Low Income Housing in the Context of Jay Forrester's Urban Dynamics: A Lesson in Framing

Abstract of

An essay presented to the Faculty

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Karen Jarzynka
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Adequate, safe, sanitary and affordable housing for low and moderate income people has been in short supply in urban areas at least since the industrial revolution. The very real issue of poverty in the United States was brought to the attention of the whole world in the recent media cover of Hurricane Katrina. People living densely packed together with no means of transportation and no money to go spend a few nights in a hotel were left behind to fend for themselves as New Orleans was destroyed by the hurricane.

In 1969, Jay Forrester wrote the book *Urban Dynamics.* His system dynamics model showed a hypothetical city's rise and subsequent fall. The book was among the first times that system dynamics was applied to a social science system. It included sectors representing the city's business and housing structures and the human population. The model showed how people are attracted to the city and how they manage to move up or down economic ladders. It assumes the city is tied to a specific land mass of a given size and shows how and why housing and businesses are built on that land. The base model shows how the city grows and the reasons why the city reaches stagnation. In subsequent runs, Forrester applies different public policies in attempts to determine what, if anything, a city can do to recover once it has fallen.

In this paper I perform an analysis of Forrester's model. I address both the model's brilliance and well as its questionable aspects. I discuss low income housing as it appears in both the base model and the various policy solutions. I discuss the intersection of the model with actual United States housing policy. I address both areas of concern and areas of agreement with his predictions of Housing Policy in the urban landscape as it has played out over time in his model and in real life. The amazing thing is how often

his model's predictions actually match researched evaluations of specific policies. I use the Detroit case to question his land availability assumptions and his mobility assumptions. I question his omission of racism and his attractiveness assumptions especially for the lowest income portion of the population. I challenge his housing deterioration and new enterprise construction assumptions.

Finally, I discuss Forrester's framing of the question. His model uses economic stagnation of the city as the measure of urban success, but that is not the only way to frame the question. Quality of life, minimum living standards and who gains and who is hurt in policies concerning urban renewal and slum demolition also could be used as measures of success.

I must acknowledge my bias against this model. Forrester's conclusion that building low income housing is never a viable option is difficult to accept. I am a believer in the need for subsidized low income housing and public housing. My grandparents moved into public housing in Nebraska when they moved off the farm. They needed to be closer to medical facilities as my grandfather was sick with lung cancer. He died shortly thereafter, but my grandmother continued to live there for the next 22 years. She paid 30% of her income, $35/month, for rent. She would not have been able to rent anything else at her income level. She was able to live independently until she was 89 and then moved in with my parents. Low income housing is a way for people to get out of abusive relationships, a way for aging people and handicapped people to live independently, a way for military families to afford housing when one spouse is overseas serving our country. The housing market fails to provide enough housing at the low end of the economic scale. Forrester's model illustrates this by showing crowding. In fact his

Housing Density constants show low income housing density twice that of middle income housing density and four times that of upper income housing density.

That said, I have been working with this model or one of its simplified versions for over a year. It is a brilliant and very comprehensive model. It has hidden gems that can be missed on the first and even on the second reading of the book. It is easy to understand why it is the seminole work that it is and why its author is held in such high regard.

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I. Introduction

Poverty is on the rise in this country and the recent hurricane Katrina crisis has focused media attention on it. Families, often single parents with children, and the elderly are two of the largest groups affected. Subsidized housing is one of ways to fight homelessness among these groups. Last year's budget proposal had President Bush slashing funding to the department of Housing and Urban Development, including many programs that help supply housing to the poor. The Katrina policy is still in flux; the uncertainty of which is highly problematic. In a speech in its aftermath, Bush said that funding for the housing of victims would come from the budgets of existing programs. Congress passed $3.5 billion in housing vouchers for the victims (Hulse 2005) but with the shortage of units that will accept such vouchers, people on waiting lists pay the price with increased waiting. In a Philadelphia example relocated hurricane victims were moved in to Section 8 housing ahead of all 47,000 local people on the waiting list (Moran 2005). This illustrates how the policy is placing a large portion of the burden on each low income person who did not get their housing voucher because it was granted instead to a Katrina victim.

In Jay Forrester's 1969 Urban Model, he proposed a series of low income housing policies and showed their implementation effects in his model. They all failed; actually they accelerated the deterioration of the city. He basically was saying that if you bring the jobs, the housing will take care of itself. In this paper, I take a close look at the model. I give a brief over view of the model. I examine and investigate various assumptions built into it. I compare various low income housing programs that have been actually implemented in the United States with the outcomes Forrester predicts. In the model,

land is used up, housing is abandoned, and population, jobs and business structures decline.

In Deborah Stone's book, "Policy Paradox," she talks about controlling the story. Bai's article refers to the faming of the problem. When a frame is accepted all conclusions are in context of this frame. A classic example to articulate the theory describes the Republican's refusal to acknowledge the Democrat's framing of Universal Health Care under President Clinton. There were those who wanted to suggest a Republican plan, but they were stopped, with the knowledge that a counter plan in Universal Health implies an acceptance of the underlying assumption that Universal Health is a good policy (Bai 2005).

Such is the case in the study of Forrester's Urban Dynamics. His results state that no policy that positively affects the lowest economic end of the population is beneficial to the city. This result is unacceptable in my world and must be contested. But does it really? Forrester's frame of the stagnation of a city is but one of many possible criteria in the definition of a successful city. Measures such as minimum living condition standards, quality of life and equitable distribution of goods are a few other criteria that might be used. Literature on this topic discusses differing policy maker's criteria and the difficulties in measuring the importance of each policy maker's criteria (Andersen and Rohrbaugh 1992 and Gardiner and Ford 1980). In 1969 when the book was published, cities were in big trouble. There were race riots, high crime rates, high unemployment rates, and cities were unable to address these issues. The political situation of the time made this a very charged scenario. That he was highly criticized for his book is not so much a reflection on him or his work, but a question of timing.

Opponents of subsidized housing claim that the free market can provide low income housing, but it has failed to do so. These same opponents concede that it takes two earners at minimum wage to afford housing in this country (Husock 2003). Obviously not all households have that luxury. I am an advocate of housing assistance to various groups: to low income seniors who want and are able to live on their own, to low income people with children to provide a stable environment and to encourage exodus from detrimental living conditions, to homeless people to get them out of shelters and to those whose mental or physical limitations make them unable to fully support themselves and their families. Despite, the U.S. Department of Housing and Urban Development's (HUD) apparent propensity toward scandal[1] (Husock, 2003), housing assistance for those in true need should not be eliminated.

The approach taken in this paper is to first identify specific challenges to Forrester's model; to modify the model to test these challenges; to test both Forrester's policies and actual U.S. housing policies against the modified model; and finally to reject or not reject Forrester's model. In Section II, Forrester's complex and amazingly comprehensive Urban Dynamics model is described for any who are unfamiliar with it. Without a solid understanding of it, the challenges make very little sense. In Section III, challenges are presented. In Section IV, housing policies are applied to the "best" model comparing them to similar runs in Forrester's Model. In Section V, framing the issue and interpreting results are discussed and finally conclusions are stated in Section VI.

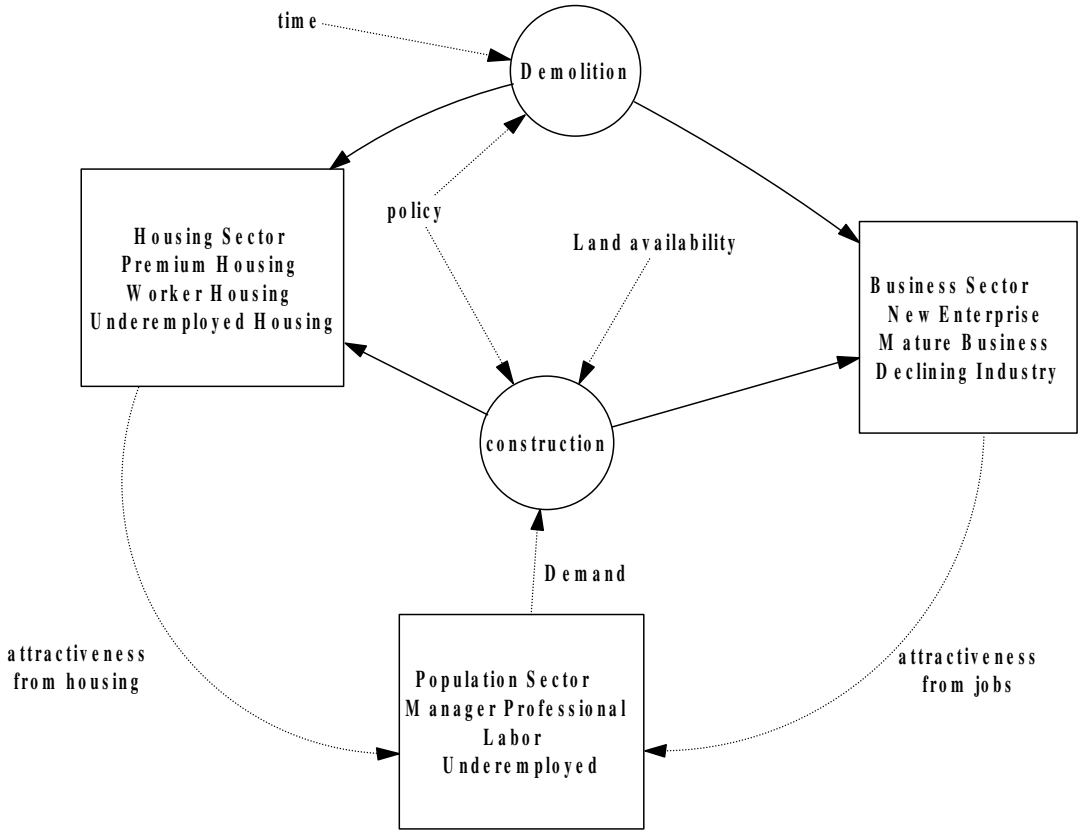
[1] This is just one of many possible sources for the charge of corruption in HUD programs throughout the history of the agency, both at the local and federal levels.

II. Jay Forrester's Urban Dynamics Model

A. Overview

Urban Dynamics is a system dynamics model of a generic city. Stocks and flows and time are the components used to simulate any dynamic system. Stocks contain accumulations of people, houses, etc. Flows describe how and at what rate things move between stocks. Time, as in real life, is what makes the system dynamic. The overview of Urban Dynamics is shown below.

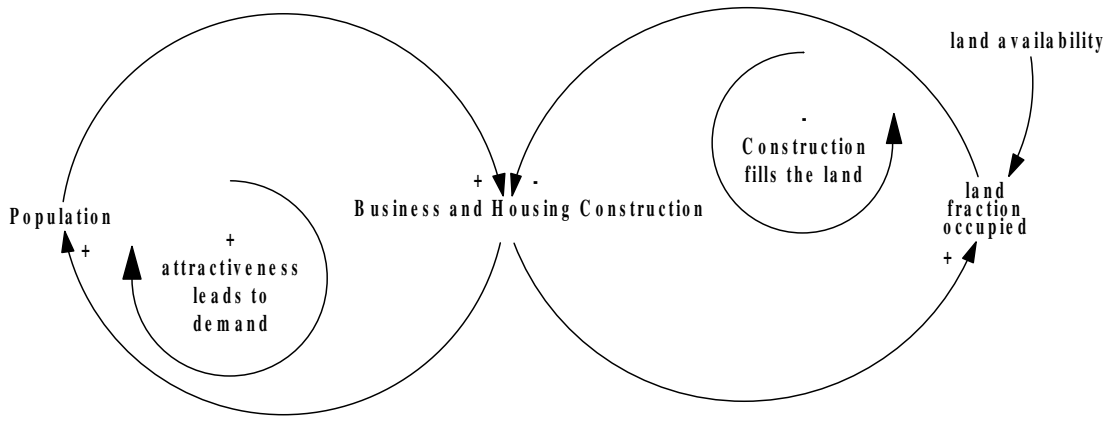
Figure 1. Sector Overview Diagram



With its conceptual boundary of a city (or a part of a city), the Urban model has three major sectors; businesses, housing and population. The limit to growth archetype

shown below is the primary system dynamic archetype present in the model. In this archetype there is a limiting commodity that once used precludes growth beyond this limit. In this model that commodity is land.

Figure 2. Limit to Growth Archetype



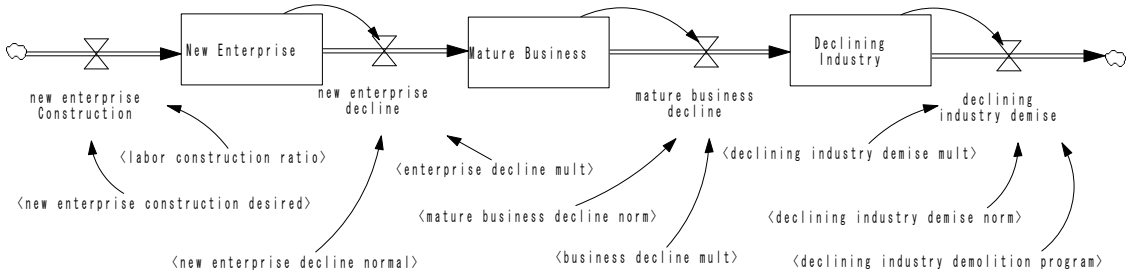
People are attracted to the city primarily because of available jobs and housing. As long as land is available, business structures and housing will be built which will attract even more people. Once all (or nearly all) the land is occupied, the attractiveness of the city decreases because the jobs and houses are occupied. When this occurs, the population stabilizes. That would be just fine except there is one other factor at work; time. Time ages business structures and housing. For business structures in this model, both the number and quality (as measured by income) of the jobs deteriorate as businesses age from new enterprises to mature business to declining industry. This means that fewer jobs are available at the site. In the case of housing, time decays property value. Affluent neighborhoods become middle income neighborhoods and middle income neighborhoods become low income neighborhoods. Populations of the various income brackets have different factors that make the city attractive. The city's attractiveness as

time goes on is for the less affluent since there is more jobs and housing in these categories. This population shift lowers the tax base and ultimately leads to urban decay.

B. Business Sector

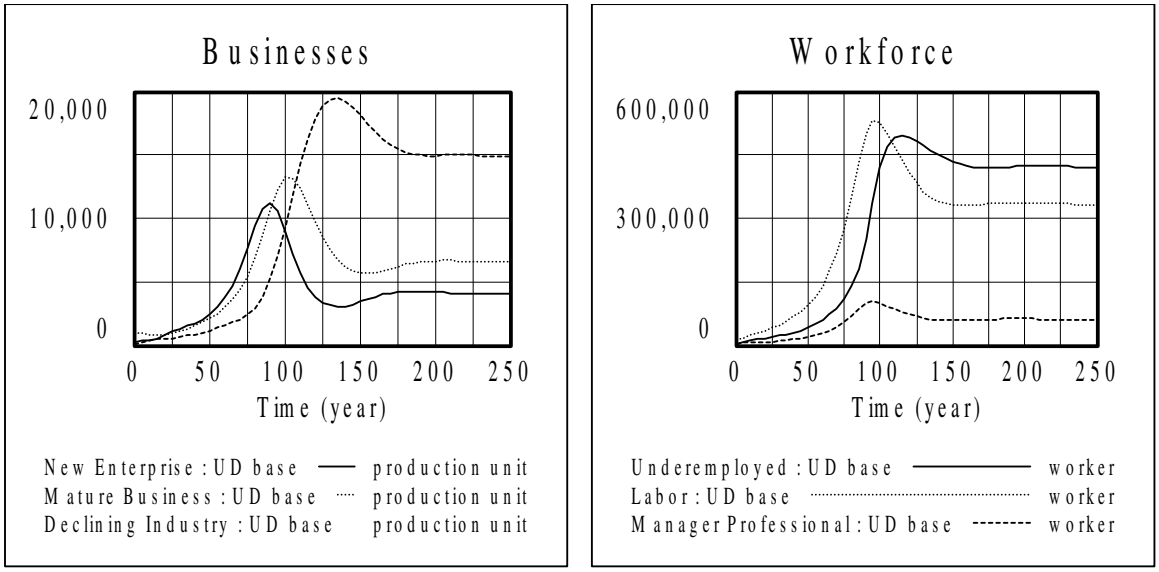
The business sector diagram below shows the aging process of the business structures.

