U.S. Low Income Housing Policy
A Dynamic System Evaluation

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I. Problem Definition

Poverty is on the rise in this country. 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. This year's budget proposal has President Bush slashing funding to the department of Housing and Urban Development, including many programs that help supply housing to the poor. In this project I investigate various low income housing policies to determine how and why they would or would not work.

Context

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. He basically was saying that if you bring the jobs, the housing will take care of itself. I have attempted to recreate his experimentation with his housing policies to see if I get the same conclusions. Then I apply various low income housing problems that have been actually implemented in the US and see if the model predicts the same fate. The reference modes below are the normal urban decay that occurs in cities across this country. Land is used up, housing is abandoned, and population, jobs and business structures decline.

Audience

My Audience is policy makers; people in the state Senate and Assembly, people in state agencies and lobbying groups.
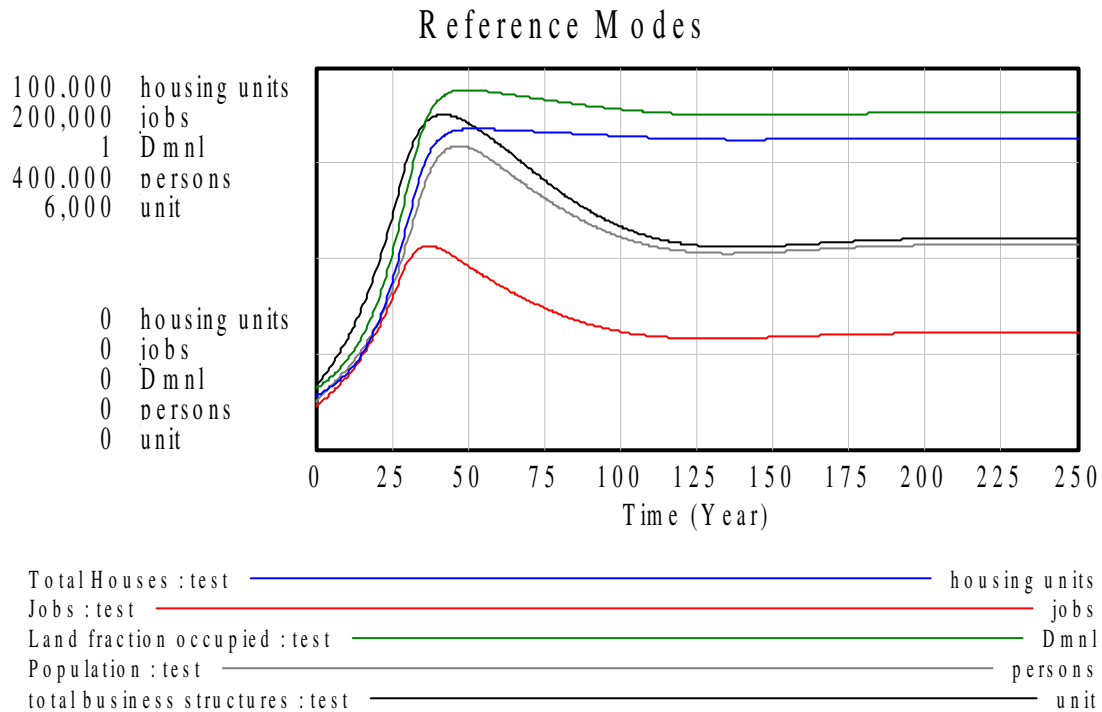
Model Purposes

The purpose of the model is to determine first if Forrester was correct , second if anything we have done in reality would have the same fate in his model and finally if slashing the budget to HUD could actually be a good thing(I don't think it is).

Model Boundaries

I started with the Urban 2 model from *Introduction to Urban Dynamics,* by Alfred and Graham (1976). The time span for the model is 250 years. The first 150 years allows the city to decay. The last 100 years is the policy implementation time frame. Conceptual boundary for the model is a city (or a part of a city). Housing policies in Jay Forrester's book shows the programs costing nothing to the city. I believe that is a way of having the money come from the US government. Programs though funded at the US level, have lower governments make proposals on how to specifically use the fund. Causal boundaries then are Endogenous, but have an implied exogenous factor if funding is cut or increased.

Reference Modes (before any interventions)

R eference M odes

100,000	housing units	
200,000	jobs	
1	D m n l	
400,000	persons	
6,000	unit	

0	housing units	
0	jobs	
0	D m n l	
0	persons	
0	unit	

Time (Year)

Total Houses : test ——————————— housing units
Jobs : test ——————————— jobs
Land fraction occupied : test ——————————— D m n l
Population : test ——————————— persons
total business structures : test ——————————— unit

Initial Policy Options (see section III for further information)

Slum Clearance demolition of a fraction of the deteriorating structures

**HOPE VI** replacement of dilapidated public housing with mixed income housing

Section 8 housing vouchers money paid to private housing providers to make up the rent differential for low income folks

Justification to look at the problem from a system dynamics perspective

The problem is one of the great case studies in systems dynamics. Cities really do decline. Neighborhoods of low income housing often have innumerable problems associated with them. Forrester's model shows the city getting worse whenever a housing plan is implemented. Why is this? Is he taking all the factors into count? Is there any housing policy that isn't tied to increases in income that would succeed, especially considering the elderly whose income is not likely to rise and are out of the workforce?
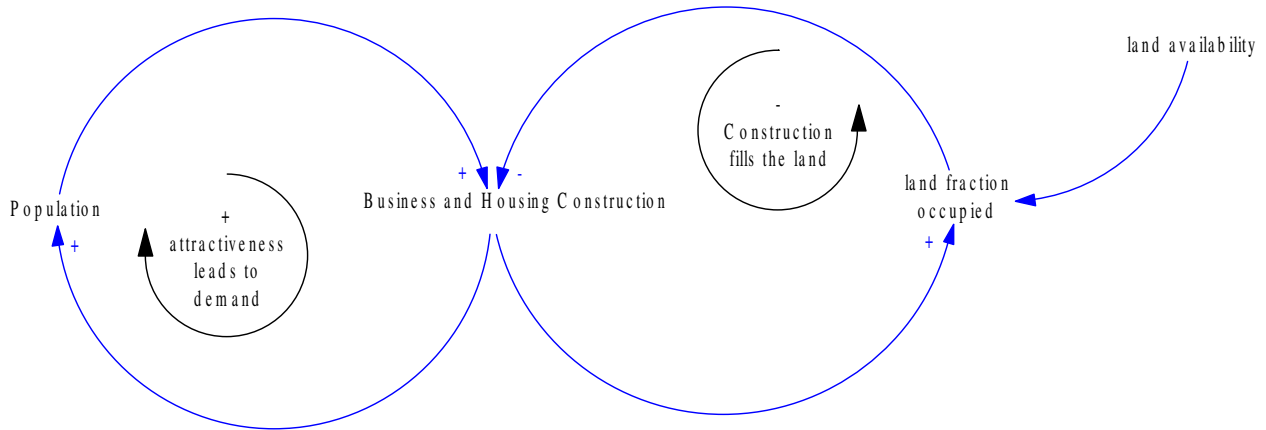
II. Model Structure

