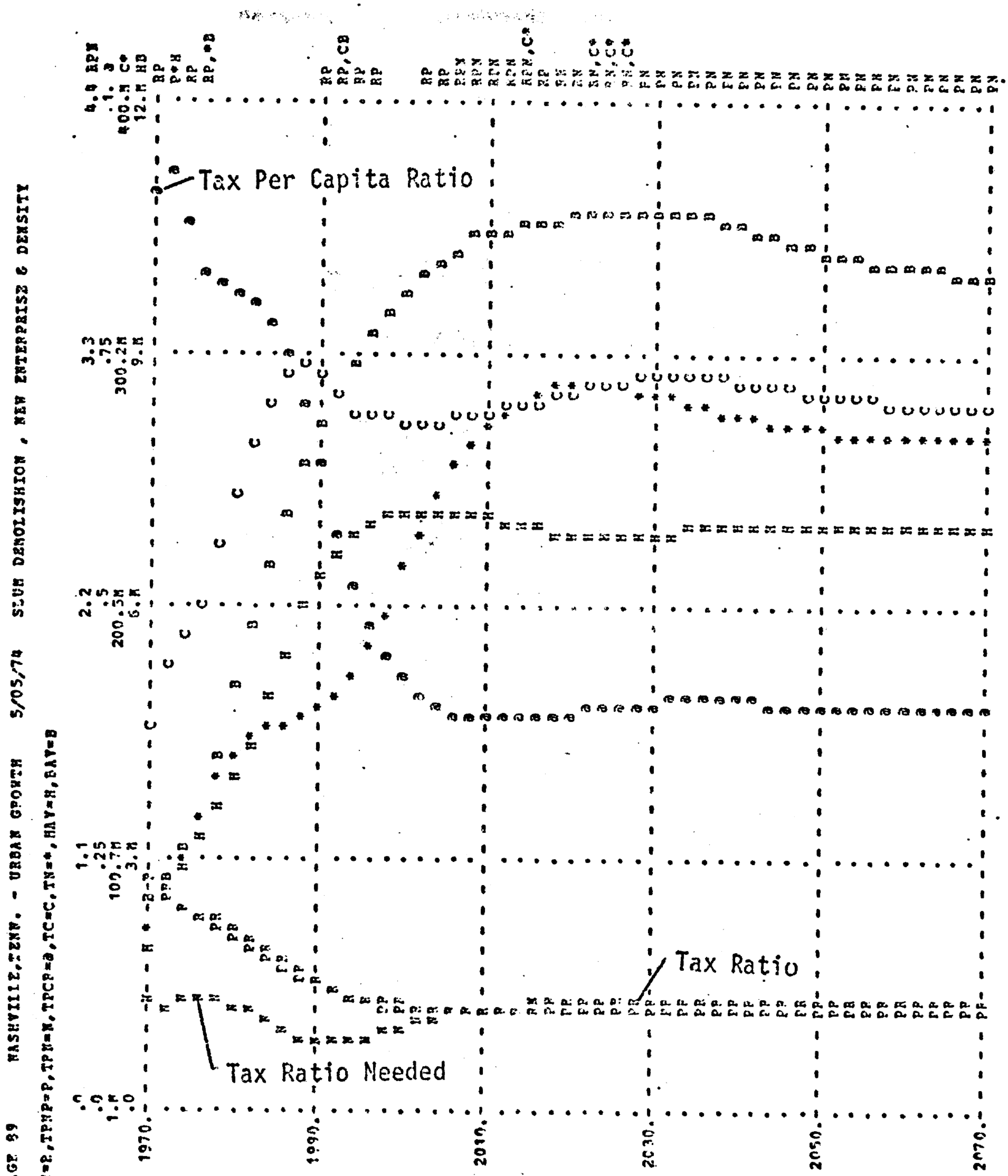

Figure 4.2 d Dynamics of Slum Demolition, New Enterprise and Increased Density

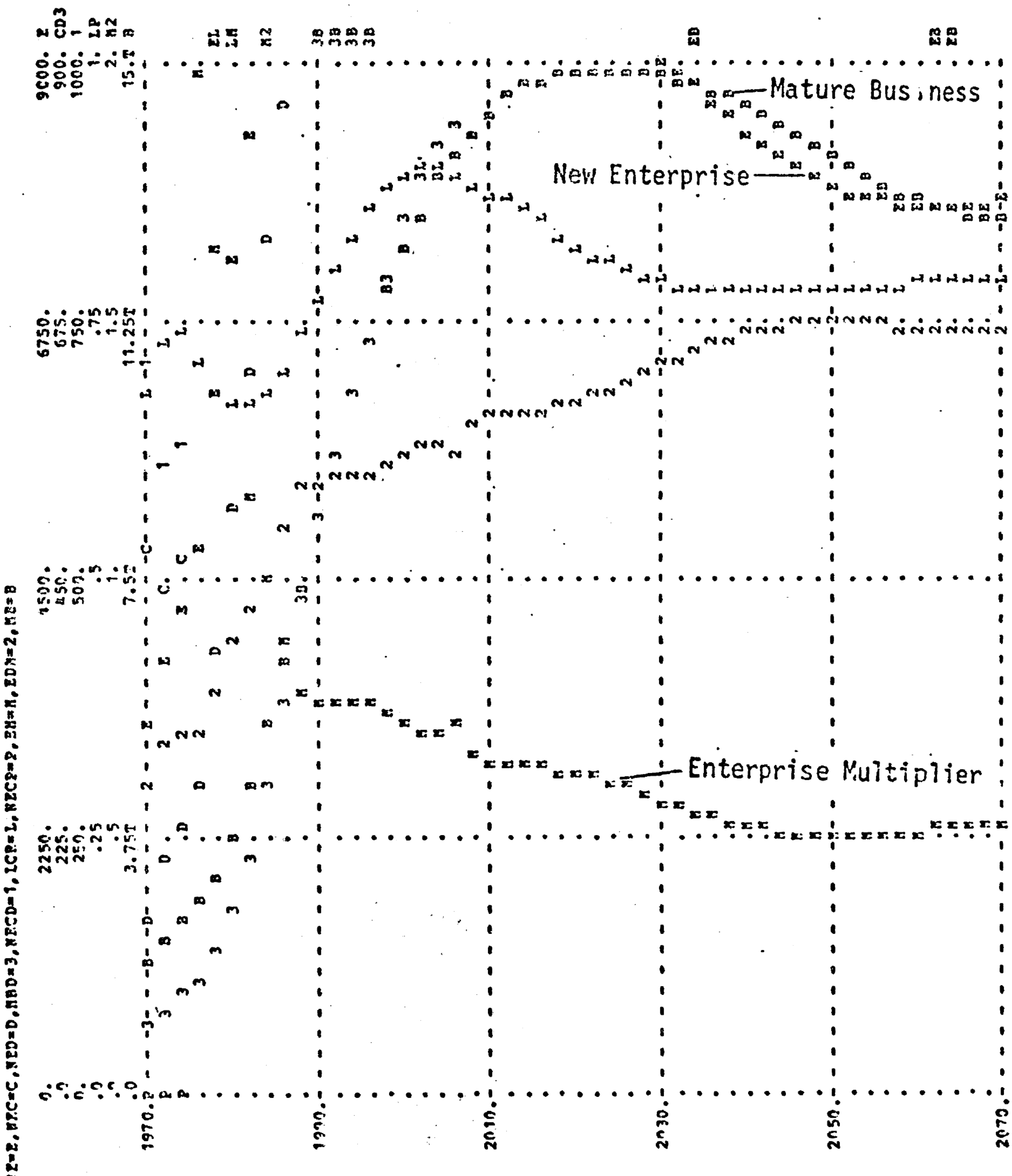

Figure 4.2 e Dynamics of Slum Demolition, New Enterprise and Increased Density

is not the only commodity that is necessary to life -- food, clothing, etc. are other staples that are also needed, and to purchase these, jobs are necessary. Besides, what purpose is served by an abundance of housing if people do not have jobs to pay for them? Therefore, jobs have been given priority over housing, but not at the expense of housing.

To conclude this chapter and also to conclude this thesis, it is important to put the Nashville model into its proper perspective. The model developed by Jay W. Forrester, and altered here to include the parameters of Nashville, is an attempt to simulate the dynamic interaction of the various components described. Perhaps the most important aspect of this model is that the consequences result from dynamic interaction, rather than from static relationships. The model however, although it attempts to represent reality, does not in fact do so. In reality, it is much more difficult to monitor what is actually happening in a city as a result of a particular policy. This is because, in reality, various policies are simultaneously at work and, as time progresses, the various policies are continually being changed and altered. They do not remain static as they have in this analysis. The model represents what results from the initial condition in 1970, with the addition of the policy being tested in the year 1975. After the policy has been initiated, the policy remains in effect for the next 100 years of the simulation, when the model reaches a state of equilibrium. In reality this would not be the case. Once different indicators -- such as the tax base -- begin to decline, the policy would be changed if the city had the capability to change the policy.

Looking at the three policies recommended as the "best" set of policies, it appears logical that they are very beneficial to the city. They are logical, intuitive, and not at all counterintuitive. Perhaps the counterintuitive nature of complex social systems such as Nashville results when one does not understand the dynamic interaction of various components in the model and how each affects the other. For example, when it is not understood how low income housing affects the total urban environment, it is possible to believe that this policy would be a good policy that would help a certain portion of the city in need of housing. But when the effect of a low income housing program is understood, it is easy to conclude that the policy is detrimental to the city.

A very important question has been raised about the validity and the accuracy of the Nashville model. It is nice to have a model that provides neat graphs illustrating consequences of various policies, but if the consequences do not reflect some semblance of reality, the model is worthless. Since this important question has been raised about Forrester's model, it has resulted in a small number of papers dealing specifically with this question.