Figure 3. Business Sector



Only new enterprise structures are built. Mature business and declining industry structures come about through the aging process. The decision to build new businesses is based primarily on land availability and the presence of an employed population. Less land available slows construction; higher population present in the labor force quickens construction. Demolishing deteriorated business structures adds to the available land. Newer businesses employ more and higher paid workers. As a business ages, the number of jobs and the quality of those jobs, housed in the structure, declines. The following graphs show the ripple of deterioration in the form of peaks in new enterprises, mature business and declining industry structures. It also shows the decline in jobs that accompanies the deterioration.

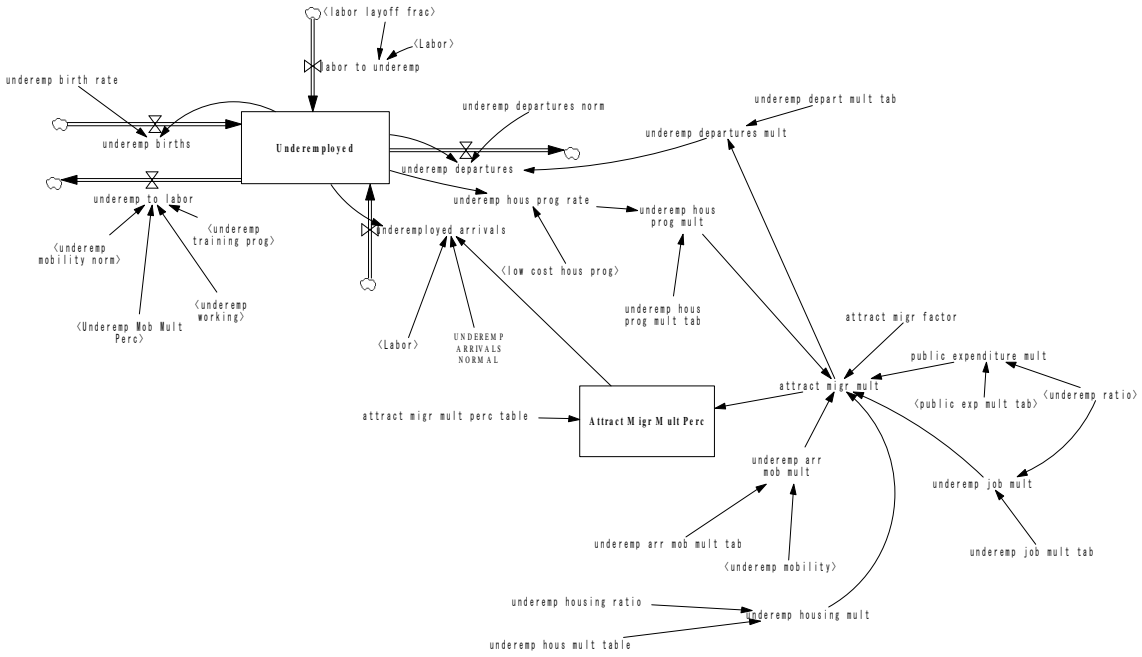
Figure 4. Base Business and Population Graphs



C. Population Sector

There is a population sector in the model for each income segment. The diagram below shows the underemployed population structure.

Figure 5. Underemployed Population Sector



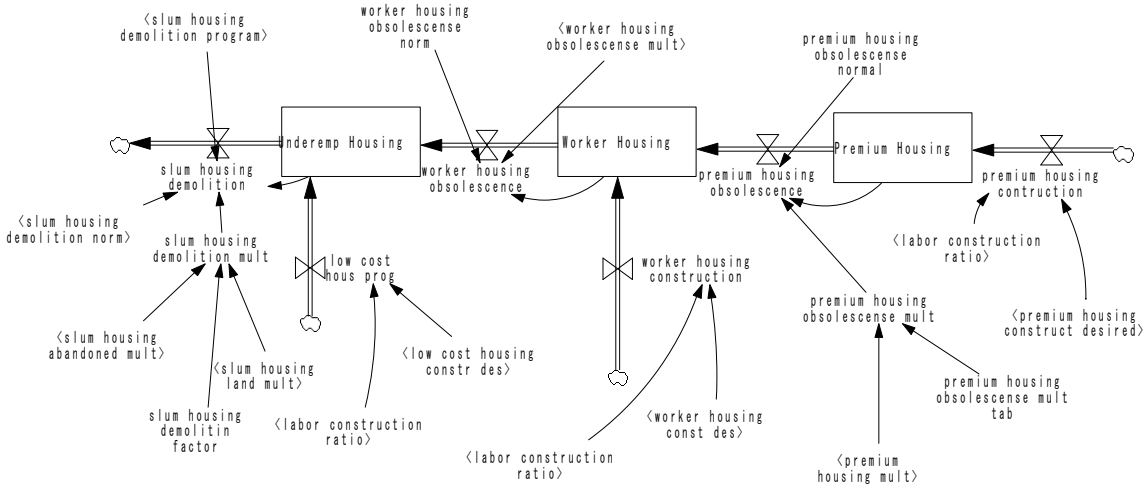
The model includes population at three income levels as defined by their job: manager/professional, worker and underemployed. The structures for the manager/professional and worker groups are not shown but are basically the same with attraction based on housing and jobs in the matching categories.

The upper income population called the manager/professional population lives in premium housing. The middle income population, the worker population, lives in worker housing and the lower income population, underemployed population lives in underemployed housing. Births and deaths are based on normal rates. In-migration and out-migration are based on the attractiveness of the city to the population segment. Availability of jobs and housing in a particular income category increases in-migration for that population. However, as the population grows the availability of jobs and housing decreases. This slows in-migration.

D. Housing Sector

Similar to business structures, housing structures deteriorate over time. Premium and worker housing is constructed if there is land and if there is demand from the population. In the base model no underemployed housing is built. Lower income people live in deteriorated premium and worker housing. As land fills up, construction slows. As population grows, demand is increased and construction quickens. Demolishing housing structures free land for other uses. The housing sector is shown below.

Figure 6. Housing Sector

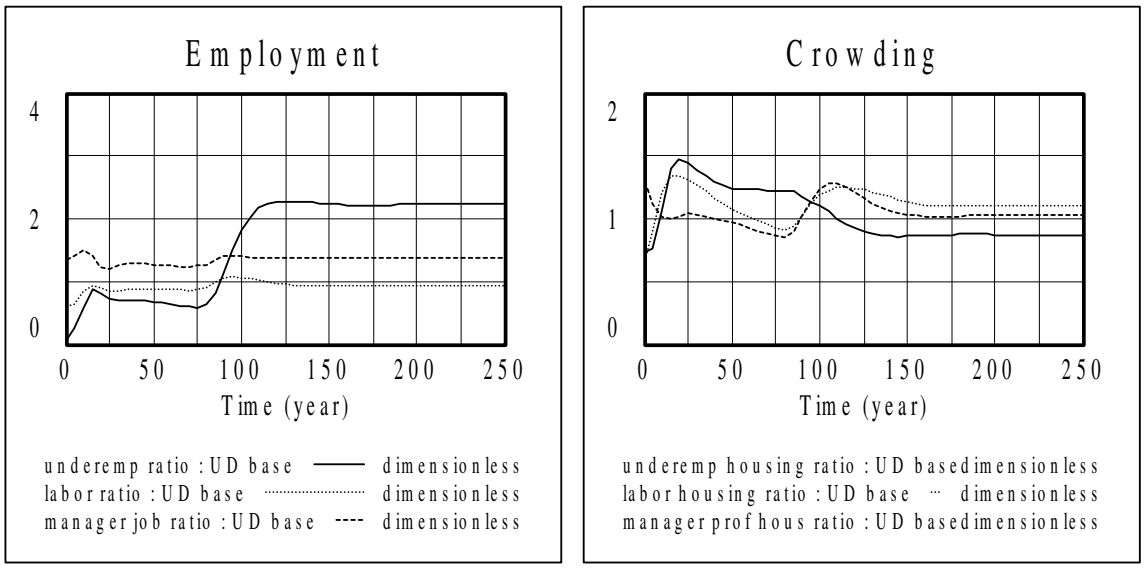


E. Base Model Behavior

The base behavior of the system has the business structures, housing structures, jobs and population all growing together until the land is mostly used up. Then businesses deteriorate and the number of jobs decline making the city less attractive and so the population declines. The attractiveness of the city is seen differently from each income segment of the population's perspective. A variety of ratios are used to define how certain indicators of city health are doing. Employment/unemployment is monitored with the worker per job ratio. Housing availability/crowding is monitored by the household per housing unit ratio. There are indicators for each income class. When these ratios are above 1, they represent unemployment or a housing shortage; fewer jobs than persons seeking jobs or fewer houses than families who need them. The ratios for each income class are shown in the graphs below.[2]

[2] The employment ratios are dimensionless because both the workforce and the number of jobs in this model are defined with the units of worker ("men" in Forrester's book). The housing ratios are dimensionless because they are calculated by combining workforce (men), family size (people/man), population density (people/housing unit) and houses (housing units). Workforce*family size => people / population density*housing units => people. People/people => dimensionless.

Figure 7. Base Employment and Crowding Ratios



The city grows and decays in the first 250 years. When policies are tested, the model runs for 300 years. The last 50 years, years 250 to 300 is generally the policy implementation time frame. The housing programs in Jay Forrester's book costs nothing to the city. This is a way of having the funding come from the US government. Programs though funded at the federal level, have lower governments make proposals on how to specifically use the funds. The causal boundaries of the model then are endogenous, but have an implied exogenous factor if funding is cut or increased. See Appendix A for the base model equations.

III. Challenges to Urban Dynamics

There are various ways to challenge the model. One is to question the structure. Does the structure represent real life? Do the assumptions about the model's structure cause reliable dynamics? The first two challenges are in this category. The first challenge is of the housing deterioration assumption. The second challenge is of the placement of all low income housing into a single stock regardless of its livability. A second way to challenge the model is to question its parameters. Are the values realistic? Are the graphical variables reasonable shapes? Are there missing parameters? The second set of challenges fall into this category. The shape of one of the attractiveness factors for the underemployed is challenged, the attraction to the city due solely to the existence of subsidized housing. Next the omission of racism as a parameter in the model is questioned. A third way to challenge the model is find an exception case. Forrester's model is of a generic city. Modifying parameters should be able to show the deterioration of a real city. If a city can be identified and shown to not be replicable in the model, then something else is missing in the model. Detroit is used as the hypothesis city.

The reasoning behind each challenge is discussed. The model changes or variable changes are described. Results are shown graphically, each with a comparative run to make the changes more evident. Finally, the results and implications to the model are discussed.

A. The Aging of Housing

Many housing markets have very old housing with very high values. Sometimes even housing originally built as lower income housing increases in value due to location regardless of age. This phenomenon is opposite of Forrester's model. In this challenge

census data from 1990 and 2000 was used to determine if the age and value of housing was correlated.[3] To represent value, the variable "Specified owner-occupied housing units: Median value" was used. Age was represented by the variable "Housing units: Median year structure built." This is a very crude measure, but if a significant correlation was found between the variables, a more precise comparison could be used. If Forrester is correct, there should be a significant positive correlation between the variables, since a newer house would have a larger build year. Pearson's correlation tests were performed on the 1990 and 2000 data in SPSS. The results are displayed in the table below.

Figure 8. Age/Value Correlation Table

	Summary		
	Mean	**Std. Deviation**	
1990 Data			
Mean Year Built	1965.4	7.7	
Mean Value	$72,523.24	$35,048.52	
Correlation details			
Pearson Correlation			0.010
Significance(2-tailed)			0.866
N			284
2000 Data			
Mean Year Built	1970.8	8.5	
Mean Value	$105,276.78	$38,765.24	
Correlation details			
Pearson Correlation			0.129(*)
Significance(2-tailed)			0.031
N			280
* Significant at the .05 level			

[3]"http://factfinder.census.gov/servlet/DatasetMainPageServlet?_ds_name=DEC_2000_SF3_U&_program=DEC&_lang=en" Census 2000 Summary File 3► Detailed Tables► geographic type ► Metropolitan Statistical Area ► All Metropolitan Statistical Areas/Consolidated Metropolitan Statistical Areas► H35 Median Year Structure Built and H85. Median Value (Dollars) for All Owner-Occupied Housing Units. 1990 Summary Tape File 3 ► Detailed Tables► geographic type ► Metropolitan Statistical Area ► All Metropolitan Statistical Areas/Consolidated Metropolitan Statistical Areas► H025A Median Year Structure Built and HO61A Median Value.

The 1990 data show that although the trend is in Forrester's direction (positive), there is no significant correlation between the two variables, i.e. age is not a significant factor in value. The story is different for the 2000 data. The direction again is as Forrester assumed (positive), but this time the correlation is significant. At the 95% confidence level, age is a significant factor in the value of a house. As a house ages, its value decreases.

These mixed results led to a test of the model. Modifications were made to account for the possibility of housing moving in the opposite direction; up in value rather than down in value with time. It appears in the model as gentrification. This is modeled by having a percentage of underemployed and worker housing move into premium housing through the process of gentrification. The change is slightly more complex since the influx of gentrified housing affects the demand for new premium housing. Less premium housing is built since the need is partially satisfied by gentrified housing. See the model structure and model run results below. For equation changes see Appendix B.1.