A. Overview

Sector Overview Diagram
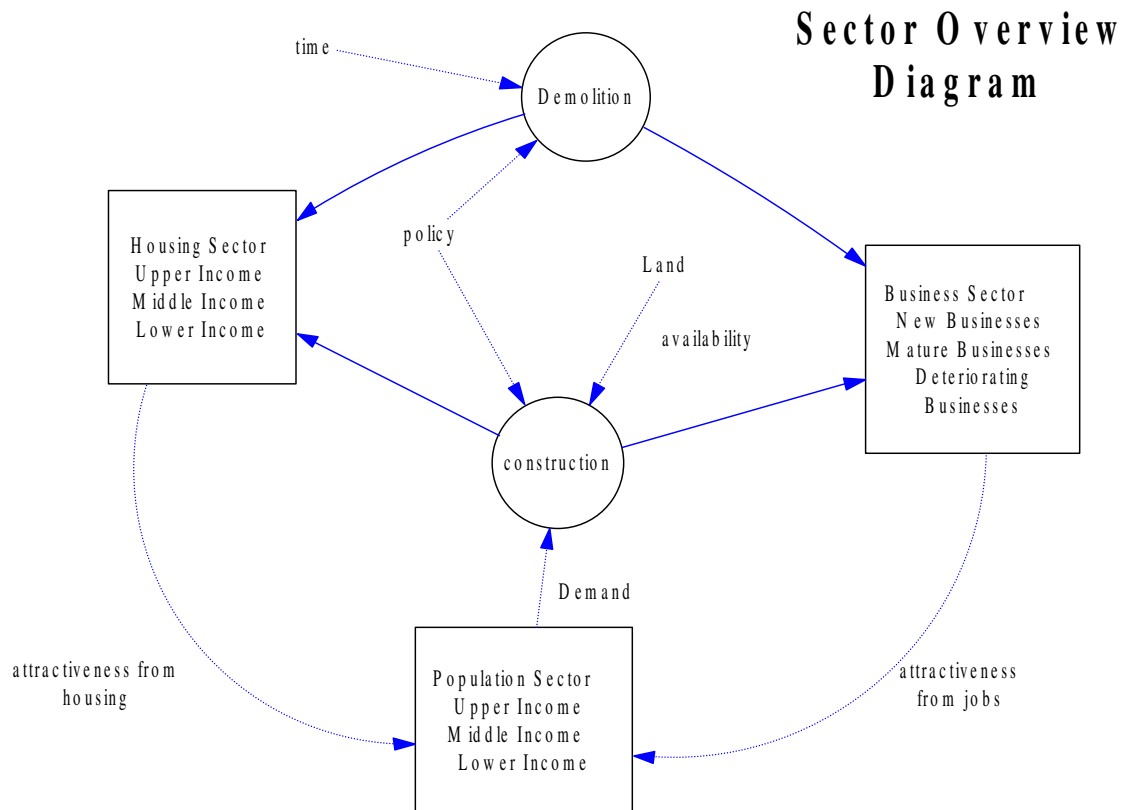
The Urban model has 3 sectors; businesses, housing and population. The limit to growth archetype shown below is the primary archetype present in the model. People are attracted to the city because of available jobs and housing. As long as land is available, business structures and housing will be built which will attract even more people. Once all (or nearly all) the land is occupied, the attractiveness of the city decreases and 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, that means that fewer jobs are available at the site. For housing, it means that property values go down. Affluent neighborhoods become middle income neighborhoods and middle income neighborhoods become low income neighborhoods. The city's attractiveness as time goes on is for the less affluent since there is more jobs and housing in these categories. This lowers the tax base and leads to urban decay.
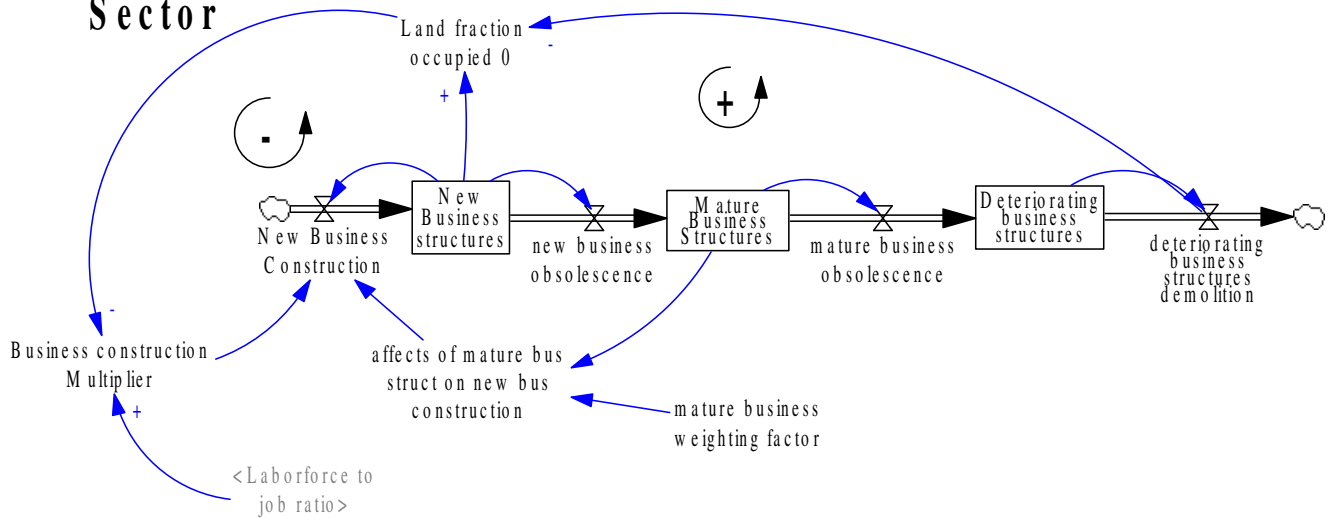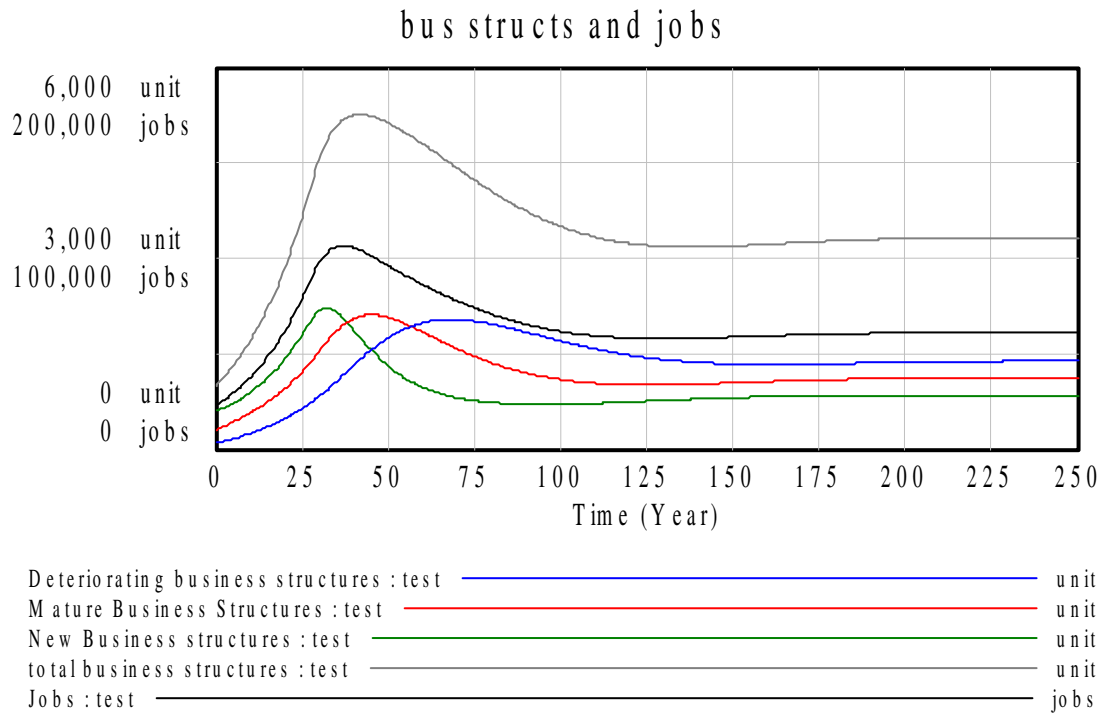
LIMIT TO GROWTH ARCHETYPE

Population   attractiveness   Business and Housing Construction   Construction fills the land   land fraction occupied   land availability
leads to demand

B. Details

Business Sector (See Appendix A for the complete model and equation list)

Simplified Business Sector

Land fraction occupied 0

New Business Construction   New Business structures   new business obsolescence   Mature Business Structures   mature business obsolescence   Deteriorating business structures   deteriorating business structures demolition

Business construction Multiplier   affects of mature bus struct on new bus construction   mature business weighting factor

<Laborforce to job ratio>

The business sector shows the aging process of the business structures. Only new business structures are built. Mature and deteriorating business structures come about through the aging process. The decision to build new business is based on land availability and demand from the 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 business employed more and higher paid workers. As a business ages, the number of jobs and the quality of the jobs, housed in the structure, declines. The following graph shows the ripple of

deterioration in the form of peaks in new, mature and deteriorating business structures. It also shows the decline in jobs that accompanies the deterioration.