In particular, two papers have been produced that compare the growth predicted by Forrester's model with actual growth. One paper, entitled Forrester's Model and Four U. S. Cities, by Otomar J. Bartos and Yung-Mei Tsai, compares Forrester's model predictions with actual growth in Chicago, New Orleans, Detroit and Philadelphia, during the years 1940, 1950, and 1960.[24] The other paper, Application of the Forrester Model to Harris County, Texas by Howeval Porter and Ernest Henley, compares Forrester's model predictions with actual growth in Houston, Texas.[25] The general conclusion drawn from both papers is that Forrester's model does come close to simulating reality, however his predictions are more pessimistic. Porter's use of Forrester's model resulted in predictions that were closer to reality than those by Bartos and Yung-Mei -- largely because more parameters were changed within the model to more closely represent Houston. This is what was done in the Nashville model, and it is believed that because of these alterations, the Nashville model is a reasonably accurate representation of reality. The overall point to consider is not so much the degree of accuracy, but whether the model gives a general indication of the consequences of various policies. It is believed that the model does point in the proper direction, therefore it can be concluded that the model is a valuable tool for understanding urban policies.

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[24]Otomar Bartos and Yung-Mei Tsai, Forrester's Model and Four U. S. Cities (Boulder, Col: University of Colorado, November 1972).

[25]Howeval Porter and Ernest J. Henley, "Application of the Forrester Model to Harris County, Texas", IEE Transactions on Systems, Man, and Cybernetics, April 1972, pp. 139-144.

Reflecting on the Forrester Model, it is important to recognize the great accomplishment of Forrester in producing a model that has generated so much interest and controversy -- as well as providing a new methodology for evaluating the urban dynamics of a city. If nothing more, Forrester's model has begun the continuing process of understanding the dynamics in our urban environment.

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APPENDIX A

THE DYNAMO LANGUAGE

The DYNAMO Language

The Nashville urban dynamics model is written in a computer language called DYNAMO, which is an acronym for DYNAmic MOdels. DYNAMO is designed to run continuous simulation models that may be described by a set of differential equations. It was developed by the industrial dynamics group at M.I.T. during the early 1960's, to simulate dynamic feedback models of business, economic and social systems; however it can be used for any continuous system.[26]

The language has been constructed for a person who is oriented toward model design rather than a person who is computer oriented. The problem of building a computer model has been simplified so that the focus of attention can be on the building of a useful model rather than on trying to figure out how to get the computer to do what is wanted. The language includes simplified time subscripts that make it easy to understand how the calculations were made. Equations for the model are coded by type, then written just as an algebraic expression.

DYNAMO contains seven equation types. The identification code appearing before each equation tells the computer which of the seven types the equation is. The seven equation types and their codes are level (L), auxilary (A), rate (R), supplementary (S), initial (N), constant (C), and table (T) equations. Alexander L. Pugh III's Dynamo User's Manual provides definitions of the seven equation types. They are:[27]

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[26]W.R. Ashby, Cybernetics Today and Its Future Contribution to the Engineering-Sciences (New York: Foundation For Instermentation, Engineering and Research, 1961), pp. 6-7.

[27]Alexander L. Pugh III, Dynamo II User's Manual (Cambridge, Mass.: The M.I.T. Press, Fourth Edition, 1973), pp. 21-22.

Level (L) equations are the integral equations of DYNAMO. They relate a quantity at the current time to its value at the previous time that calculations were made, and to its rate of change during the interval between calculation.

Auxiliary (A) equations are simple algebraic functions of levels and other auxiliary variables at the same time instant. Auxiliary equations may not depend upon other auxiliaries which in turn depend on the auxiliary defined; i.e., simultaneous equations among auxiliary equations are not permitted.

Rate (R) equations are much like auxiliary equations in that they are algebraic functions of levels and auxiliaries at the same time instant.

Supplementary (S) equations are algebraic equations that are computed only to provide output. If there is a significant number of solution intervals between each output period, a small saving in computer time can be made by computing as supplementaries those quantities that are only printed or plotted, or are used only in other supplementary equations.

An initial value (N) equation must be provided for every level, and may be provided for any auxiliary or rate. A constant may also be computed initially by this equation type.

A given constant (C) differs from an initially computed constant in that the right of the equal sign is restricted to a numerical value.

A table (T) is an array of numerical values that provides the values upon which the table look-up function operates.

The Nashville urban dynamics model written in DYNAMO is presented in Appendix B. The model is divided into primary and secondary sections as described in Chapter 1, Model Components. Following the model equations are the output cards that begin with either the word PRINT or PLOT. If desired, the PRINT card will print-out specified variables for each or all periods of simulation time. The PLOT card is used to graphically display the value of specified variables over time. Figures in Chapter III illustrate output from PLOT cards. Notice that the variables have been relabled to a single character. For example, PH for premium housing has been set to equal P (PH=P), therefore the letter P on the graph represents premium housing. The scaling of variables to fit on the graph can be specified or set automatically by DYNAMO. The scaling of the variables is shown in the top left hand corner. The time value beginning in 1970 runs along the bottom of the graph.