Figure 9. Housing Sector with Gentrification

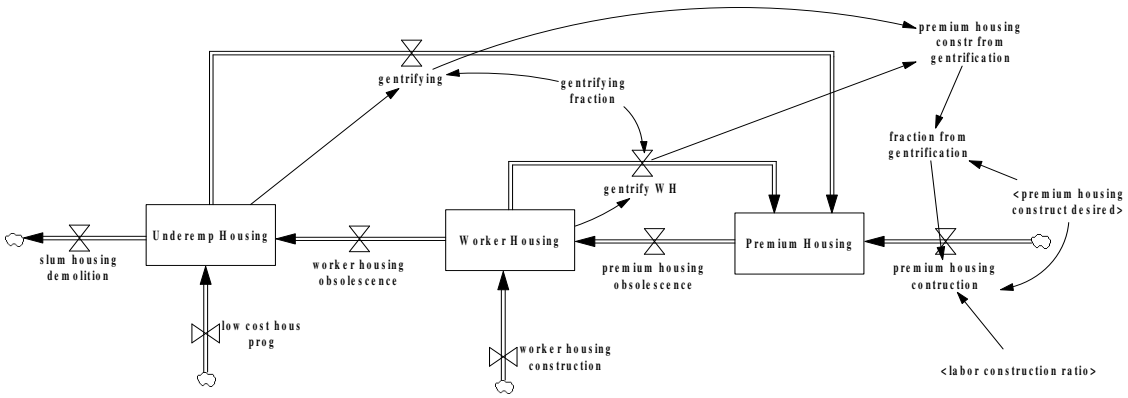
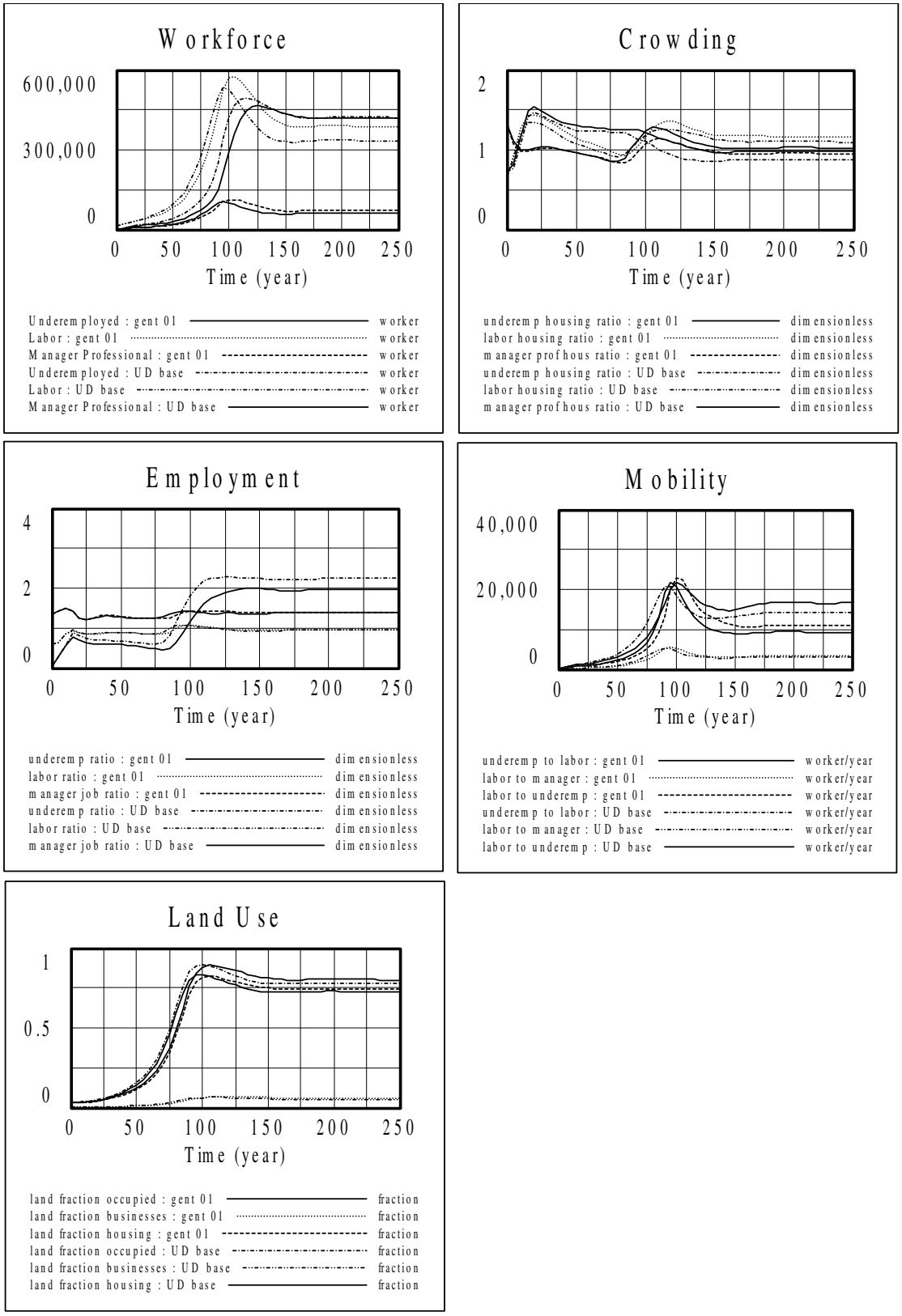


Figure 10. Gentrification Output



The results show no real difference in the shapes of the any of the curves. This indicates that even with gentrification the model behaves the same. So it does not matter if the age and value are correlated or not. Crowding goes up for the worker population. There is already a shortage of worker housing in the base model which increases when some of the housing is diverted to premium housing. The increased crowding slows in-migration. The jobs for the group are still there, however. The mobility graph shows that the underemployed happily fill those jobs.

When considering why gentrification does not make any real difference, it might be useful to consider the gentrified housing as units that are torn down with new premium housing built on the same land. The two scenarios would have about the same effect. Incidentally, Forrester seems to be against this sort of historical preservation since the goal is to have less land used as housing and more for industrial uses. Old housing should be replaced by industry through rezoning and demolition.

B. Livability of Low Income Housing

Forrester states on page 8 (Forrester, 1969), in the stagnant city there is crowding and empty housing at the same time. The ratio of people to housing may be low, but for economic reasons, many of the dwellings are unoccupied. Scarce jobs and low income force people to share space and rental costs.

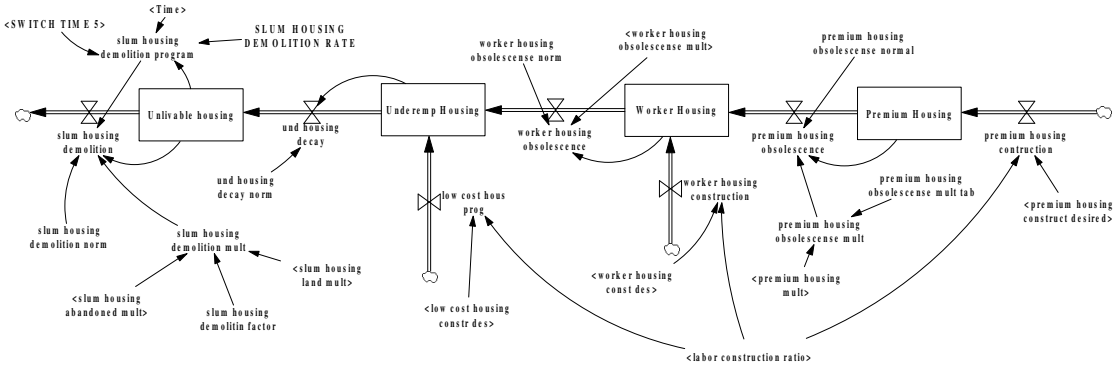
In Forrester's model the land used by housing is the sum of the three housing stocks. No where is there land being used up by unlivable or empty housing. This housing therefore, must be included in the low income housing stock. There are differing opinions on the number of vacancies in very low income units, but most agree that the

vacancies often indicate inadequate living conditions. Many of the units have been condemned (Wright, et. al. 1998).

Two problems occur because of this structure. The first is that the actual availability of housing for the underemployed is inflated. As one of the attractors for the underemployed population, an inflated availability will draw them to the city quicker. Second, when Forrester applies his low income housing construction policy (or any of his policies for that matter), the ratio of low income households to housing units is below one. This implies that there is no low cost housing shortage. Adding additional housing, when there is no discernible housing shortage, does not make sense. The result, of course, is an increase in underemployed persons entering the city and because of the added attractiveness of these subsidized units as discussed above, not only do the underemployed arrive but they do so in large numbers.

To address these issues, the model is modified by adding an additional stock at the end of the housing chain to account for the "unlivable" housing. In so doing, the non-livable underemployed housing is removed from the livable underemployed housing stock. Variables concerning attractiveness use the crowding factors based only on the livable housing. Demolition of housing is based on non-livable housing. The original normal deterioration rate is split between the two rates (und housing decay and slum housing demolition), such that the time for deterioration is unchanged from the original model. See the model structure in Figure 11 and the model run results in Figure 12. For equations changes, see Appendix B.2

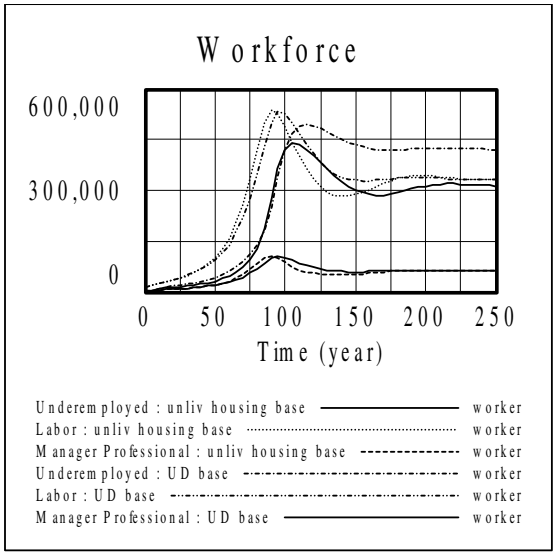
Figure 11. Unlivable Housing Model Changes

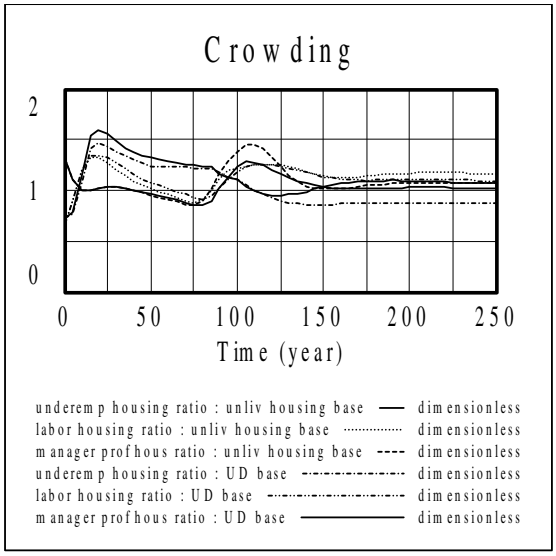


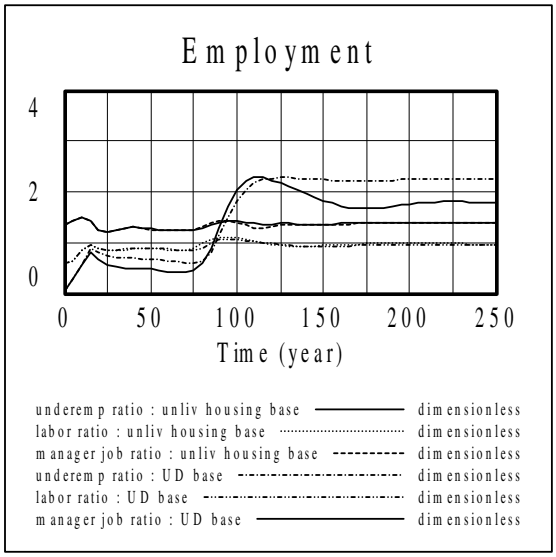
The run from this challenge shows some interesting results. The biggest difference to notice is that underemployed crowding is now reflected. The attractiveness of the city is decreased with the housing shortage and this is reflected in the decrease in the underemployed population. With fewer people, the unemployment decreases for the group. Nothing else changes in the model. However, since mobility is in absolute numbers, the underemployed to labor is a higher percentage of the population since the total population for the group is lower.

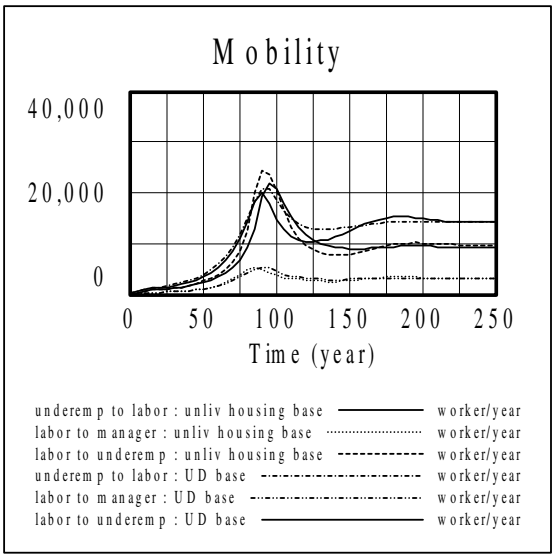
Forrester's model cannot be rejected by these results, but the change seems to more closely match reality in terms of the underemployed housing shortage that is seen in cities across the country.

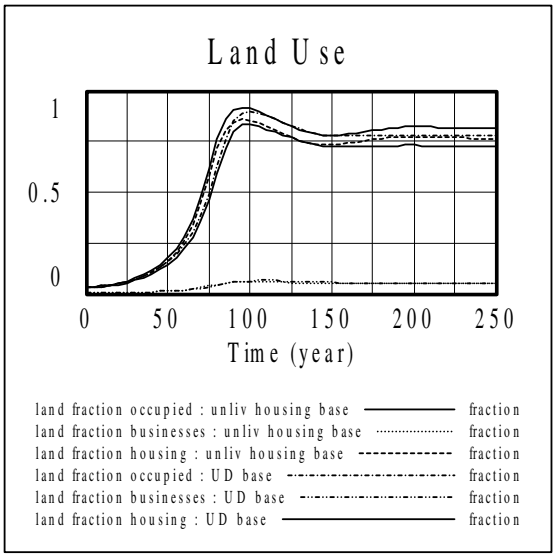
Figure 12. Output From Livable Housing Changes







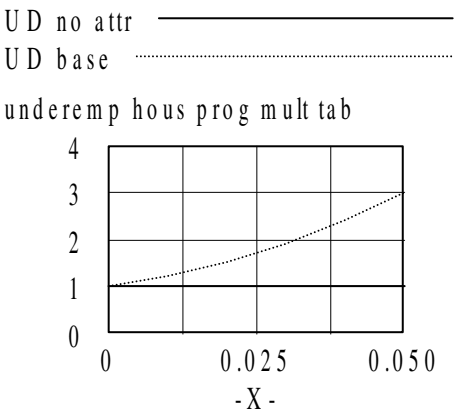




C. Attractiveness of Low Income Housing Programs

In Forester's examination of the impact of programs that includes building low income housing in the urban model, he adds a multiplier to the underemployed attractiveness variable. The graph of the multiplier is shown below. It varies from a value of one to a value of three based on the amount of housing built. This means at the high end of this scale, underemployed people are three times as likely to be drawn to the city solely due to the presence of subsidized housing. For many reasons this number seems to be too high.

Figure 13. Underemployed Attraction from Housing Program Multiplier



First, there is already an attractiveness multiplier for the availability of housing of the same class. Second, attractiveness is relative to other options (other urban areas). If funding exists at the Federal level as Forrester assumes for these programs, all or most cities would get money for low income housing. In fact all cities have housing authorities that administer these funds. Our city, therefore, compared to others would not appear more attractive, based only on the presence of the program. Third, all over America, housing authorities, currently and historically, have long waiting lists to get into subsidized housing. Many cities have closed waiting lists due to excessive demand

(Wright, et. al. 1998). Just because it is built, does not mean that people moving to the area will get housing. Of course the program is need based, so some number of incoming folks may qualify even with a very long waiting list. Fourth, in the housing turnover literature (vacancy chains) the data suggests that housing at the tail end of the vacancy chains (the lowest income level) are more likely to go to people already residing in the city, not new comers in to the city (Sands and Bower 1976). These people would come from less adequate housing or from an overcrowding situation or from people moving into housing for the first time such as young people moving out of parental housing, newly weds, etc. Fifth, migration literature suggests that decisions on moving to a city are based on opportunity, means and information that is often imperfect—1) if underemployed housing is built the opportunity(if it truly exists) may not be known to people in other locations, 2) even if the people know about opportunity, they may not have the means to move. Again from the vacancy chain literature, when the vacancy chains were ended due to in-migration to the city, the household was more likely to be of higher income (Sands and Bower 1976). These five reasons indicate that the multiplier is either too high or too steep.