## bus structs and jobs

Legend:

Deteriorating business structures : test	unit
Mature Business Structures : test	unit
New Business structures : test	unit
total business structures : test	unit
Jobs : test	jobs

Population Sector (See Appendices B, C and D for Upper, Middle and Lower
income sectors and equation lists)

Generic
Population Sector

Attractiveness-of-jobs
multiplier

jobs
attractiveness
(balancing
loop)

<Labor participation
fraction>

Attractiveness-of-housing
multiplier

population to Job
ratio

<houses>

household to
housing ratio

housing
attractiveness
(balancing
loop)

jobs for this
population

Attractiveness
multiplier

households

<Out migration
normal>

Population of a
specific income
level

Population In
migration

Population Out
migration

<In migration normal>

Population Deaths

Population
Births

<Births normal>

<Deaths normal>

There is a population sector in the model for each income segment of the population.
The diagram above shows the generic structure. Births, Deaths and Out Migration
are based on normal rates. In Migration is based on the attractiveness of the city to
the population segment. Availability of jobs and housing increases In Migration.
However, as the population grows the availability of jobs and housing decreases.
This slows In Migration.

Housing Sector (see Appendix E for Housing Sector and equation list)
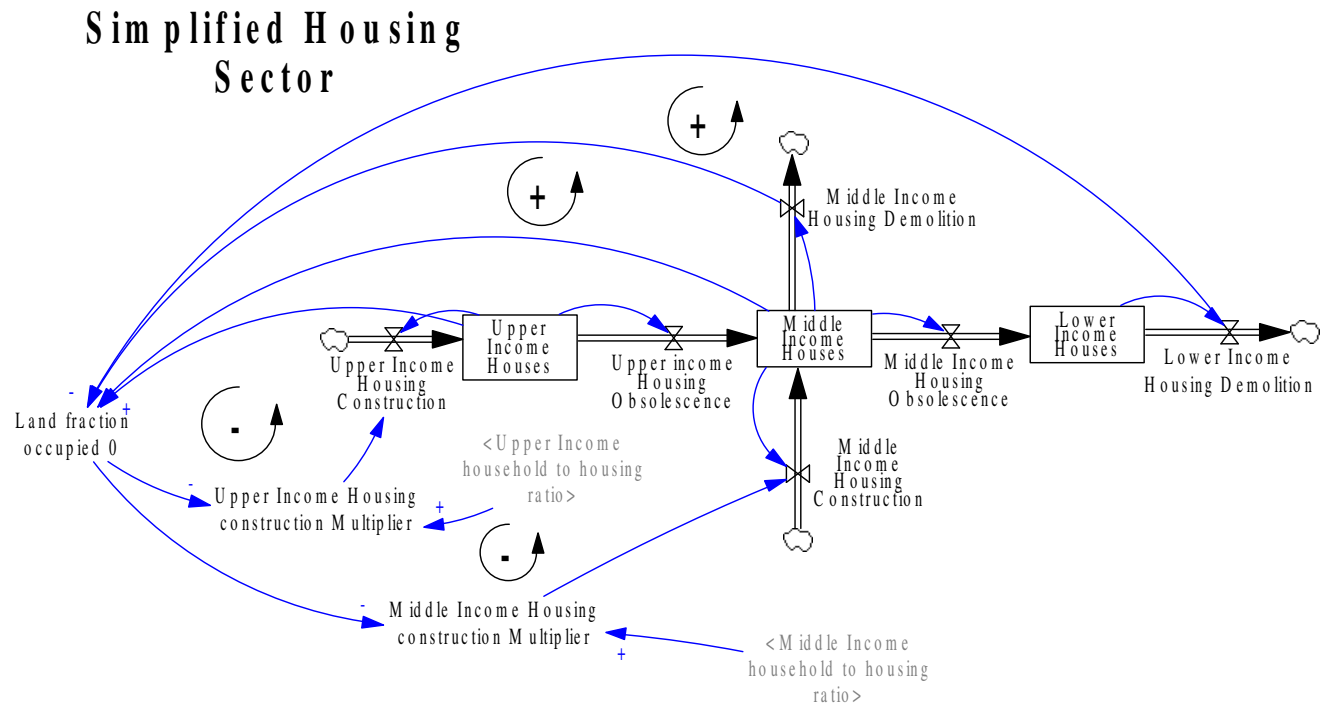
The upper income population lives in upper income housing, the middle income population lives in middle income housing and the lower income population lives in lower income housing. In the base model no lower income houses are built. Lower income people live in deteriorated upper and middle income housing. Similar to business structures, housing structures deteriorate over time. Upper and middle income houses are constructed if there is land and if there is demand from the population. As land fills up, construction slows, as population grows demand is increased and construction quickens. Demolishing housing structures free land for other uses.
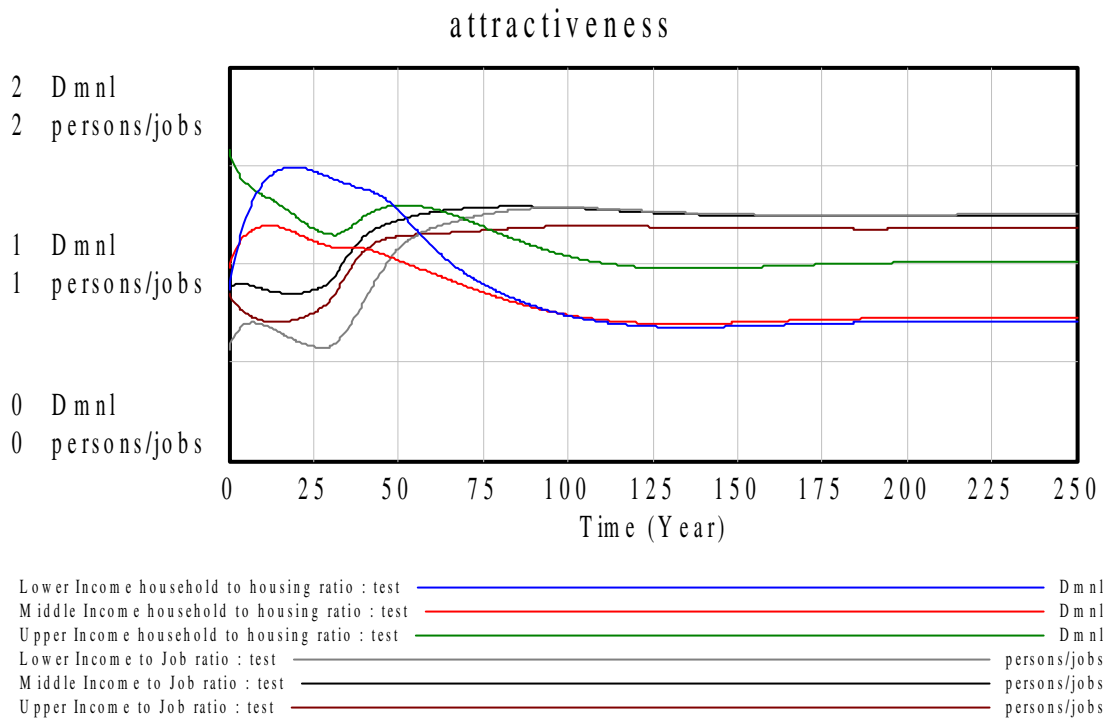
Interaction between the sectors including an equation list is shown in Appendix F.