APPENDIX B

THE NASHVILLE MODEL

NASHVILLE,TENN. - URBAN GROWTH 5/05/74

```
*      NASHVILLE,TENN. - URBAN GROWTH
NOTE
NOTE *****************UNDEREMPLOYED SECTOR
R  UA.KL=(U.K+L.K)(UAN)(AMMP.K)
C UAN=.05
L  AMMP.K=AMMP.J+(DT/AMMPT)(AMM.J-AMMP.J)
N  AMMP=1
C AMMPT=20
A  AMM.K=(UAMM.K)(UHM.K)(PEM.K)(UJM.K)(UHPM.K)(AMF)
A  UAMM.K=TABLE(UAMMT,UM.K,0,.15,.025)
T UAMMT=.3/.7/1/1.2/1.3/1.4/1.5
A UHM.K=TABHL(UHMT,UHR.K,0,2,.25)
T UHMT=2.5/2.4/2.2/1.7/1/.4/.2/.1/.05
A  UHR.K=(U.K*UFS)/(UH.K*UHPD)
C   UHPD=7
A PEM.K=TABHL(PEMT,TPCR.K,0,3,.5)
T PEMT=.2/.6/1/1.6/2.4/3.2/4
A TPCR.K=((TC.K/P.K)+TPCSP.K)/TPCN
C TPCN=250
A P.K=(MP.K)(MPFS)+(L.K)(LFS)+(U.K)(UFS)
NOTE **** MPP=MGT/PROF. POP.
NOTE **** LP= LABOR POP.
NOTE **** UP= UNDEREMPLOYED POP.
NOTE **** UADN= UNDEREMPLOYED ARRIVALS - DEPARTURES NET
A UADN.K=UA.JK-UD.JK         UNDEREMPLOYED ARRIVALS - DEPARTURES NET
A    MPP.K=(MP.K)(MPFS)
A    LP.K=(L.K)(LFS)
A    UP.K=(U.K)(UFS)
C    MPFS=3.4
C    LFS=3.05
C    UFS=3.3
A UJM.K=TABHL(UJMT,UR.K,0,3,.25)
T UJMT=2/2/1.9/1.6/1/1.6/.4/.3/.2/.15/.1/.05/.02
A UHPM.K=TABHL(UHPMT,UHPR.K,0,.05,.01)
T UHPMT=1/1.2/1.5/1.9/2.4/3
A UHPR.K=LCHP.JK/U.K
R UD.KL=(UDN)(U.K)(UDM.K)
C UDN=.02
A UDM.K=TABHL(UDMT,1.44*LOGN(AMM.K),-3,3,1)
T UDMT=8/4/2/1/.5/.25/.125
R UB.KL=(U.K)(UBR)
C   UBR=.0226
L U.K=U.J+(DT)(UA.JK+UB.JK+LTU.JK-UD.JK-UTL.JK)
N U=59758
NOTE $$$$$$$$$$$$$$$$ LABOR SECTOR
NOTE
R UTL.KL=(UMN)(UW.K)(UMMP.K)+UTP.K
C UMN=.1
A UW.K=(U.K)(UFW.K)
A UFW.K=TABHL(UFWT,UR.K,0,4,1)
T UFWT=.9/.8/.5/.33/.25
L UTLP.K=UTLP.J+(DT/UTLPT)(UTL.JK-UTLP.J)
N UTLP=75
C UTLPT=10
A  UM.K=UTLP.K/U.K
L  UMMP.K=UMMP.J+(DT/UMMPT)(UMM.J-UMMP.J)
N UMMP=1
C UMMPT=10
```

```
NASHVILLE,TENN. - URBAN GROWTH     5/05/78

A UMM.K=(LSM.K)(LUM.K)(UEM.K)(UMF)
C UMF=1
A LSM.K=TABHL(LSMT,LP.K,0,2,.5)
T LSMT=2.4/2/1/.4/.2
A LUM.K=TABHL(LUMT,LUR.K,0,5,1)
T  LUMT=.2/.7/1/1.2/1.3/1.4
A LUR.K=L.K/U.K
A UEM.K=TABHL(UEMT,TPCF.K,0,3,.5)
T UEMT=.2/.7/1/1.3/1.5/1.6/1.7
R LB.KL=(L.K)(LBR)
C   LBR=.015
L L.K=L.J+(DT)(UTL.JK+LB.JK-LTM.JK+LA.JK-LD.JK-LTU.JK)
N L=119515
R LTU.KL=(L.K)(LLF.K)
A LLF.K=TABLE(LLFT,LP.K,0,2,.5)
T  LLFT=0/.01/.03/.1/.3
R LTM.KL=(LMN)(L.K)(LMMP.K)+LTPG.K
C LMN=.02
L LMMP.K=LMMP.J+(DT/LMMPT)(LMM.J-LMMP.J)
C AMF=1
N LMMP=1
C LMMPT=15
A LMM.K=(MSM.K)(MLM.K)(LEM.K)(LMF)
C LMF=1
A MSM.K=TABHL(MSMT,MR.K,0,2,.25)
T MSMT=2.3/2.2/2/1.6/1/.5/.2/.1/.05
A MR.K=MP.K/MJ.K
A MJ.K=(NE.K)(NEM)+(MB.K)(MBM)+(DI.K)(DIM)
C   NEM=4
C   MBM=3
C   DIM=2
A MLM.K=TABHL(MLMT,MLR.K,0,.2,.05)