There may indeed be an increase in in-migration when new housing is built, but it is can as easily be explained by the increased availability of affordable housing rather than by the fact that it is subsidized.

Tolerance testing in a system dynamic model is defined as running a model with various values for a variable. This kind of testing is done to test the structure of the model or the reasonableness of the variable. Forrester did not do tolerance testing on this variable (any way none that is documented in his book). Limited tolerance testing is

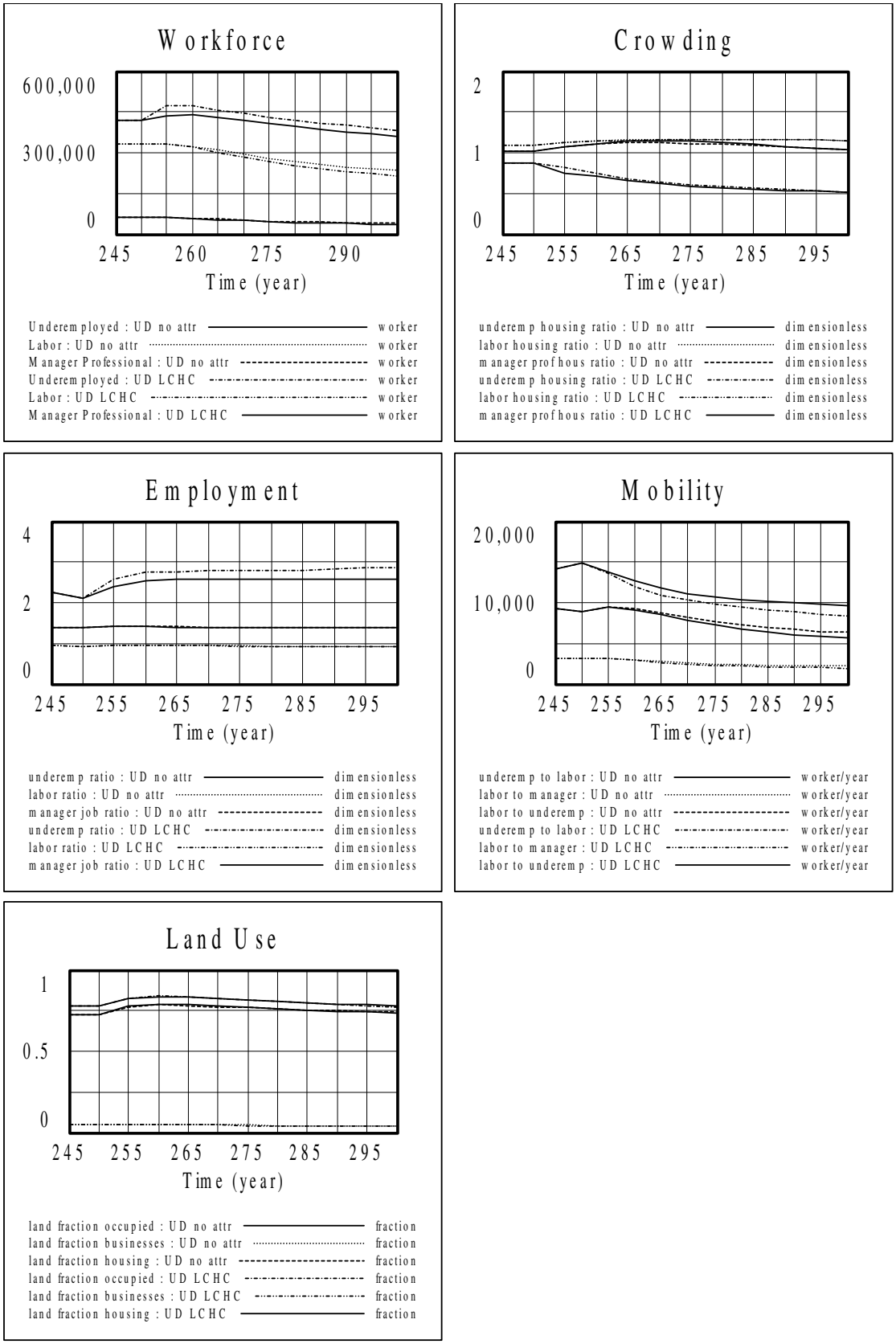
performed here to determine whether the value of this variable significantly affects the model. This variable as shown above is graphical and is used as a multiplier. To make the variable have no effect on the model it can be set to the value of one. One, because anything multiplied by one is equal to the original value, i.e. no effect. That is no additional effect to attractiveness occurs due solely to the construction of low income housing.

The results are shown below in Figure 14. Note that the comparative run in this test is not the base run for the original model. In the base model no underemployed housing is built so the multiplier is never activated. The comparative run for this test is one of Forrester's policy runs. It is his Low Cost Housing Construction policy that he describes in the Chapter titled "Failures in Urban Programs." The policy is to build housing for 5% of the underemployed each year. The policy goes into effect at year 250 and runs until the end of the simulation, year 300. The graphs cover only the time period of the policy.

The results show no change in the shape of any of the displayed graphs. Since the attractiveness for the programs were not multiplied in, the underemployed population decreased. The employment ratio improved slightly and crowding was unaffected. Remember that this run is off the original model so the underemployed population is not experiencing a housing shortage.

Since the changes are so negligible, it can be concluded that removing or nullifying this attractiveness multiplier has minimal impact on the system. Or, depending on your frame, leaving it in has minimal impact on the system.

Figure 14. No Extra Attraction for Low Cost Housing Program (0.05)



To make quite sure that removal is acceptable, additional tests are run on the modified model with different levels of underemployed housing construction. Values equal to half and twice the percentage of underemployed housing construction funded by the program, 2.5% and 10% of the underemployed population each year were chosen. Comparative runs with matching policies were run on the original model. The results for the 2.5% run are found in Figure 15. The results for the 10% run are found in Figure 16 below. They both are as expected, with no real difference from the original model comparative runs.

Figure 15. No Extra Attraction for Low Cost Housing Program (0.025)

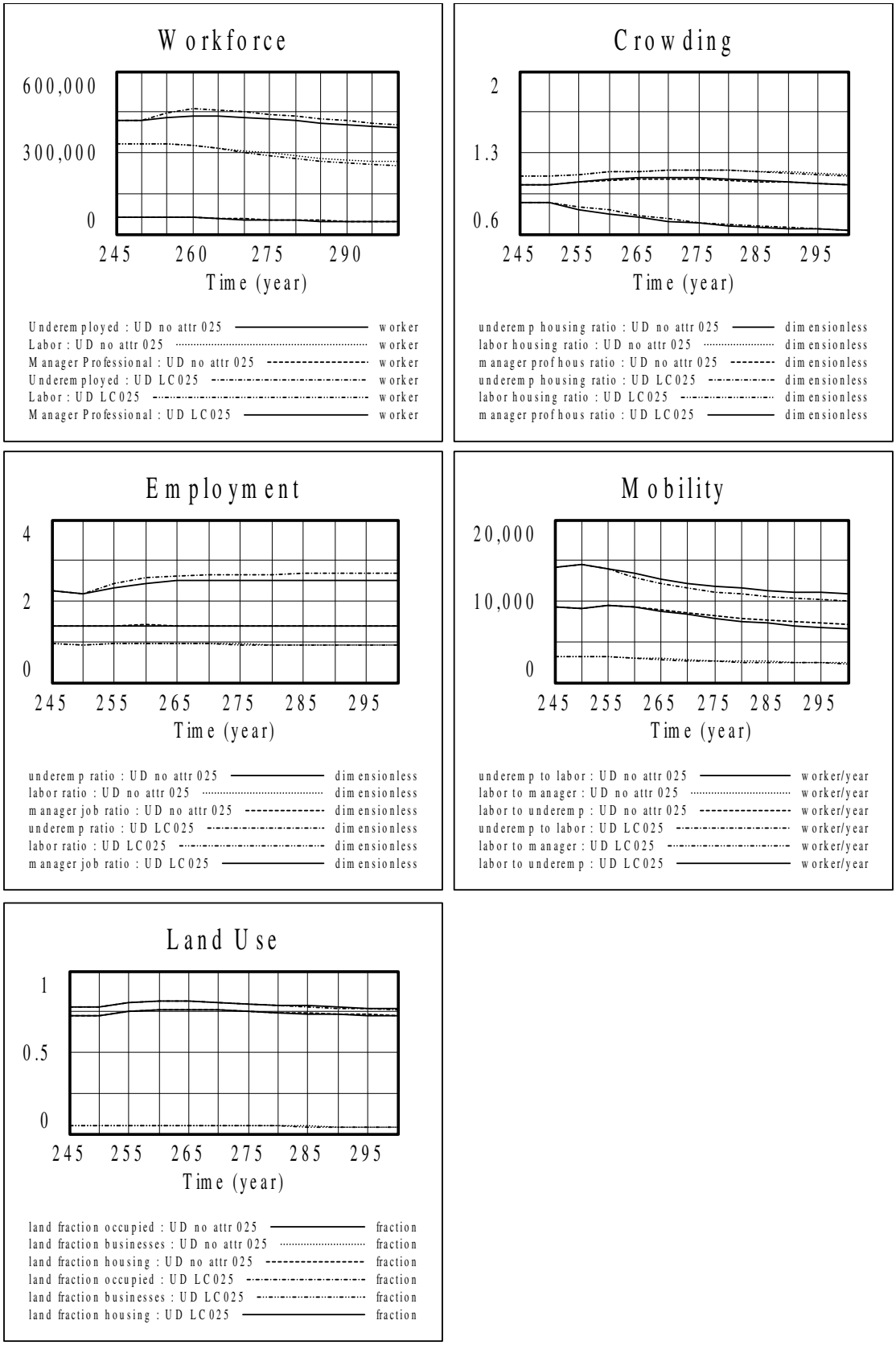
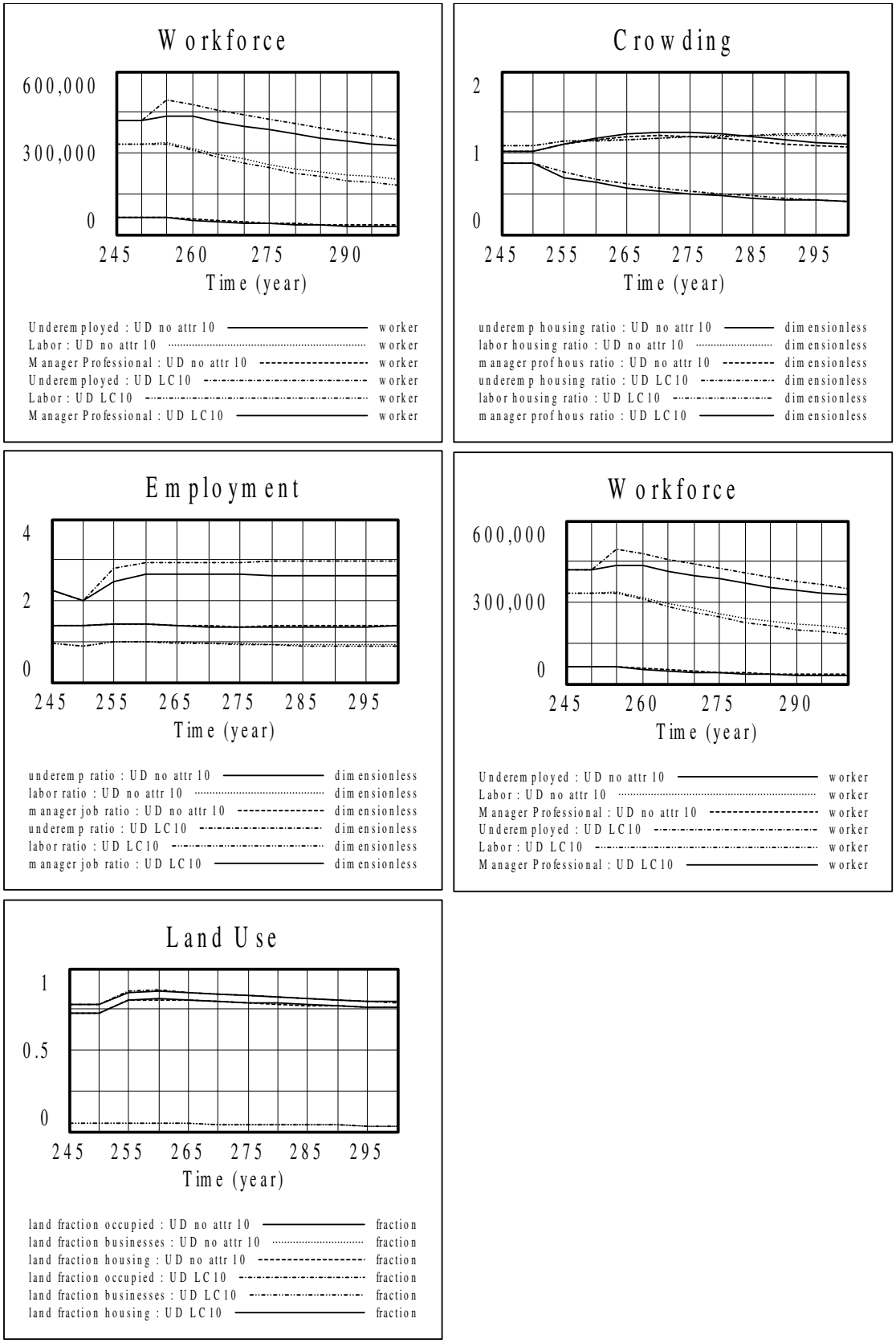


Figure 16. No Extra Attraction for Low Cost Housing Program (0.10)



D. Racism, Classism and the Story of Detroit

These sections are merged together for reasons that will become apparent. Detroit's empty land – if there is space they will build theory- is the primary reason it is the challenge city. Forrester's model has business construction based primarily on land availability.

His model is at equilibrium (though he adds a caveat that the equilibrium is minus the random influence due to technological advances, economic cycles and world events) after 250 years. However in the Detroit scenario, the equilibrium is not based on the unavailability of the land as suggested in the model. In Detroit there is space; 60,000 lots empty (Vergara 1995). If Forrester's model cannot achieve this scenario, then something else is missing from his model.

Detroit is in a severe state of urban decay. There is excess housing, abandoned housing and abandoned business structures. Detroit has an interesting history in respect to Forrester's model. The city historically built very little public housing, far less than most other cities. There were political reasons for this but also economic. The construction companies could build private housing at a greater profit and the demand for private housing was high as opposed to cities like New York. Detroit also, as time went on, used slum clearance and zoning to make large land tracts available to businesses. Land that was close to transportation infrastructure, but the businesses did not come. This was after the boom of the car industry and the World War II defense manufacturing boom. In the 1950s and 1960s when other cities saw large increases in jobs and prosperity, Detroit and other "rust belt" cities saw huge declines. The automotive companies moved to locations with cheaper labor and the supporting contract companies followed. The result was that

the city had plenty of empty land for business, zoning that made the land usable by businesses, minimal subsidized housing programs and a highly skilled workforce (Sugrue 1996). In deed Detroit was Forrester's ideal city, but the businesses did not come.

Urban Dynamics contains no demographic information on its population except income in the form of what could be called "class"; manager/professional class, worker class and underemployed class. Forrester allows for the movement between these classes but he includes no information on age, race, gender, education attainment or any other characteristic.