III.Presentation and Analyses of Model Behavior

A. Base Model Behavior

A few words are warranted on the differences between the model built here and Jay Forrester's Urban model. This model has no way to transition between income levels unlike the original Urban model. This is not a problem at this stage since housing only policies are implemented. However, policies that have job components should not be added to this version of the model. Population in this model is total population. In the original urban model the stocks represent the workforce only. Family sizes in the original Urban model are larger than those used here. Household size has fallen over the years. I performed Sensitivity Analysis on these parameters and found that the shape of the output was the same (not sensitive).
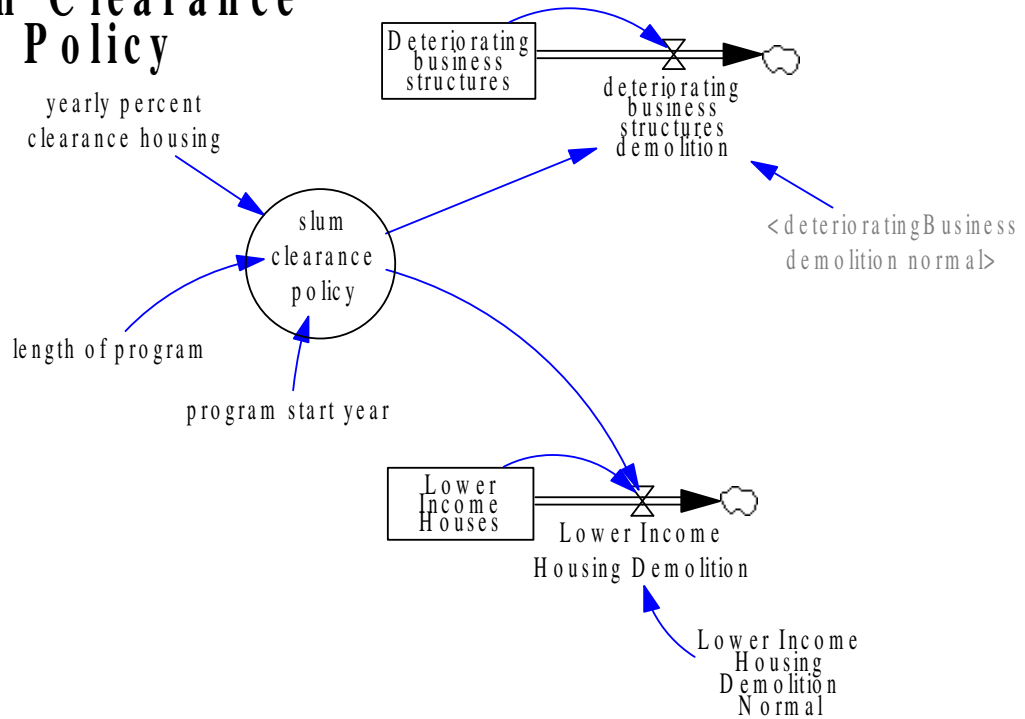
The Reference mode graph in **Section I** above shows the base behavior of the system. This graph show the business structures, housing structures, jobs and population all growing together until the land is mostly used up. Then businesses deteriorate and the number of jobs decline making the city less attractive and so the population declines. The following graph shows the attractiveness of the city as seen from each population's perspective. When the ratios displayed are above 1, they represent unemployment and a housing shortage. When they are below one, they represent a housing surplus and available jobs. The city therefore is attractive when these values are equal to or less than 1. In the base model there is unemployment in all 3 income segments and a surplus of housing for both the lower and middle income populations.

attractiveness

Lower Income household to housing ratio : test ———————————————————— Dmnl
Middle Income household to housing ratio : test ———————————————————— Dmnl
Upper Income household to housing ratio : test ———————————————————— Dmnl
Lower Income to Job ratio : test ———————————————————— persons/jobs
Middle Income to Job ratio : test ———————————————————— persons/jobs
Upper Income to Job ratio : test ———————————————————— persons/jobs

B. Policy Analyses

Slum Clearance

As already known, we run out of land in this model. Too much land is being used for
housing and we have a surplus of housing for our lower and middle income
populations. What the city needs is jobs, but no sites are available to build them.
Forrester's model performs slum clearance. In fact he also performs low income
housing construction which as he shows, makes the situation worse since there
wasn't a shortage in the first place. His numbers may be showing crowding being
relieved but I need to investigate this situation further.

In this model, slum clearance is implemented basically the same as in the original
model except that this model includes business structures in the clearance. A fraction
(5%) of low income houses and deteriorating businesses are destroyed per year. The
program starts in year 150 which is in an already at risk city. The program runs to the
end of the simulation or 100 years.

The 2 graphs below show the results of the policy. The attractiveness graph shows a
decrease in unemployment for all income levels, but introduces a low income
housing shortage to the city. The structures graph shows reflects the same concept.
Business structures increase as a result of the policy (explaining the decrease in
unemployment). The graph also shows new construction of housing for upper and
middle income levels increasing due to the attractiveness increase in jobs for those
sectors. Remember that low income housing is not built in this model so even though
there is more low income jobs, low income housing does not increase.

attractiveness
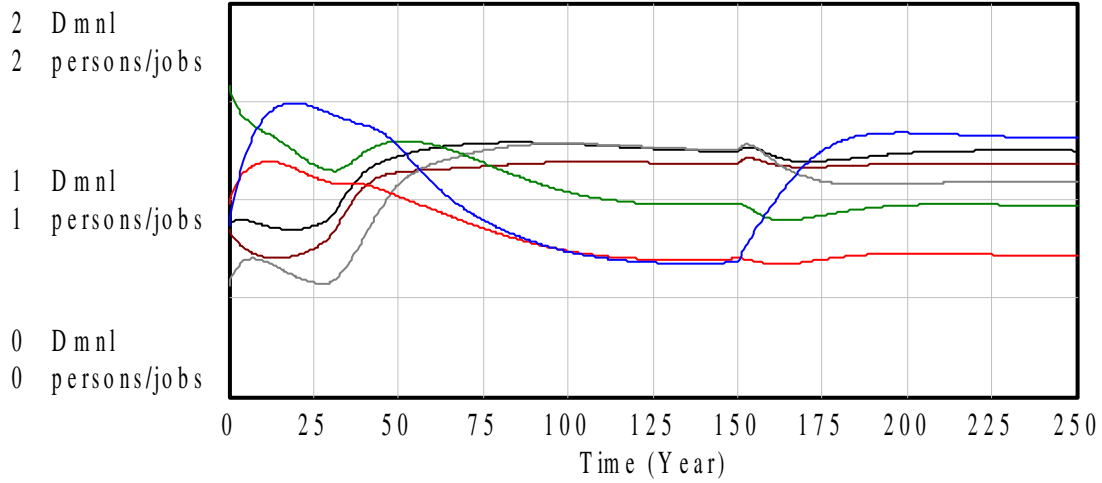
Lower Income household to housing ratio : test w slum clearance ———————	Dmnl
Middle Income household to housing ratio : test w slum clearance ———————	Dmnl
Upper Income household to housing ratio : test w slum clearance ———————	Dmnl
Lower Income to Job ratio : test w slum clearance ———————	persons/jobs
Middle Income to Job ratio : test w slum clearance ———————	persons/jobs
Upper Income to Job ratio : test w slum clearance ———————	persons/jobs

Structures
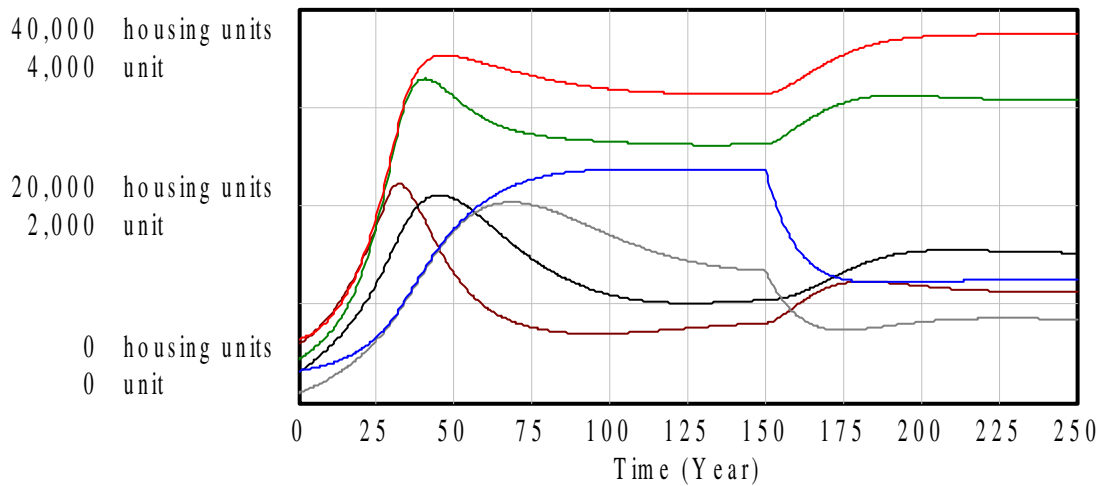
Lower Income Houses : test w slum clearance ———————	housing units
Middle Income Houses : test w slum clearance ———————	housing units
Upper Income Houses : test w slum clearance ———————	housing units
Deteriorating business structures : test w slum clearance ———————	unit
Mature Business Structures : test w slum clearance ———————	unit
New Business structures : test w slum clearance ———————	unit