T MLMT=.2/.7/1/1.2/1.3
A MLR.K=MP.K/L.K
A LEM.K=TABHL(LEMT,TPCF.K,0,3,.5)
T LEMT=.2/.7/1/1.3/1.5/1.6/1.7
R LA.KL=(LAN)(L.K)(LAMP.K)
C LAN=.03
L LAMP.K=LAMP.J+(DT/LAMPT)(LAM.J-LAMP.J)
N LAMP=1
C LAMPT=15
A LAM.K=(LAJM.K)(LAUM.K)(LATM.K)(LAHM.K)(LAF)
C LAF=1
T LAJMT=2.6/2.6/2.4/1.8/1/.4/.2/.1/.05
A LAJM.K=TABLE(LAJMT,LP.K,0,2,.25)
A LAUM.K=TABHL(LAUMT,LUR.K,0,5,1)
T LAUMT=.4/.8/1/1.2/1.3/1.3
A LATM.K=TABLE(LATMT,1.44*LOGN(TR.K),-2,4,2)
T LATMT=1.2/1/.7/.3
A LAHM.K=TABLE(LAHMT,LHR.K,0,3,.5)
T LAHMT=1.3/1.2/1/.5/.2/.1/.05
A LHR.K=(L.K*LFS)/(WH.K*WHPD)
C   WHPD=5
R LD.KL=(LDN)(L.K)(LDM.K)
C LDN=.02
A LDM.K=TABHL(LDMT,1.44*LOGN(LAM.K),-3,3,1)
T LDMT=8/4/2/1/.5/.25/.125
NOTE
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NASHVILLE,TENN. - URBAN GROWTH     5/05/74
 NOTE ******************** MANAGERIAL-PROFESSIONAL SECTOR
 R MPB.KL=(MP.K)(MPBR)
 C    MPBR=.0113
 L MP.K=MP.J+(DT)(LTM.JK+MPB.JK+MA.JK-MD.JK)
 N MP=33903
 R MA.KL=(MAN)(MP.K)(MAMP.K)
 C MAN=.03
 L MAMP.K=MAMP.J+(DT/MAMPT)(MAM.J-MAMP.J)
 N MAMP=1
 C MAMPT=10
 A MAM.K=(MAJM.K)(MAPM.K)(MATM.K)(MAHM.K)(MAF)
 C MAF=1
 A MAJM.K=TABLE(MAJMT,MR.K,0,2,.25)
 T MAJMT=2.7/2.6/2.4/2/1/.4/.2/.1/.05
 A MAPM.K=TABHL(MAPMT,MPR.K,0,.1,.02)
 T MAPMT=.3/.7/1/1.2/1.3/1.3
 A MPR.K=MP.K/(L.K+U.K)
 A MATM.K=TABLE(MATMT,1.44*LOGN(TR.K),-2,4,2)
 T MATMT=1.4/1/.7/.3
 A  MAHM.K=TABLE(MAHMT,MHR.K,0,3,.5)
 T MAHMT=1.3/1.2/1/.5/.2/.1/.05
 A MHR.K=(MP.K*MPFS)/(PH.K*PHPD)
 C PHPD=3
 R MD.KL=(MDN)(MP.K)(MDM.K)
 C MDN=.02
 A MDM.K=TABHL(MDMT,1.44*LOGN(MAM.K),-3,3,1)
 T MDMT=8/4/2/1/.5/.25/.125
NOTE
NOTE ****************PREMIUM HOUSING SECTOR
R PHC.KL=(PHCD.K)(LCP.K)
A PHCD.K=(PHCN)(PH.K)(PHM.K)+PHCP.K
C PHCN=.03
A PHM.K=(PHAM.K)(PHLM.K)(PHPM.K)(PHTM.K)(PHEM.K)(PHGM.K)(PHF)
C PHF=1
A PHAM.K=TABLE(PHAMT,MHR.K,0,2,.25)
T PHAMT=0/.001/.01/.2/1/3/4.6/5.6/6
A PHLM.K=TABHL(PHLMT,LFO.K,0,1,.1)
T PHLMT=.4/.9/1.3/1.6/1.8/1.9/1.8/1.4/.7/.2/0
A LFO.K=(HUT.K*LPH.K+PUT.K*LPP)/AREA  LAND FRACTION OCCUPIED
C    DENSITY=.5648
N  LPHP=DENSITY
L  LPHP.K=LPHP.J-CLIP(0,1,SWT11,TIME.K)*DENSITY*PERCENT/30
A  LPH.K=MAX(DD,LPHP.K)
C  DD=.5084          MAX DENSITY
C    LPP=.344
C    AREA=229863 TOTAL DEVELOPABLE LAND (ACRES)
A HUT.K=PH.K+WH.K+UH.K        HOUSING UNITS TOTAL
A  PUT.K=NE.K+ME.K+DI.K   PRODUCTIVE UNITS TOTAL
A PHPM.K=TABHL(PHPMT,MPR.K,0,.1,.02)
T PHPMT=.3/.7/1/1.2/1.3/1.3
A PHTM.K=TABHL(PHTMT,1.44*LOGN(TR.K),-2,4,2)
T PHTMT=1.2/1/.7/.3
A PHEM.K=TABHL(PHEMT,NEGR.K,-.1,.15,.05)