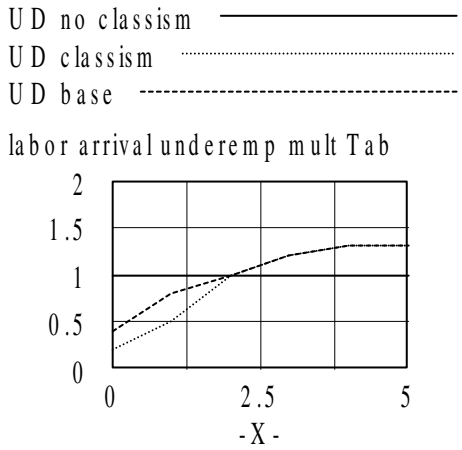
In the history of the U.S. it is difficult to disregard the effects of prejudice based on race, national origin, etc. Adding demographics to the model when none exist is outside the scope of this project. Instead, racism is addressed loosely in terms of classism. "Classism" is defined as prejudice based on economic well being. Racism is only partially to blame for the economic stratification in Detroit. But, racism plays into political and economic issues. Even President George W. Bush in a speech in the aftermath of hurricane Katrina said, "poverty has roots in a history of racial discrimination, which cut off generations from the opportunity of America." (Bumiller, et. al. 2005) Among the Detroit examples of this were that FHA loans were denied to blacks, making home ownership more difficult and more expensive, African Americans were excluded from trade guilds and apprenticeships and segregated schools for this population had lower expectations, smaller budgets and fewer qualified teachers. Structural prejudice is what allowed blacks for example to only fill low end jobs that had minimal upward mobility and were the most likely to be replaced with technological advancements. In Detroit, as well as in other places, this structural prejudice limited the

African American population as a whole to fewer opportunities to move between classes (Sugrue 1996). For these reasons, racism is replaced with classism for the purpose of this analysis.

In Forester's model, there is one variable that can loosely be considered to be a measure of classism. This variable is the ratio of the working class to the underemployed class. It is a graphical multiplier that affects the city's attractiveness to the worker class. As the population of the underemployed increases in relation to the worker class, the worker class is less attracted to the city. Likewise, the worker class will be more likely to leave as this ratio decreases. Forrester has his "no effect" value at two, meaning that if there are twice as many working class people as underemployed people then there is no effect of the underemployed population on the worker class. If there are more than twice as many workers as underemployed, the worker class will be more attracted to city based on this fact alone. If there are fewer than twice as many worker to underemployed people, then the worker population will leave the city at a quicker rate as well as be less attracted to it. The graphical function is shown below.[4]

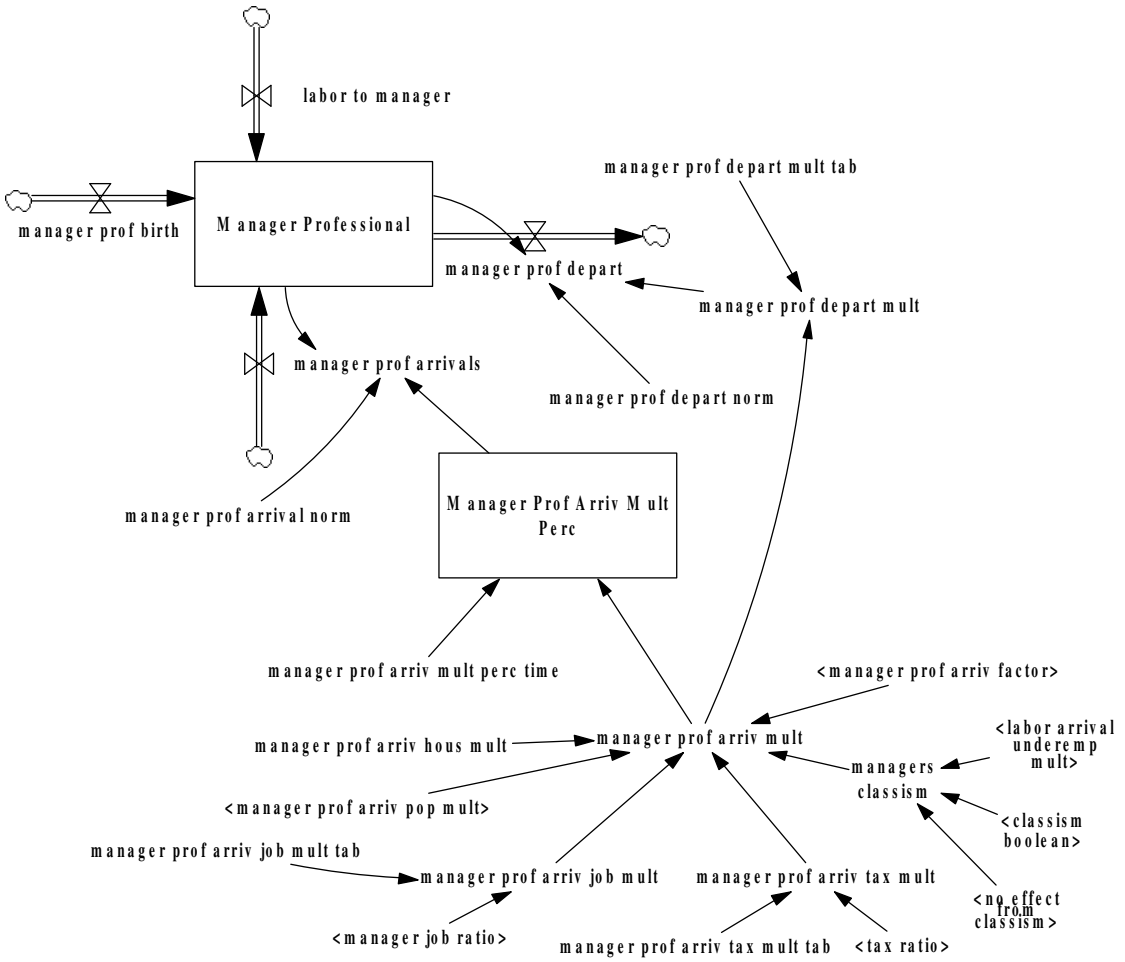
[4] "UD base" is the original shape of the variable in Forrester's model. The other lines are the values used for the two test runs in this challenge.

Figure 17. Classism Graphical Function



The premise of this challenge is that classism has a bigger effect on the city than is assumed by this multiplier. To simulate an increased effect from classism, two changes were made to the model. First a classism multiplier was applied to the attractiveness formulation for the managerial population. See model graph below and Appendix B.3. for equations.

Figure 18. Manager Classism Model Changes



Since the original model does not include this multiplier, a switch to activate the effect is added. When the switch is turned on (set to one) the multiplier that is used for worker class' attractiveness is also applied to the managerial class. Modifying the worker class graphical variable for classism is the other piece of the modification. The graphs were shown above. The "UD classism" run increases the effect of classism and the "UD no classism" removes even the original effect from the model by setting the multiplier to always be one. Again, a multiplier of one results in no change to the attractiveness. To increase the effect of the multiplier, attractiveness needs to be decreased. In the original model for example, when the worker population equals the underemployed population,

the attractiveness of the city is 80% of what it was when there were two times as many workers to underemployed persons. In the challenge run that number is decreased to 50%.

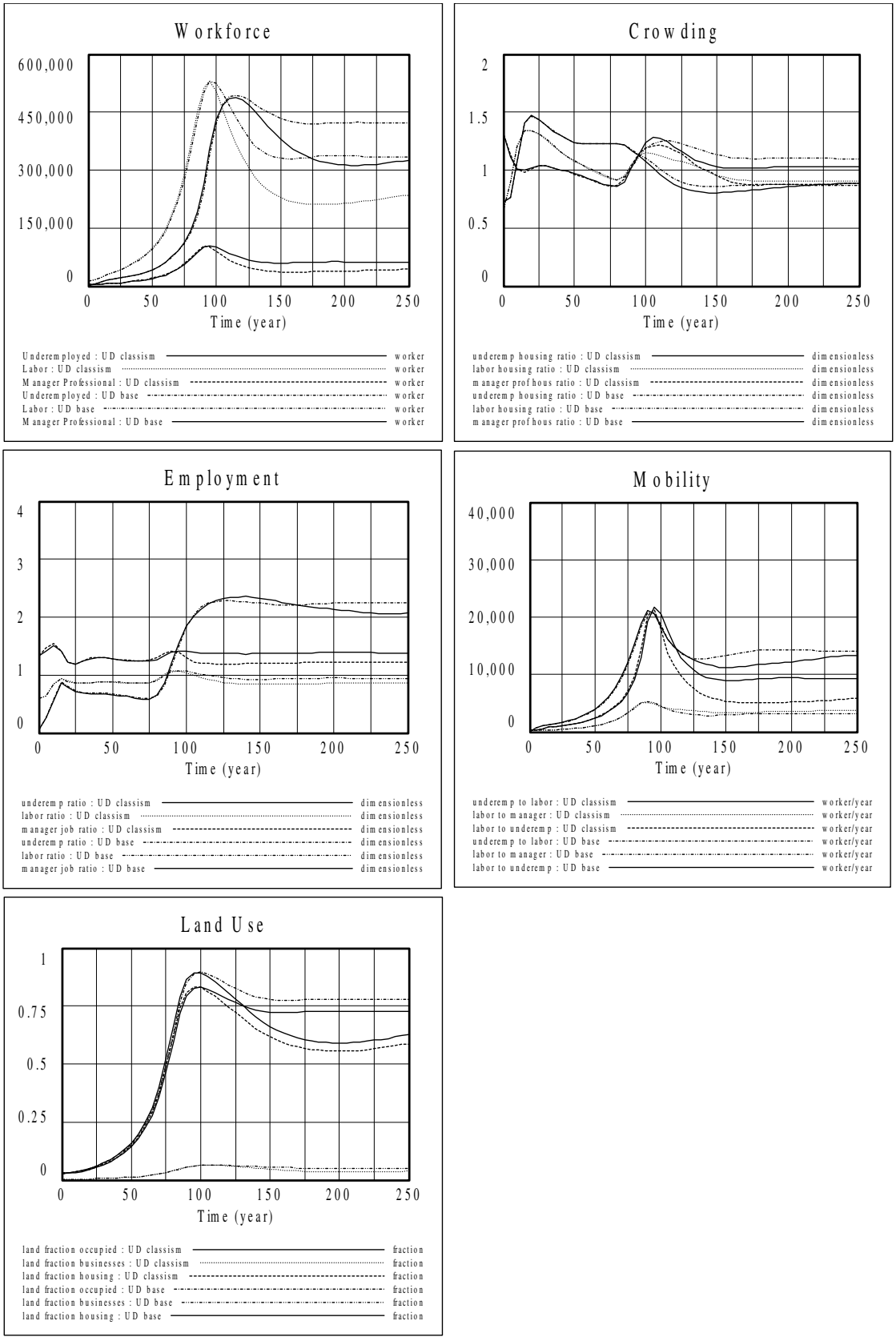
See Figure 19 below for the graphical output.

The results are astonishing. The population falls 10% or more in all categories, with huge drops among the underemployed and labor populations. Land use plummets. Underemployed to labor mobility drops and labor to underemployed mobility rises. Unemployment and crowding have small changes in comparison to the dramatic changes in the other indicators.

Increasing classism has dramatic effects on the model; depopulation, high unemployment and plenty of empty land. The model has indeed produced Detroit. The changes to the model needed to produce this result are very minor and would more likely support the model rather than disprove it.

Determining a “real life” function for classism is definitely out of the scope of this project, but migration information that contained income level may be a starting point.

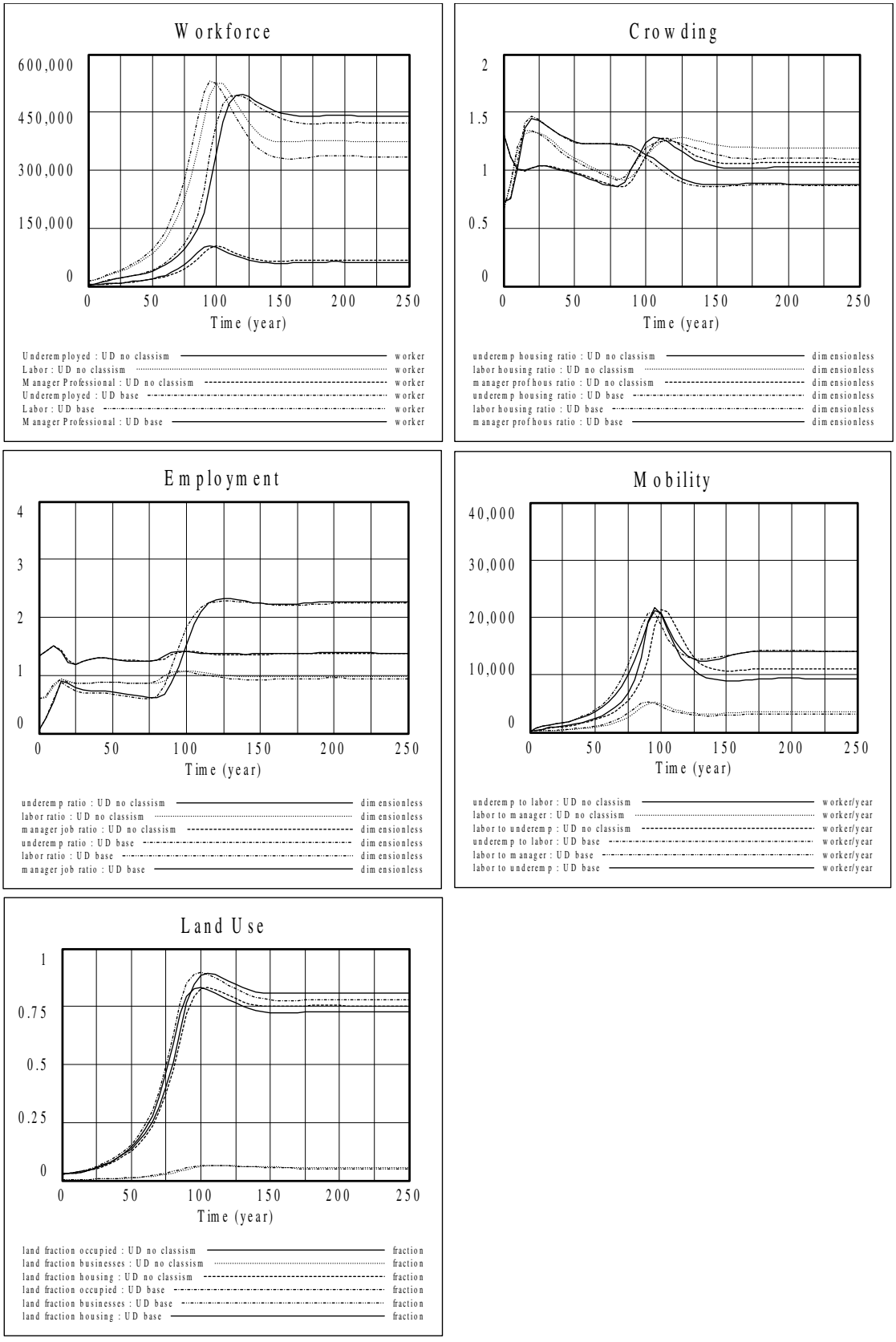
Figure 19. Classism Output



For completeness, a run with no classism is performed. Remember that this variable is in the model already. The challenge just increased its effect and applied it to the manager class as well as the labor class. For this run the same multiplier is set to always equal one, no effect. The results for the no classism run are shown below in Figure 20.