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 replace with mixed income housing, lessening concentrations of poverty by placing public housing in non-poverty neighborhoods and promoting mixed-income communities.[1] 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.[2]
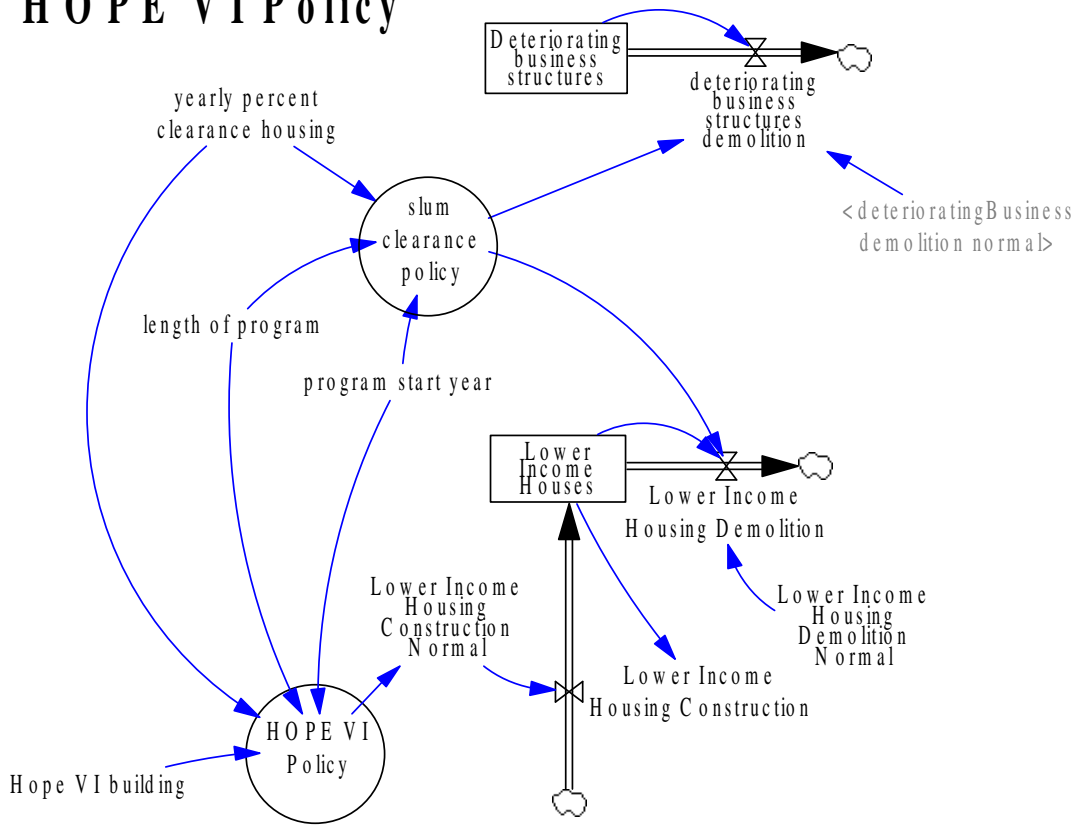
In this model, HOPE VI is implemented as a combination of slum clearance and rebuilding of low income housing. Again, a fraction (5%) of low income houses and deteriorating businesses are destroyed per year with the program starting in year 150 running until the end of the simulation. The rebuilding piece of the policy is implemented by rebuilding a fraction (60%) of that which is torn down.

The same 2 graphs are shown for this policy. The attractiveness graph shows the same decrease in unemployment for upper and middle income people but less of an improvement for lower income people as compared to the slum clearance policy.

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

[2] U.S. General Accounting Office, November 21, 2003, *Public Housing: HOPE VI Resident Issues and Changes in Neighborhoods Surrounding Grant Sites*, GAO-04-109 (Washington D.C.).

Again a low income housing shortage is introduced to the city, but not as severe. The way this policy is implemented is the equivalent to a lower percentage of slum clearance. There are a couple of problems in this. Since HOPE VI housing is intended to be mixed income and less dense then normal low income housing, I should have increased the construction of middle income housing or added a stock to represent HOPE VI housing. The deterioration rates and density would need to match what is acceptable for the middle income population. The structures graph is nearly identical to slum clearance alone for business structures. The difference in middle and upper income housing is due to the construction of the lower income housing.
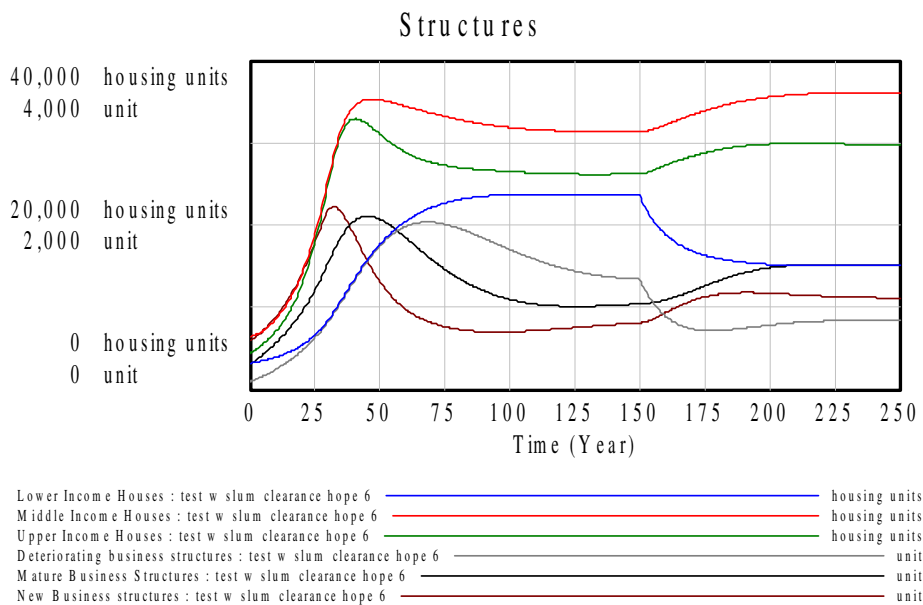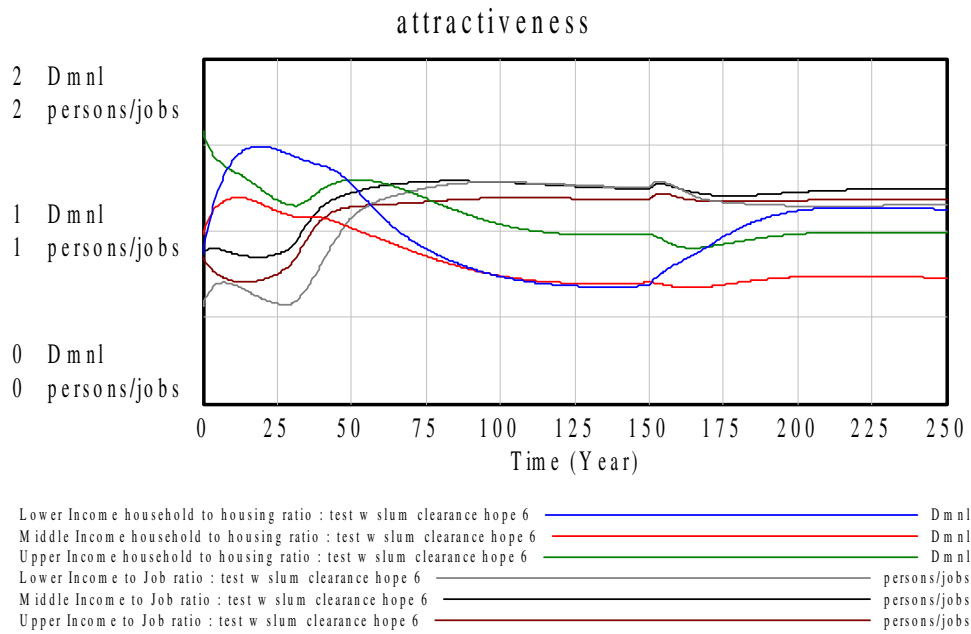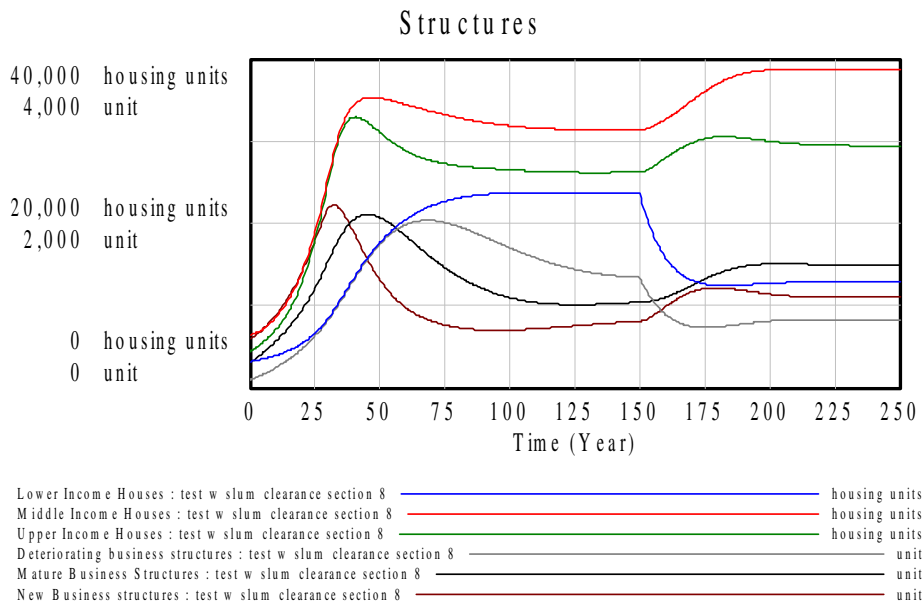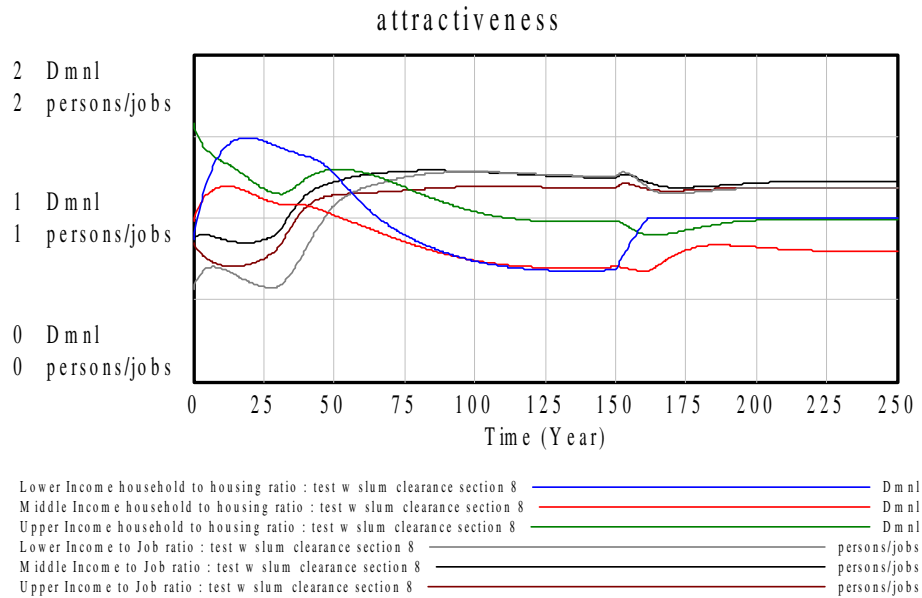
Section 8 Housing Vouchers (See Appendix G for Section 8 implementation and equation list)