T PHEMT=.2/.6/1/1.4/1.8/2.2
A PHGM.K=TABHL(PHGMT,PHGR.K,-.1,.15,.05)
T PHGMT=.2/.6/1/1.4/1.8/2.2
A PHGR.K=(PH.K-PHA.K)/(PH.K*PHAT)
L PHA.K=PHA.J+(DT/PHAT)(PH.J-PHA.J)
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NASHVILLE,TENN. - URBAN GROWTH    5/05/74

N PHA=PH-(PHGPI)(PHAT)(PH)
C PHAT=10
C PHGPI=.03      ---
L PH.K=PH.J+(DT)(PHC.JK-PHO.JK)
N   PH=21689
R PHC.KL=(PHON)(PH.K)(PHOM.K)
C PHON=.03
A PHOM.K=TABHL(PHOMT,1.44*LOGN(PHM.K),-3,3,1)
T PHOMT=2.8/2.6/2/1/.5/.3/.2
NOTE
NOTE ********** WORKER HOUSING SECTOR
L WH.K=WH.J+(DT)(PHO.JK+WHC.JK-WHO.JK)
N   WH=68973
R WHC.KL=(WHCD.K)(LCR.K)
A WHCD.K=(WHCN)(WH.K)(WHM.K)+WHCP.K
C WHCN=.03
A WHM.K=(WHAM.K)(WHLM.K)(WHUM.K)(WHTM.K)(WHEM.K)(WHGM.K)(WHF)
C WHF=1
A WHAM.K=TABHL(WHAMT,LHR.K,0,2,.25)
T WHAMT=0/.05/.1/.3/1/1.8/2.4/2.8/3
A WHLM.K=TABHL(WHLMT,LFO.K,0,1,.1)
T WHLMT=.4/.9/1.3/1.6/1.8/1.9/1.8/1.4/.7/.2/0
A WHUM.K=TABHL(WHUMT,LUR.K,0,5,1)
T WHUMT=.5/.8/1/1.2/1.3/1.3
A WHTM.K=TABHL(WHTMT,1.44*LOGN(TR.K),-2,4,2)
T WHTMT=1.2/1/.7/.3
A WHEM.K=TABHL(WHEMT,NEGP.K,-.2,.3,.1)
T  WHEMT=.3/.7/1/1.2/1.3/1.4
A WHGM.K=TABHL(WHGMT,WHGR.K,-.1,.15,.05)
T WHGMT=.2/.6/1/1.4/1.8/2.2
A WHGR.K=(WH.K-WHA.K)/(WH.K*WHAT)
L WHA.K=WHA.J+(DT/WHAT)(WH.J-WHA.J)
N WHA=WH-(WHGRI)(WHAT)(WH)
C WHAT=10
C WHGRI=.03
R WHO.KL=(WHON)(WH.K)(WHOM.K)
C WHON=.02
A WHOM.K=TABHL(WHOMT,1.44*LOGN(WHM.K),-3,3,1)
T WHOMT=2.2/2/1.6/1/.7/.5/.4
NOTE
NOTE ********** UNDEREMPLOYED HOUSING SECTOR
L UH.K=UH.J+(DT)(WHO.JK-SHD.JK+LCHP.JK)
N   UH=49747
R SHD.KL=(SHDN)(UH.K)(SHDM.K)+SHDP.K
C  SHDN=.02
A SHDM.K=(SHAM.K)(SHLM.K)(SHDF)
C SHDF=1
A SHAM.K=TABLE(SHAMT,UHR.K,0,2,.5)
T  SHAMT=3.6/2/1/.6/.4
A  SHLM.K=TABHL(SHLMT,LFO.K,.8,1,.05)
T  SHLMT=1/1.2/1.6/2.2/6
NOTE
NOTE  ********** NEW ENTERPRISE SECTOR
L  NE.K=NE.J+(DT)(NEC.JK-NED.JK)
N  NE=3221
R  NEC.KL=(NECD.K)(LCR.K)
A  NECD.K=(NECN)(NECF*NE.K+MBCF*MB.K+DICF*DI.K)(EM.K)+NECP.K
C  NECF=1
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C  MBCF=.5
C  DICF=.3
C  NECN=.05
A  EM.K=(EMM.K)(ELM.K)(ELJM.K)(ETM.K)(EGM.K)(EF)
C  EF=1
A  EMM.K=TABHL(EMMT,MR.K,0,2,.25)
T  EMMT=.1/.15/.3/.5/1/1.4/1.7/1.9/2
A  ELM.K=TABHL(ELMT,LFO.K,0,1,.1)
T  ELMT=1/1.15/1.3/1.4/1.45/1.4/1.3/1/.7/.4/0
A  ELJM.K=TABHL(ELJMT,LRP.K,0,2,.25)
T  ELJMT=0/.05/.15/.4/1/1.5/1.7/1.8/1.8
A  ETM.K=TABHL(ETMT,1.44*LOGN(TR.K),-2,4,1)
T  ETMT=1.3/1.2/1/.8/.5/.25/.1
A  EGM.K=TABHL(EGMT,NEGR.K,-.1,.15,.05)
T  EGMT=.2/.6/1/1.4/1.8/2.2
A  NEGR.K=(NE.K-NEA.K)/(NE.K*NEAT)
L  NEA.K=NEA.J+(DT/NEAT)(NE.J/NEA.J)