In the no classism run, the only difference is an increase in the labor population and the crowding increase that accompanies a population increase. It is interesting that removing the base model effect of classism altogether has such a small effect on the model. It seems that the original setting is too close to "no effect" and that increasing it may be in order for a "true" effect. Forrester stresses throughout his book that all parameters can and should be modified to fit a specific city.

Figure 20. Classism Removed Output



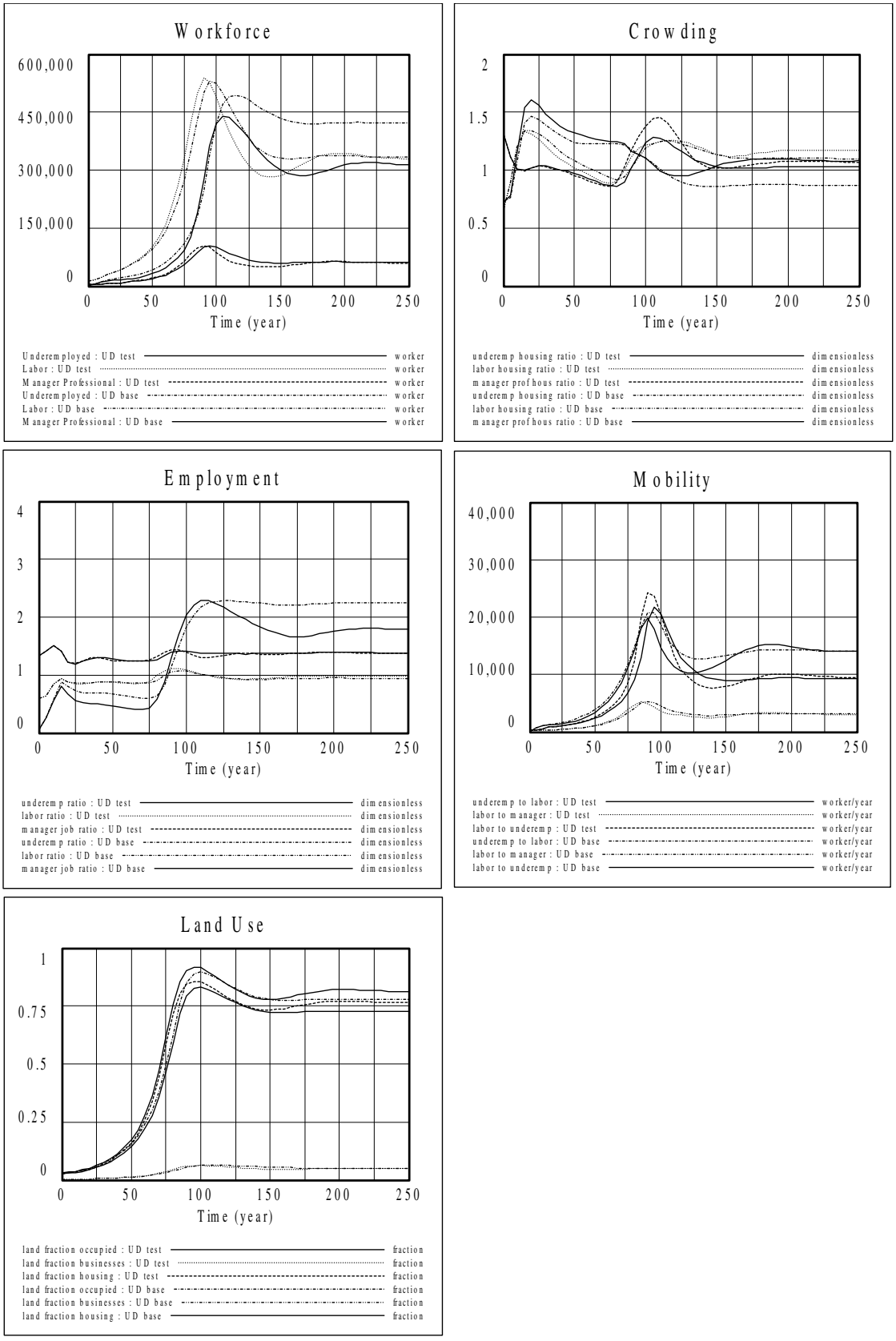
IV. Housing Policy in Urban Dynamics

The original purpose of this paper was to determine if housing policies really lead to the downfall of the city. With this in mind, comparative policy runs are performed between Forrester's model and the modified model generated from the previous section. The final modified model includes only the unlivable housing change and the flattened attractiveness factor for subsidized housing. Gentrification is not included because of its minimal effects. Classism is not included since a better guess at reality values is unattainable.

Five policies are examined; slum clearance, public housing, filtering, HOPE VI and Section 8. Most of these are simulated by parameter changes to the base model and indeed were run under different names in Forrester's book. Similar to the last section rational is followed by implementation, results and analysis.

The output on the following page shows the base run comparison between Forrester's model and the modified model. All subsequent runs are policy runs. The policy start times are the year 250. The end time for each is at year 300. Graphical output is only shown for the policy run time frame.

Figure 21. Policy Baseline Output



A. Slum Clearance

As already known, we run out of land in this model. Too much land is being used for housing. What the city needs is jobs, but few sites are available to build businesses to provide them. Forrester's model and many American cities performed slum clearance to free land for other uses.

There is no spatial detail in this model. Slum clearance is done only on unlivable housing in the modified model. This kind of slum clearance politically would be much more palatable than that from the original model which demolished regardless of occupancy. Historically, these clearance projects were spatial. A section of slum that was cleared contained dilapidated houses, inhabited housing, dilapidated office space and occupied office space. This kind of clearance produced a large section of land that could be regenerated into something else. In Albany, NY for example, slum clearance was used to make room for the Empire State Plaza. The modified model's version of slum clearance does not tend to attract rebuilders because the land is in neighborhoods where both housing and business investment opportunities are limited. The mass clearance removed both the buildings and neighborhoods.

The goal of slum clearance in both the real world and the model is to revitalize the city. The models show an increase in businesses and jobs once land was again available. However, this policy is a political nightmare. The old buildings are often part of the character of a city. Neighborhood demolition often required eminent domain to acquire the land. Just because a place is run down does not mean that the people who live there want to leave. Forrester does not discuss the social costs of his proposed solutions (Jaeckel 1972).

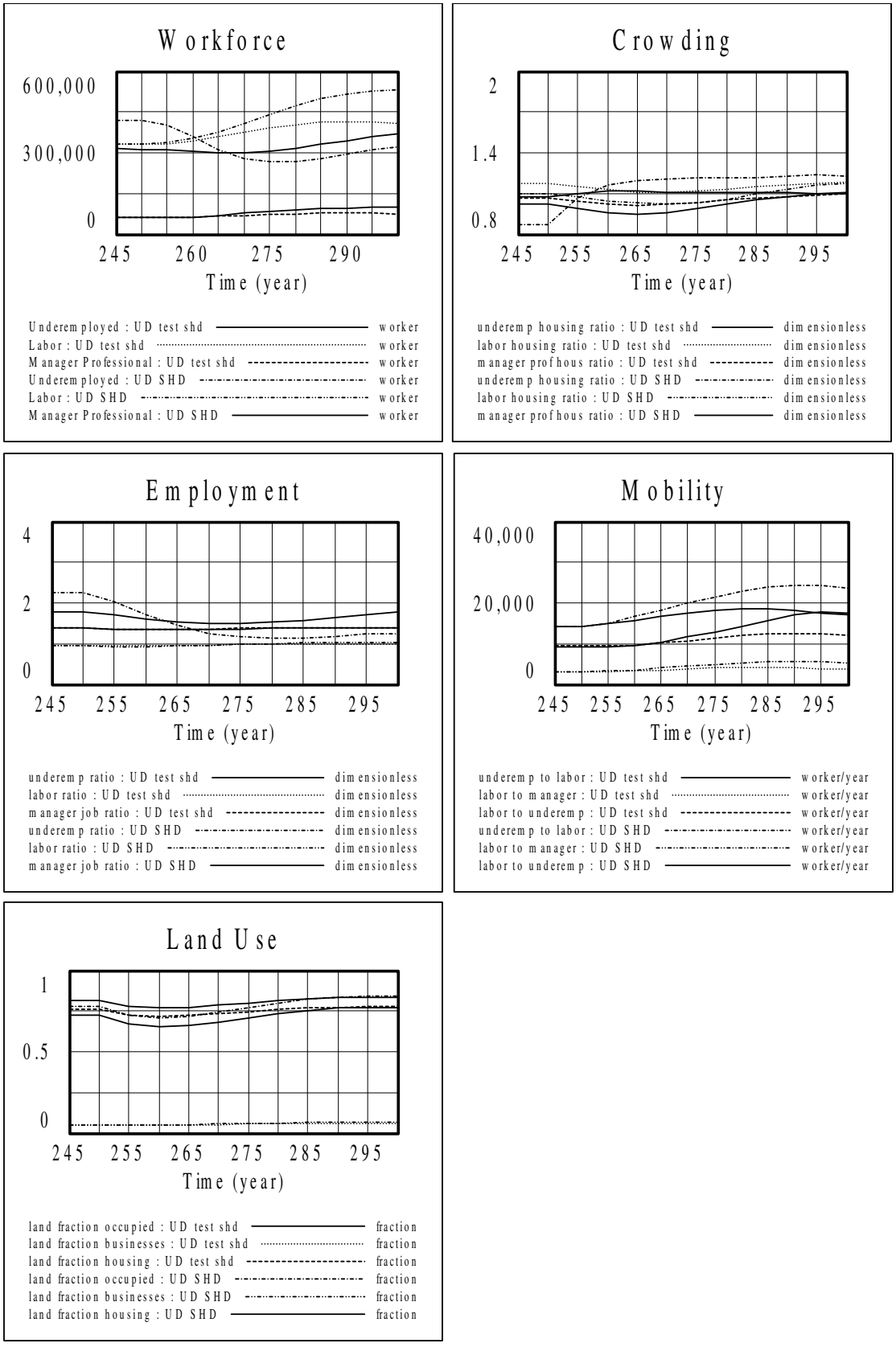
In this policy run, 5% of underemployed or unlivable housing is removed per year of the program. The results are shown in Figure 22. Note that in reading these results, the change in the indicator for the run should be compared to change in the indicator for the base run, i.e. how did the same policy affect the equilibrium level in each case.

The results are much more favorable in Forrester's model than in the modified model. He sees a drop in the underemployed population and a rise in the labor population. Unemployment drops for the underemployed and the underemployed to labor mobility factor is up. The cost of this is the increase in crowding among the underemployed, but in this model there was a housing surplus for this class so the cost is fairly low. The other cost is that the labor to underemployed mobility factor increases, downward mobility.

The modified model by contrast shows minimal effects due to the policy. The labor and underemployed populations both increase by smaller amounts and that is about the only change. Land use in either run is not affected in the long term.

This run illustrates the relevance of the starting point at policy implementation time. Slum clearance is a political hot potato and in the modified model does nothing to improve the city. While in Forrester's model the benefits probably outweigh the political costs.

Figure 22. Slum Clearance Results



B. Public Housing

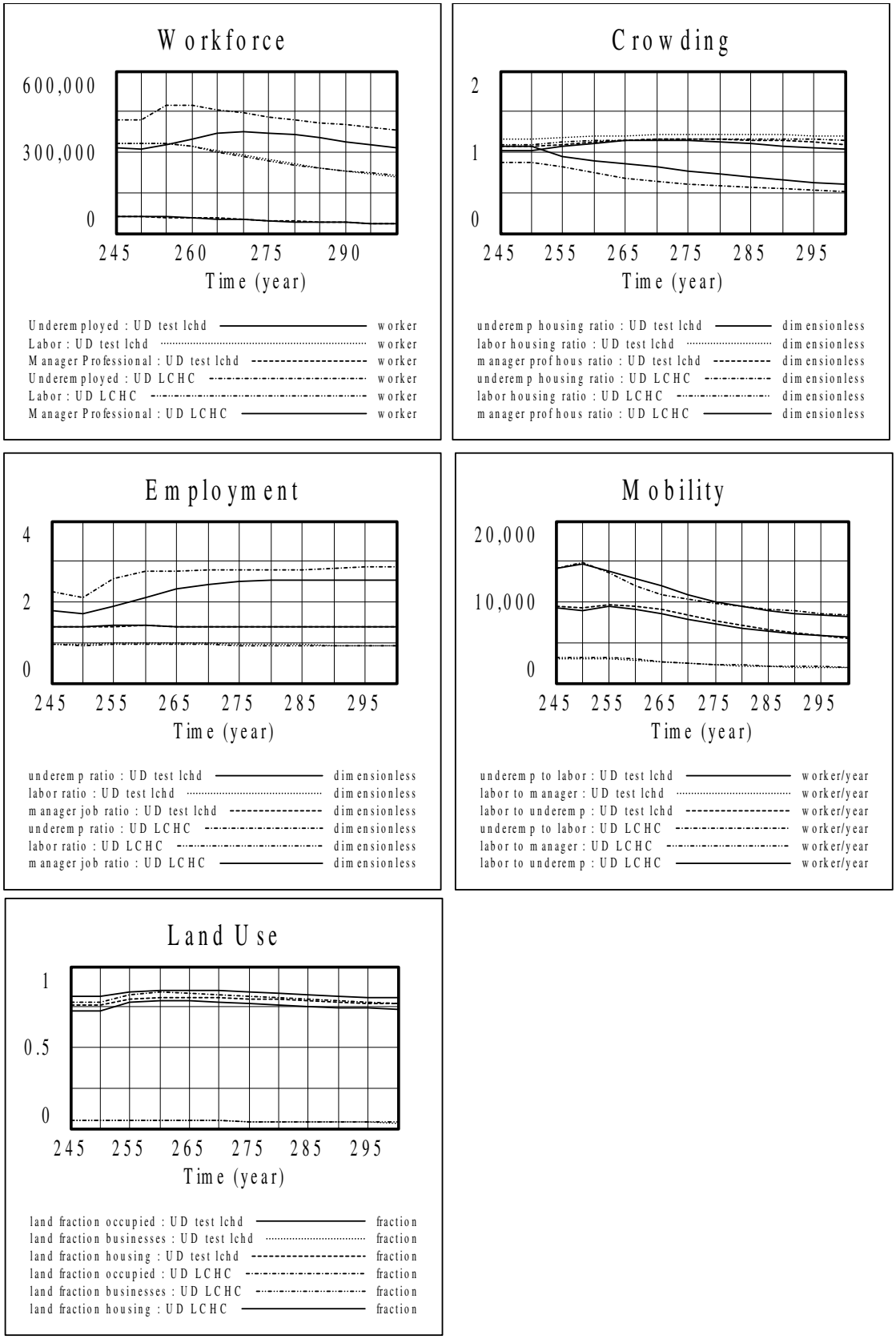
Public housing equates to the low cost housing construction policy in Forrester's book. Building is at a rate to accommodate 5% of the underemployed population per year. A whole other paper could be written to describe the history and effects, good and bad, of public housing. The point is to examine how the models react to this policy. The results are shown in Figure 23.

These results are surprising. Both models show similar bad effects especially for the underemployed. Unemployment goes up and upward mobility goes down. Crowding is relieved but the construction makes the situation much worse in Forrester's model at least partially due to the lack of a shortage.

It seems that too much housing was built. Perhaps a more modest rate would be better. In further testing of smaller rates of 2.5% and 1% (results are not shown) the shapes of the outputs remain unchanged. At the 1% level the modified model is not adversely affected since the crowding is just satisfied but the employment trends continue in the adverse manner.