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, he 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.[3]

In this model, section 8 is implemented with slum clearance since the no housing shortage exists prior to slum clearance. The same fraction (5%) of low income houses and deteriorating businesses are destroyed per year with the program starting in year 150 running until the end of the simulation. The formulation of Section 8 houses was the trickiest piece of the model. I first formulated it based on the availability of middle income housing, but used up more housing than needed. Next I formulated it based only on need, but extreme condition testing showed the error in that method. Finally, the formulation is based on both availability and need. Middle income housing surplus and lower income housing shortage are calculated. The minimum of these is the number of potential Section 8 houses. The potential is multiplied by a fraction that is intended to represent political will. In the run shown, 100% was used. This formulation passed all tests.

The same 2 graphs are shown for this policy. The attractiveness graph shows the no improvement in unemployment for upper and middle income people and only a slight improvement for lower income people compared with the base run. Compared with the slum clearance only run, the unemployment is higher for lower income people and about the same for the others. The low income housing shortage that is introduced is eliminated by this policy. Additionally, the middle income housing surplus is decreased. The structures graph is nearly identical to slum clearance alone for business structures. For housing, the overall quality of the housing stock is increased with much higher percentage of upper and middle income houses.

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

attractiveness

Lower Income household to housing ratio : test w slum clearance section 8	——————————————— Dmnl
Middle Income household to housing ratio : test w slum clearance section 8	——————————————— Dmnl
Upper Income household to housing ratio : test w slum clearance section 8	——————————————— Dmnl
Lower Income to Job ratio : test w slum clearance section 8	——————————————— persons/jobs
Middle Income to Job ratio : test w slum clearance section 8	——————————————— persons/jobs
Upper Income to Job ratio : test w slum clearance section 8	——————————————— persons/jobs

Structures

Lower Income Houses : test w slum clearance section 8	——————————————— housing units
Middle Income Houses : test w slum clearance section 8	——————————————— housing units
Upper Income Houses : test w slum clearance section 8	——————————————— housing units
Deteriorating business structures : test w slum clearance section 8	——————————————— unit
Mature Business Structures : test w slum clearance section 8	——————————————— unit
New Business structures : test w slum clearance section 8	——————————————— unit

C. Links Between the Model and the Real World

Slum Clearance

The goal of slum clearance in the real world and the results in the model are both to
revitalize the city. The model showed an increase in businesses and jobs once land
was once 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.

HOPE VI

The link between the model and the real world is inconclusive since there are problems in the implementation. For example in the real world, cities with high vacancy rates have the HOPE VI housing intended for middle income people remain empty. Cities with a middle income housing shortage, like Washington D.C., have low vacancy rates in the same housing. This model, as implemented cannot show this phenomena.

Section 8 Housing Vouchers

One goal of section 8 housing is to disperse the lower income population throughout the city to avoid pockets of deep poverty. The model could be showing this by the increase in percentage of housing that is in the upper and middle income categories. The implantation in this model is not based in reality. In reality budget constraints are probably the biggest determinant rather than political will. More research is needed to determine the most realistic implementation for this policy.

IV.   Conclusions

A. Policy Conclusions

Housing Alone cannot turn around a deteriorating city but they help alleviate housing shortages. Further research is needed before any conclusions can be drawn about Forrester's model.

B. Insights

Results are inconclusive because of my inability to verify the assumptions in Forrester's model. His tie of households to wage earners seems to miss both the disabled as well as the elderly. His policies that are effective involve the movement of people up the income ladder. Understanding is required of his model to determine if he accounts for these missed populations.

While it may seem that section 8 housing is the best policy; it is especially vulnerable to funding. In traditional public housing, once built, the housing is there. For section 8 voucher users, budget cuts or even the failure to keep up with the cost of living could make people lose their housing.

This model is unable to determine the craziness of cutting HUD's budget, but perhaps with more work it will be.

C. Future Work

My first task is to convert to Forrester's Urban model. The differences between this model and his are too great for a true comparison. Sensitivity testing of parameters and assumptions within the Urban model is required to determine if changes since 1969 matter; work force participation, tie of household to an earner, ratio of the different populations, etc.). Along with this may be a case study of a couple of actual cities to understand income mix, homelessness rates and abandoned housing.

Second, research is needed on how Section 8 is really implemented as well as more holistic policies like the Community Development Block Grant (CDBG). An understanding of the actual effectiveness of these programs as well as their political feasibility is needed.
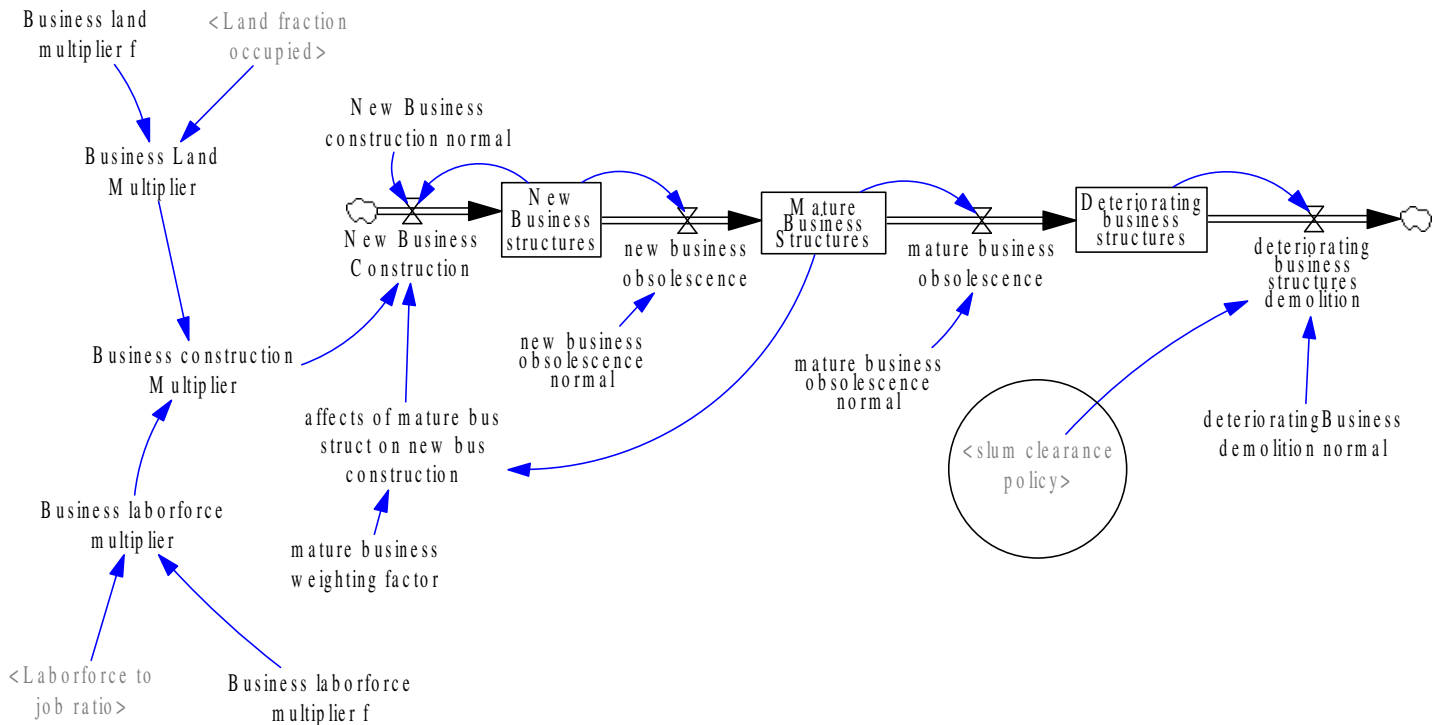
References