N  NEA=NE-(NEGRI)(NEAT)(NE)
C  NEAT=10
C  NEGRI=.03
NOTE
NOTE   ********** MATURE BUSINESS SECTOR
R  NED.KL=(NEDN)(NE.K)(EDM.K)
C  NEDN=.08
A  EDM.K=TABHL(EDMT,1.44*LOGN(EM.K),-3,3,1)
T  EDMT=2/1.8/1.5/1/.7/.5/.5
L  MB.K=MB.J+(DT)(NED.JK-MBD.JK)
N  MB=2015
R  MBD.KL=(MBDN)(MB.K)(BDM.K)
C  MBDN=.05
A  BDM.K=TABHL(BDMT,1.44*LOGN(EM.K),-3,3,1)
T  BDMT=2/1.8/1.5/1/.7/.5/.4
NOTE
NOTE   *********** DECLINING INDUSTRY SECTOR
L  DI.K=DI.J+(DT)(MBD.JK-DID.JK)
N  DI=2487
R  DID.KL=(DIDN)(DI.K)(DIDM.K)+DIDP.K
C  DIDN=.03
A  DIDM.K=(DIEM.K)(DILM.K)(DIDF)
C  DIDF=1
A  DIEM.K=TABLE(DIEMT,1.44*LOGN(EM.K),-3,3,1)
T  DIEMT=.4/.5/.7/1/1.6/2.4/4
A  DILM.K=TABHL(DILMT,LFO.K,.8,1,.05)
T  DILMT=1/1.2/1.6/2.2/6
NOTE
NOTE   ********** TAX SECTOR
A  TC.K=(AV.K)(TAN)(TR.K)
C  TAN=35  TAX ASSESMENT NORMAL
A  TR.K=TABHL(TRT,1.44*LOGN(TRNP.K),-2,4,1)
T  TRT=.3/.5/1/1.8/2.8/3.6/4
L  TRNP.K=TRNP.J+(DT/TRNPT)(TRN.J-TRNP.J)
N   TRNP=1
C   TRNPT=15
A  TRN.K=TAI.K/TAN
A  TAI.K=TN.K/AV.K
A  TN.K=(TMP*MBFS*MP.K+TLP*LFS*L.K+TUP*UFS*U.K)(TCM.K)
C   TMP=71.5
C   TLP=95.7
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C   TUP=143.55
A  TCM.K=TABHL(TCMT,LUP.K,0,3,.5)
T  TCMT=2/1.6/1.3/1.1/1/.9/.8
A  AV.K=(HAV.K+BAV.K)
A  HAV.K=PHAV*PH.K+WHAV*WH.K+UHAV*UH.K
C  PHAV=30
C  WHAV=15
C  UHAV=5
A  BAV.K=NEAV*NE.K+MBAV*MB.K+DIAV*DI.K
C  NEAV=500
C  MBAV=300
C  DIAV=100
NOTE
NOTE  ********** JOB SECTOR
A  LDC.K=PHCD.K*PHCL+WHCD.K*WHCL+NECD.K*NECL+LCHCD.K*LCHCL
C  PHCL=2
C  WHCL=1
C  NECL=20
C  LCHCL=.6
A  LDI.K=NE.K*NEL+MB.K*MBL+DI.K*DIL
C   NEL=20
C   MBL=15
C   DIL=10
A  LJ.K=LDC.K+LDI.K
A  LR.K=L.K/LJ.K
A  ULJR.K=TABHL(ULJRT,LR.K,0,2,.5)
T  ULJRT=1.15/.8/.5/.25/.1
A  UJ.K=LC.K*ULJR.K+UJP.K
A  UR.K=U.K/UJ.K
T  LCRT=0/.5/.9/1.1/1.15
A  LCR.K=TABHL(LCRT,LR.K,0,2,.5)
L  LRP.K=LRP.J+(DT/LRPT)(LR.J-LRP.J)
N  LRP=1
C  LRPT=5
NOTE
NOTE  ********** CITY DEVELOPMENT PROGRAMS
A  UTP.K=UTR*U.K*CLIP(0,1,SWT1,TIME.K)
C  UTR=0
C  SWT1=0
A  LTPS.K=LTR*CLIP(0,1,SWT2,TIME.K)
C  LTR=0
C  SWT2=0
A  PHCP.K=PHCR*PH.K*PHLM.K*CLIP(0,1,SWT3,TIME.K) PROF. HOUSE CONSTR. PROG.
C  PHCR=0          NOTE LAND MULTIPLIER TERM
C  SWT3=0
A  WHCP.K=WHCR*HUT.K*WHLM.K*CLIP(0,1,SWT4,TIME.K)
C  WHCR=0         NOTE LAND MULTIPLIER TERM
C  SWT4=0
A  SHDP.K=SHDR*UH.K*CLIP(0,1,SWT5,TIME.K)
C  SHDR=0
C  SWT5=0
A  NECP.K=NECR*PUT.K*ELM.K*CLIP(0,1,SWT6,TIME.K)
C  NECR=0
C  SWT6=0
A  DIDP.K=DIDR*DI.K*CLIP(0,1,SWT7,TIME.K)
C  DIDR=0
C  SWT7=0
A  TPCSP.K=TPCS*CLIP(0,1,SWT8,TIME.K)