A city with a larger shortage of low cost housing may fair better with this policy but in both Forrester's and the modified models, public housing alone as a policy negatively affect the low income population's employment opportunities.

Figure 23. Public Housing Comparison



C. Filtering

Filtering is the theory that by providing benefits for economically higher persons, the benefits will filter down to people lower on the economic ladder. The vacancy chain model is the filtering model for housing. The vacancy chain theory is that new housing is added to market at whatever level, premium, worker, or low income, government sponsored or private market generated. When a household moves into the new housing unit, the vacated housing unit becomes available. When a household moves into the vacated unit, they in turn leave a vacated unit that becomes an opportunity available for another family and so on. This string of vacancies is referred to as a vacancy chain. The research on these chains shows some interesting but no surprising characteristics. The housing quality decreases down the chain as well as the affluence of the new household.

The chain can end in a couple of different ways. First, the chain can end by in migration, i.e. someone moves into the area from outside the city. The link is not followed since the unit of measure is generally at the city level. Second, the housing left behind may not be available. It may be inhabitable. It may be non-existent, when a homeless household moves into housing, for example. It may still be use, i.e. when the new house is purchased as a second home or when half of a divorcing couple moves out, or when children move out of their parents' house, or when doubled up families can finally afford to get their own place or when owners simply want out of the rental business. How ever it happens, the chain ends when no vacancy remains for new inhabitants.

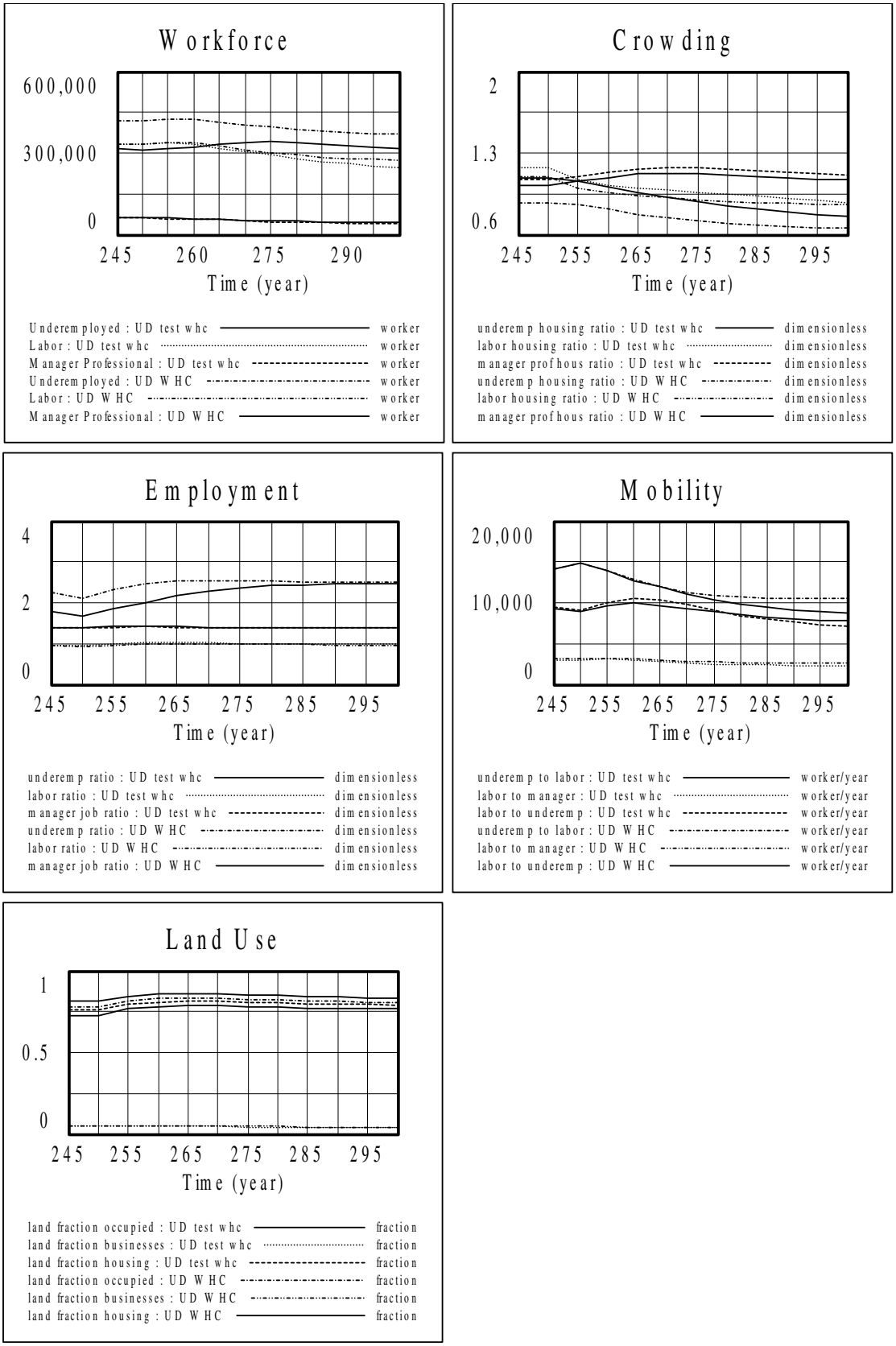
The data gathered from actual vacancy chain studies match the work that Forrester presents in his chapter on urban renewal, albeit with a different spin on the

results. The vacancy chains followed in Sands and Bower had average chain lengths just over two.[5] What this means is that by the new construction of a unit three households improved their housing situation. In Forrester's model, he proposed an urban renewal program that increased middle income (worker class) housing. The results matched closely to Sands and Bower observations. Even though worker housing was increased by 2% in Forrester's model the net increase in worker housing was less. As Forrester explains, when more worker housing is available and there are not enough workers to occupy it, the housing "deteriorates" into low income housing. In the vacancy chain literature, it is described as low income people improving their housing situation by the availability of higher quality housing at lower rates. The vacancy chain literature's numbers match closely to Forrester's. The model does not distinguish between this deteriorated worker housing and other underemployed housing but it could be assumed that the deterioration rate for such housing would be at least a little slower due to the quality of housing. No where in the model does Forrester state that deterioration of housing is due to the occupants of the housing rather than the age of the housing. Although in ownership scenarios or in absentee landlord situations, deterioration can be increased due to lack of reinvestment whether it is from the inability to reinvest or the lack of desire to reinvest.

Forrester runs a worker housing construction program that provides housing for 2% of the labor population per year. The results are shown in Figure 24. He also runs a program that provides housing for 5% of the manager/professional population per year.

[5] Higher value units for the original "link" does not always equate to longer chains. In-migration stops the chain and these were generally higher income people moving into higher income homes.

Figure 24. Worker Housing Construction Comparison

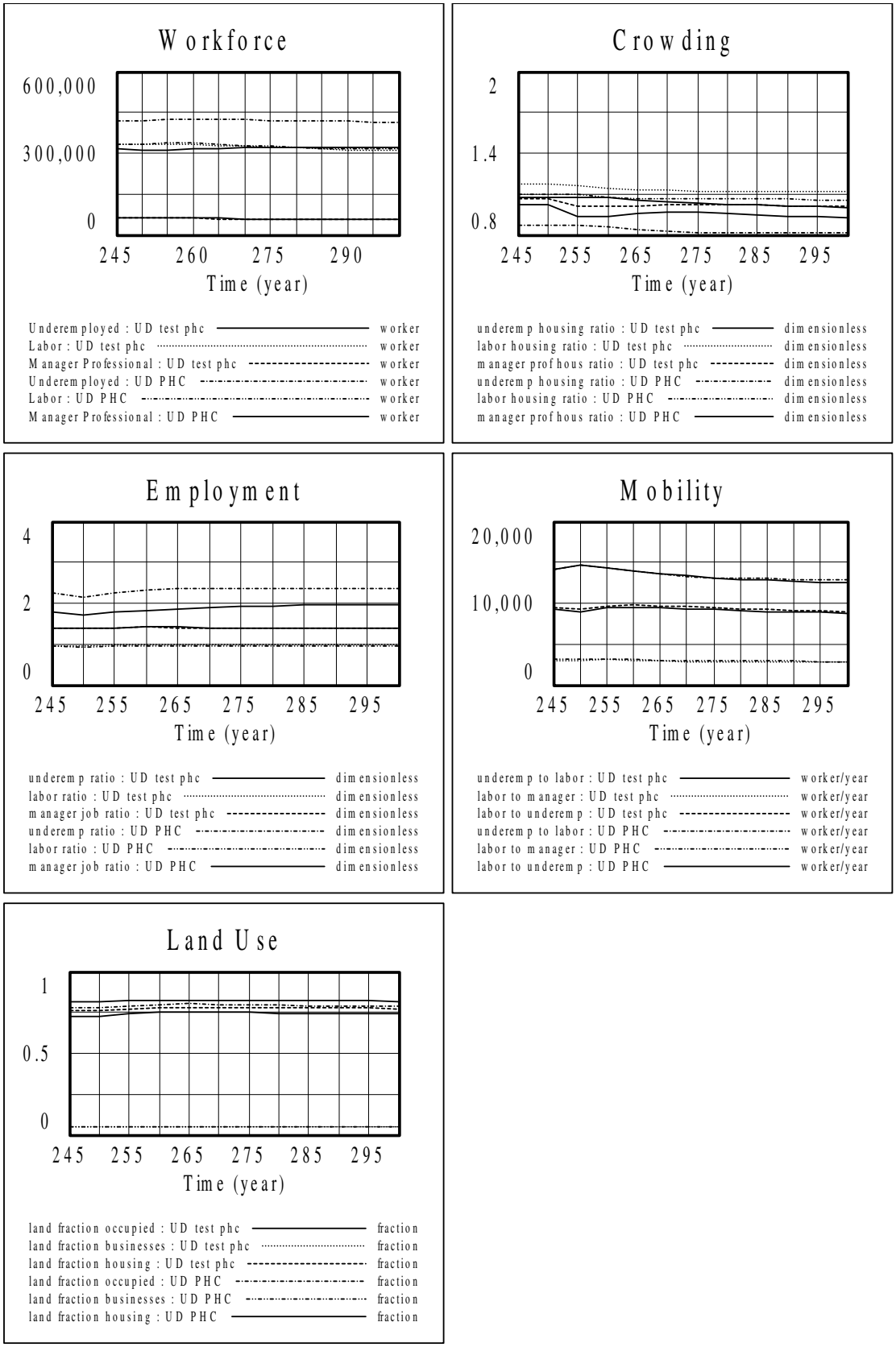


The results are shown in Figure 25. Either one of these are expected to show the filtering phenomenon.

The modified model's results match Forrester's and the vacancy chain literature. In the worker housing run, crowding is decreased for both the labor and underemployed populations. The interesting thing though is the employment ratio. Unemployment increases and upward mobility decreases similar to the low cost housing construction program. Population decreases slightly and land use is only slightly affected.

The quality of housing may have improved for the people participating in the vacancy chains but the employment consequences are very difficult to ignore.

Figure 25. Premium Housing Construction Comparison



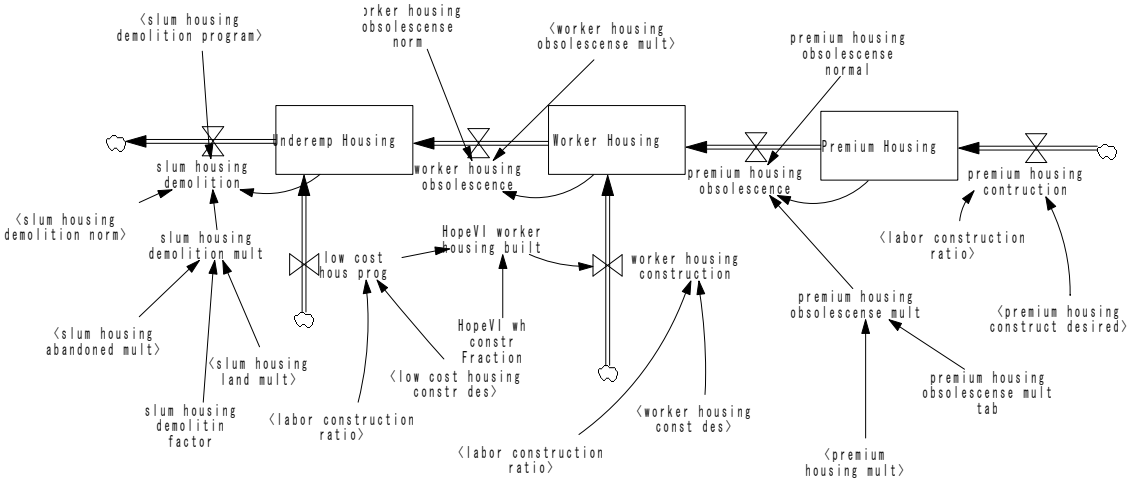
D. HOPE VI

HOPE VI is a program, originally known as the Urban Revitalization Demonstration (URD), developed as a result of recommendations by the National Commission on Severely Distressed Public Housing, which was charged with proposing a National Action Plan to eradicate severely distressed public housing. Under this program, distressed housing projects are demolished and replaced with mixed income housing, lessening concentrations of poverty by placing public housing in non-poverty neighborhoods and promoting mixed-income communities.[6] As of June 30, 2003, 76,393 housing units had been demolished or were slated for demolition and 44,871 units had been built or renovated as replacement (GAO 2003).

HOPE VI is simulated in this model by using a combination of Forrester's slum clearance policy and low cost housing construction policy. Additionally, a percentage of the rebuilt housing is slated for the middle income (worker) population. A number of units is calculated and added to the worker housing construction flow. The model modification is shown below. Equation changes are in Appendix B.4. Matching modifications are made to the modified model.