Introduction to Urban Dynamics, Alfred and Graham (1976)

Urban Dynamics, Forrester (1969)

This year's budget effects on HUD funding, supplied by Prof. David Lewis

Appendix A – Business Sector

affects of mature bus struct on new bus construction=
        Mature Business Structures*mature business weighting factor
Units: unit

Business construction Multiplier=
        Business laborforce multiplier*Business Land Multiplier
Units: Dmnl

Business laborforce multiplier=
        Business laborforce multiplier f(Laborforce to job ratio)
Units: Dmnl

Business laborforce multiplier f(
        [(0,0)-(2,2)],(0,0.2),(0.2,0.25),(0.4,0.35),(0.6,0.5),(0.8,0.7),(1,1),(1.2,1.35),(1.4,1.6),(1.6,1.8),(1.8,1.95),(2,2))
Units: Dmnl

Business Land Multiplier=
        Business land multiplier f(Land fraction occupied)
Units: Dmnl

Business land multiplier f(
        [(0,0)-(1,2)],(0,1),(0.1,1.15),(0.2,1.3),(0.3,1.4),(0.4,1.45),(0.5,1.4),(0.6,1.3),(0.7,0.9),(0.8,0.5),(0.9,0.25),(1,0))
Units: Dmnl

Deteriorating business structures= INTEG (
        +mature business obsolescence-deteriorating business structures demolition,100)
Units: unit

deteriorating business structures demolition=
        Deteriorating business structures*(deterioratingBusiness demolition normal+slum clearance policy)
Units: unit/Year

deterioratingBusiness demolition normal=
            0.04
Units: 1/Year

Laborforce to job ratio=
            Laborforce/Jobs
Units: persons/jobs

Land fraction occupied=
            (land occupied by businesses+land occupied by housing)/Area
Units: Dmnl

mature business obsolescence=
            Mature Business Structures*mature business obsolescence normal
Units: unit/Year

mature business obsolescence normal=
            0.05
Units: 1/Year

Mature Business Structures= INTEG (
            +new business obsolescence-mature business obsolescence,300)
Units: unit

mature business weighting factor=
            0.6
Units: Dmnl

New Business Construction=
            (New Business structures+affects of mature bus struct on new bus construction)*
            New Business construction normal*Business construction Multiplier
Units: unit/Year

New Business construction normal=
            0.09
Units: 1/Year

new business obsolescence=
            New Business structures*new business obsolescence normal
Units: unit/Year

new business obsolescence normal=
            0.067
Units: 1/Year

New Business structures= INTEG (
            New Business Construction-new business obsolescence,600)
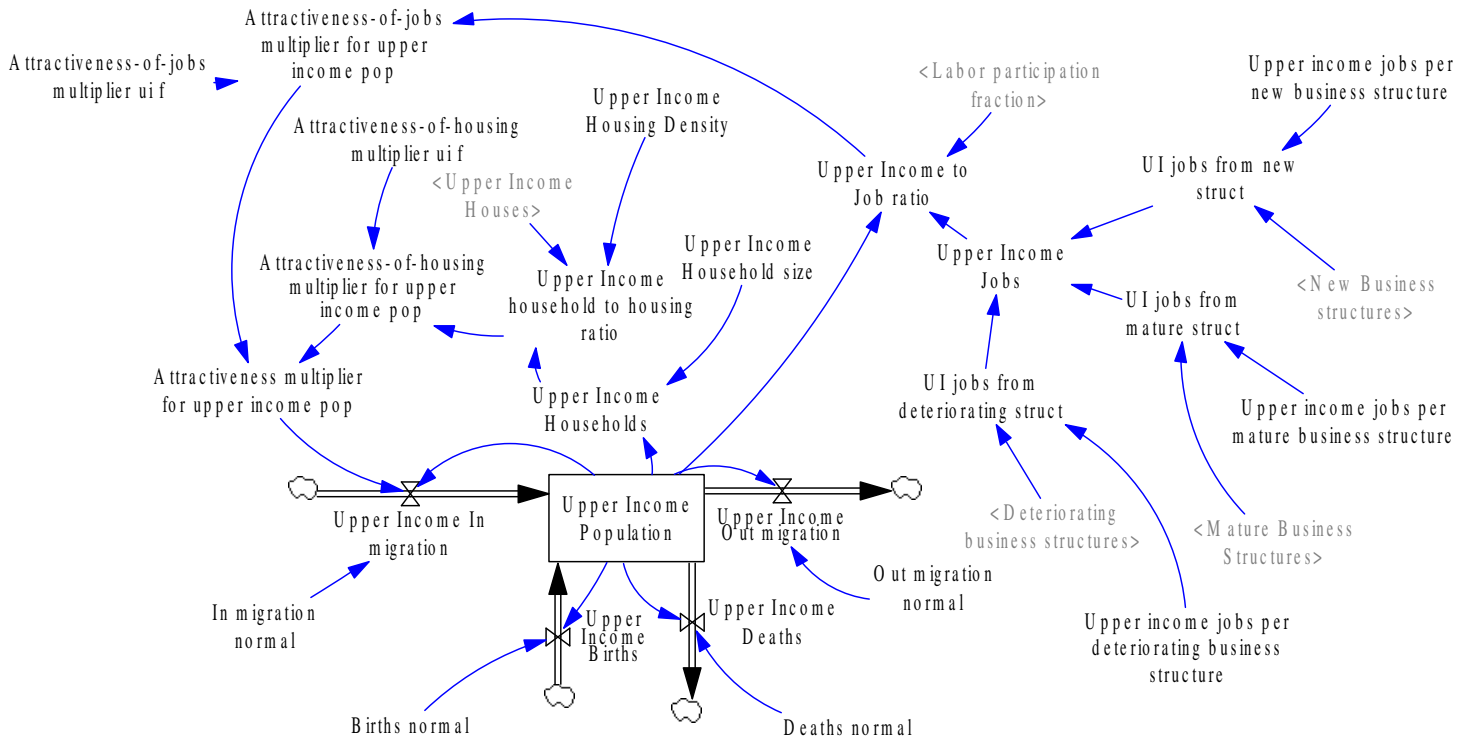**Units: unit**

slum clearance policy=
            PULSE(program start year, length of program)*yearly percent clearance housing
Units: 1/Year

total business structures=
            New Business structures+Mature Business Structures+Deteriorating business structures
Units: unit

Appendix B – Upper Income Population Sector

Attractiveness multiplier for upper income pop=
      **"Attractiveness-of-housing multiplier for upper income pop"*"Attractiveness-of-jobs multiplier for
      upper income pop"**
Units: Dmnl

"Attractiveness-of-housing multiplier for upper income pop"=
      "Attractiveness-of-housing multiplier ui f"(Upper Income household to housing ratio)
Units: Dmnl