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 C   TPCS=0
 C   SWT8=0
 A   UJP.K=UJPC*U.K*CLIP(0,1,SWT9,TIME.K)
 C   UJPC=0
 C   SWT9=0
 R   LCHP.KL=(LCHCD.K) (LCR.K)
 A   LCHCD.K=LCHPC*U.K*WHLM.K*CLIP(0,1,SWT10,TIME.K)
 C   LCHPC=0
 C   SWT10=0
 C   SWT11=0          TIME TO CHANGE DENSITY IF DESIRED
 C   PERCENT=0
NOTE
NOTE CONTROL CARDS
NOTE
SPEC PRTPER=50/PLTPER=2
C DT=1
N    TIME=1970
C   LENGTH=100
C PLTCT=500
C PRTCT=160
C   PLTMAX=5
S   UTIN.K=UTL.JK-LTU.JK
PLOT U=U,L=L(0,6E5)/MP=M(0,15E4)/UH=H,WH=W,PH=P(C,25E4)/DI=D,MB=B,NE=N
X (0,22E3)
PLOT P=P(1E5,3E6)/MPP=M,LP=L,UP=U(0,18E5)/HUT=H(C,4E5)/PUT=$(0,4E4)/LFO=
X O(0,1.1)
PLOT UHR=U,LHR=L,MHR=M(0,2)/UR=3,LR=2,MR=1(0,1.5)/TRN=N,TRNP=P,TR=T
X (0,2)
PLOT UA=A,UD=D,UTL=U,LTU=L(0,24E3)/PHC=P,WHC=W,SHD=*(0,9E3)/NEC=C,DID=O
X (C,12CC),LHR(.5,1.5)
PLOT TP=P,TPNP=P,TRN=N(0,4.4)/TPCR=@(0,1)/TC=C,TN=*(1E6,4E8)/HAV=H,BAV=B
X (0,12E6)
PLOT NE=E(0,9E3)/NEC=C,NED=D,MBD=3(0,900)/NECD=1(0,1000)/LCR=L,NECP=P
X    (0,1)/EM=M,EDM=2(0,2)/MB=B(0,15E3)
RUN METROPOLITAIN NASHVILLE URBAN DYNAMICS MODEL
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Consequences Of Ten Urban Policies In The

Nashville Urban Dynamics Model

By

Randall Bruce Ashelman

(Abstract)

Drawing from general systems theory and based on Jay W. Forrester's generalized Urban Dynamics Model developed at the Massachusetts Institute of Technology, the consequences of ten city development policies in Nashville, Tennessee are examined with recommendations for a "best" set of policies. The policies examined include changes in housing density, changes in the supply of housing for various income groups, changes in tax policies, creation of new enterprise, job training programs, low income job programs and the impact on the city of financial aid from the state or Federal government. The "best" set of policies that provide the most sustaining environment for balanced growth are the demolition of slum housing, the promotion of new enterprise construction and a ten percent increase in housing density over a thirty year period. The methodology used to examine the consequences of policies is through a nonlinear, computerized, dynamic feedback model, with the perameters custom tailored to represent Nashville. The model is written in a user oriented computer language called DYNAMO. Use of the model permits the evaluation of urban policies to determine their long range impact on housing, business, population, the tax base, and employment.