[6] US department of Housing and Urban Development, 2005, http://www.hud.gov/offices/pih/programs/ph/hope6/about/

Figure 26. HOPE VI Model Changes

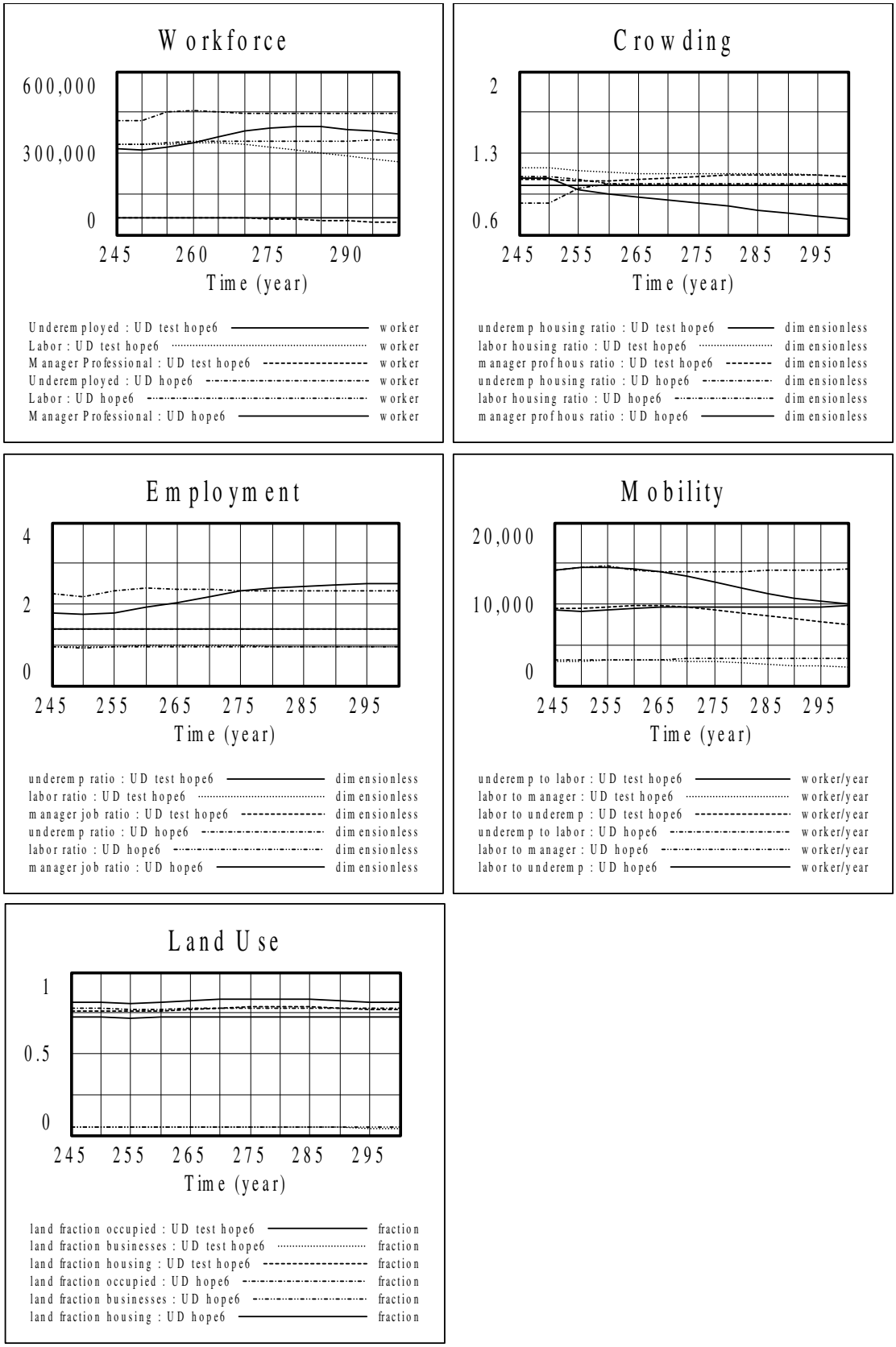


Comparative runs are shown in Figure 27. The policy uses a 5% rate for slum clearance, 3% rate for the low cost housing construction piece and worker housing units are built at a rate of 25% of the number of low cost housing units built.

The results are similar to the low cost housing construction policy for the modified model. Too much housing is built for the system to absorb and the adverse unemployment effects occur. For Forrester's model, it almost looks like no program got run. Almost everything is flat except a slight increase in the underemployed population.

HOPE VI at the levels specified does not have a large negative affect on Forrester's city. It does not make an improvement either based on the criteria of evaluation. It seems this and other programs could be implemented if information was predictable about how much housing a city could absorb. As seen in the modified model run, too much housing is a very bad thing.

Figure 27. HOPE VI Comparison



E. Section 8 Housing Vouchers

Section 8 is a program to increase affordable housing choices for very low-income families. Families with a tenant-based voucher choose and lease safe, decent, and affordable privately-owned rental housing. Very low-income families (i.e. families with incomes below 50% of area median income) and a few specific categories of families with incomes up to 80% of the area median income are eligible for the program. Within limits, the Public Housing Authority pays the owner the difference between 30 percent of adjusted family income and the gross rent for the unit. The family may choose a unit with a higher rent than the payment standard and pay the owner the difference.[7]

One goal of section 8 housing is to disperse the lower income population throughout the city to avoid pockets of deep poverty. As discussed earlier in this paper, there is a severe shortage both of vouchers and places that will accept vouchers.

Section 8 is implemented in the model by adding two new stocks to contain worker quality housing and underemployed quality housing that is being used for Section 8 voucher holders. Landlords are more willing to rent to underemployed renters when the vacancy rate is higher.[8] Similarly, landlords want out of Section 8 rental agreements if the vacancy rate is low. A low vacancy rate assumes that housing is in higher demand and therefore can command higher rents for the same units. The worker housing used for Section 8 deteriorates into underemployed quality housing with time. Once this occurs, opting out is presumed less favorable since subsidized rents from Section 8 should be higher than what could be obtained from market based underemployed renters.

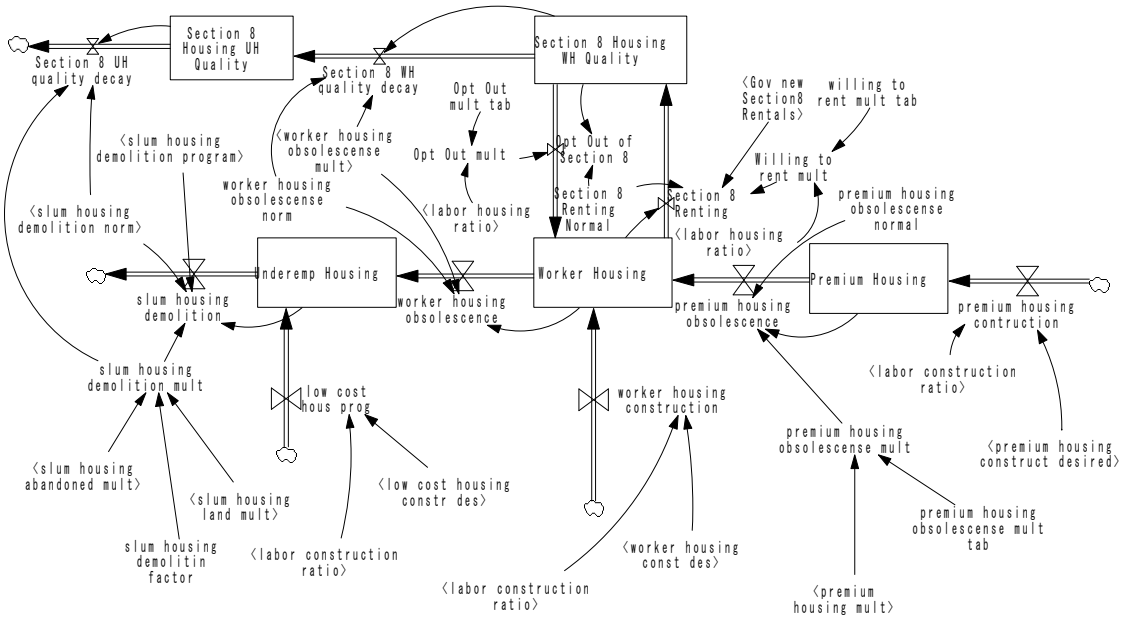
[7] US department of Housing and Urban Development, 2005, http://www.hud.gov/offices/pih/programs/hcv/tenant.cfm

[8] The labor housing ratio is used as an indicator of vacancy.

Section 8 housing stocks are added in all the summary variables to be used for tax assessment, calculations of land usage, etc. A policy switch is added to the models, "Gov new section 8 rentals". Like the other policy switches in the model, it uses time to enable the policy and a value to determine the scope of that policy. In this case the value is the fraction of the underemployed population that will be provided new Section 8 housing vouchers per year.

In Forrester's model the Section 8 housing of Underemployed housing quality deteriorates through slum housing demolition. In the modified model it deteriorates into the unlivable housing stock. The changes to Forrester's model are shown below. The changes to the modified model are not displayed but equations for both are in Appendix B.5.[9]

Figure 28. Section 8 Model Changes



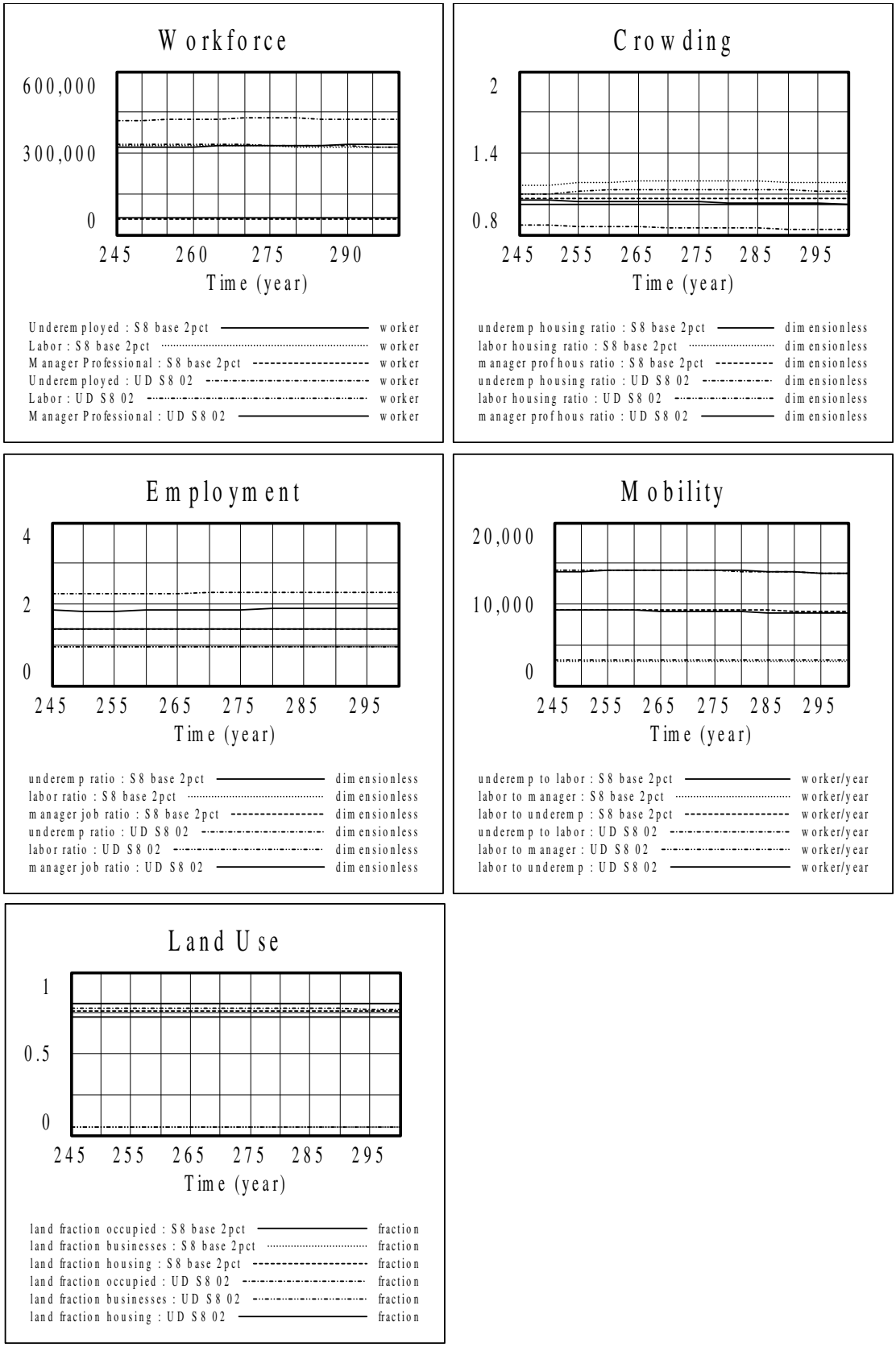
[9] Building Section 8 housing was once part of the program but it was discontinued in the early 1990s. This model does not attempt to implement that piece of Section 8 but it could reasonably be simulated with the inclusion of the worker housing construction program.

The following test runs use a rate of 2% of the underemployed population to receive new Section 8 vouchers each year. Figure 29 displays the output.

The results show nearly no effect on the system with the implementation of this policy. One reason is that relatively few worker housing units are being used by voucher holders since the total number of worker housing units is so large. When larger percentages of the underemployed population are issued vouchers (these results are not shown) the crowding for the labor population creeps up. However, a ridiculously large percentage must be used before the effects are even really noticeable.

Forrester's model does not show a housing shortage so using non-underemployed housing can be beneficial since the higher the vacancy rate, the quicker it deteriorates and is demolished. In the modified model there is a housing shortage and for the first time alleviating the problem does not come at the cost of adverse employment effects. Using the evaluation criteria that have been used throughout this analysis, Section 8 is an acceptable policy for improving the housing quality of the underemployed.

Figure 29. Section 8 Comparison



V. Framing the Issue and Interpreting Results

Framing an issue means determining what is important to that issue. It is a lens with which to look at a problem. Every dynamic system modeler frames the problem when she selects which stocks, flows and parameters to include in the model and which to omit.

Forrester chose the frame of the initial problem of the city as stagnation at a low economic level. His primary criteria were land use and population composition. He determined that too much land was being consumed by housing and too little land was used for businesses. Also, he determined that the ratio of underemployed population to labor was too high. Other choices might have been unemployment, segregation or overcrowding. Defining the frame scopes the relevance, the analysis, the conclusions and the recommendations (Jaeckel 1972).

In addition to defining the criteria with which to look at the problem, a modeler also defines the time frame to be considered. Short term and long term fixes have different political and social costs (Arvech and Levine 1971). Forrester's analysis was heavily biased toward the long run health of the city. Not all individuals agree with his preferred time frame (Andersen and Rohrbaugh 1992). Nor would they all agree with his criteria.

The single most amazing thing about this model is its comprehensiveness. It allows the kind of analysis that is performed in this paper as well as those used in the hundreds of critiques of his model. In several places in his book, Forrester invites the reader to perform their own analysis, to change parameters, to add new pieces. He

encourages customizing the model for a specific use. He therefore encourages the use of other frames. The work by Gardiner and Ford and Andersen and Rohrbaugh among others is done in attempts to find consensus among frames. By using decision making techniques on top of models, they attempt to analytically determine policy decisions.

Forrester's results are indeed a function of his frame, but no person come to any project without a frame. My frame is shorter term. I prefer to first cause no harm to the city as well as to improve the living conditions for the underemployed population. The graphical outputs and my analysis reflect my frame just as Dr. Forrester's reflected his.

VI. Conclusions

The results from the challenges made to Forrester's model do not disprove it. They in fact mostly reinforce it. That gentrification had little effect and that Detroit was recreatable by making only minor changes to the model shows robustness. Even the unlivable housing changes used in the final modified model did very little to influence the outcome of housing policies with the exception of slum clearance and HOPE VI.

Forrester's conclusion that housing is the problem is difficult to dispute. Every program that built housing for any income level resulted in adverse employment effects especially for the underemployed population. The lack of demographics, especially age and workforce participation make it difficult to determine if underemployed, non-working individuals, retired or disabled for example, are also adversely affected. About a third of public housing is for senior citizens who are unable to improve their status by getting a better job.

The Section 8 results are promising in that the negative employment consequences do not coexist with improving the housing for the underemployed. The focus of this paper is on housing, but an analysis of what else is happening in the model when the Section 8 program is implemented may be useful.

Considering different frames for an issue is a good thing. As a society we need people looking out for the whole city in the long term. We also need people looking out for the population in need right now. Often common ground can be found through consensus building where both groups can be satisfied. Housing programs that do not make the city worse, but help to improve the housing of those in need, is a possible example. With the homeless population in this country numbering between a quarter of a

million and three million[10] persons (Yeich 1994) it is difficult to imagine that housing is not at least part of the solution to the still present urban crisis. In the end, it comes down to what as a society we see as problematic and what we are willing to do to fix it.

[10] Depending on who is counting and how the counting is done.

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Appendix A

Appendix B