"Attractiveness-of-housing multiplier ui f"(
      **[(0,0)-(2,2)],(0,1.4),(0.2,1.4),(0.4,1.35),(0.6,1.3),(0.8,1.15),(1,1),(1.2,0.8),(1.4,0.65),
      (1.6,0.5),(1.8,0.45),(2,0.4))**
Units: Dmnl

"Attractiveness-of-jobs multiplier for upper income pop"=
      "Attractiveness-of-jobs multiplier ui f"(Upper Income to Job ratio)
Units: Dmnl

"Attractiveness-of-jobs multiplier ui f"(
      [(0,0)-(2,2)],(0,2),(0.2,1.95),(0.4,1.8),(0.6,1.6),(0.8,1.35),(1,1),(1.2,0.5),(1.4,0.3),(1.6,0.2),(1.8,0.15),(2,0.1))
Units: Dmnl

Births normal=
      0.03
Units: 1/Year

Deaths normal=
      0.015
Units: 1/Year

Deteriorating business structures= INTEG (
      +mature business obsolescence-deteriorating business structures demolition,100)
Units: unit

In migration normal=
      0.1
Units: 1/Year

Labor participation fraction=
      0.35
Units: Dmnl

Mature Business Structures= INTEG (
      +new business obsolescence-mature business obsolescence,300)
Units: unit

New Business structures= INTEG (
      New Business Construction-new business obsolescence,600)
Units: unit

Out migration normal=
      0.07
Units: 1/Year

UI jobs from deteriorating struct=
      Deteriorating business structures*Upper income jobs per deteriorating business structure
Units: jobs

UI jobs from mature struct=
      Mature Business Structures*Upper income jobs per mature business structure
Units: jobs

UI jobs from new struct=
      Upper income jobs per new business structure*New Business structures
Units: jobs

Upper Income Births=
      Upper Income Population*Births normal
Units: persons/Year

Upper Income Deaths=
      Upper Income Population*Deaths normal
Units: persons/Year

Upper Income Household size=
      3
Units: persons/household

Upper Income household to housing ratio=
      Upper Income Households/(Upper Income Housing Density*Upper Income Houses)
Units: Dmnl

Upper Income Households=
      Upper Income Population/Upper Income Household size
Units: household

Upper Income Houses= INTEG (
      Upper Income Housing Construction-Upper income Housing Obsolescence,4400)
Units: housing units

Upper Income Housing Density=

0.6
Units: household/housing units

Upper Income In migration=
  Upper Income Population*In migration normal*Attractiveness multiplier for upper income pop
Units: persons/Year

Upper Income Jobs=
  UI jobs from deteriorating struct+UI jobs from mature struct+UI jobs from new struct
Units: jobs

Upper income jobs per deteriorating business structure=
  3.5
Units: jobs/unit

Upper income jobs per mature business structure=
  4
Units: jobs/unit

Upper income jobs per new business structure=
  6
Units: jobs/unit

Upper Income Out migration=
  Upper Income Population*Out migration normal
Units: persons/Year

Upper Income Population= INTEG (
  Upper Income Births+Upper Income In migration-Upper Income Deaths-Upper Income Out migration,
  12500)
Units: persons

Upper Income to Job ratio=
  Upper Income Population*Labor participation fraction/Upper Income Jobs
Units: persons/jobs

Appendix C – Middle Income Population Sector
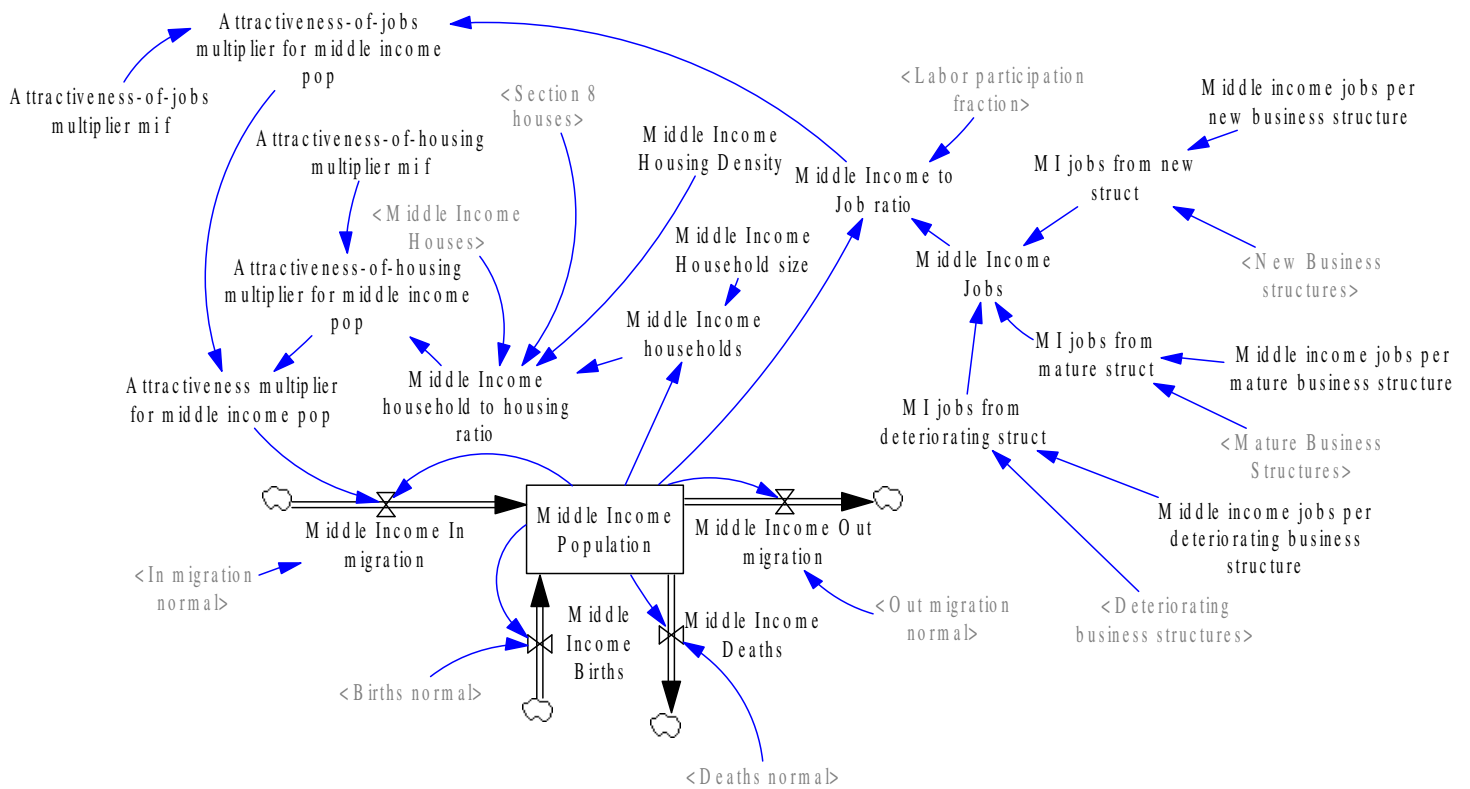
Attractiveness multiplier for middle income pop=
        "Attractiveness-of-housing multiplier for middle income pop"*
        "Attractiveness-of-jobs multiplier for middle income pop"
Units: Dmnl

"Attractiveness-of-housing multiplier for middle income pop"=
        "Attractiveness-of-housing multiplier mi f"(Middle Income household to housing ratio)
Units: Dmnl

"Attractiveness-of-housing multiplier mi f"(
        [(0,0)-(2,2)],(0,1.4),(0.2,1.4),(0.4,1.35),(0.6,1.3),(0.8,1.15),(1,1),(1.2,0.8),(1.4,0.65),
        (1.6,0.5),(1.8,0.45),(2,0.4))
Units: Dmnl

"Attractiveness-of-jobs multiplier for middle income pop"=
        "Attractiveness-of-jobs multiplier mi f"(Middle Income to Job ratio)
Units: Dmnl

"Attractiveness-of-jobs multiplier mi f"(
        [(0,0)-(2,2)],(0,2),(0.2,1.95),(0.4,1.8),(0.6,1.6),(0.8,1.35),(1,1),(1.2,0.5),(1.4,0.3),(1.6,0.2),(1.8,0.15),(2,0.1))
Units: Dmnl

Births normal=
        0.03
Units: 1/Year

Deaths normal=
        0.015
Units: 1/Year

Deteriorating business structures= INTEG (
          +mature business obsolescence-deteriorating business structures demolition,100)
Units: unit

In migration normal=
          0.1
Units: 1/Year

Labor participation fraction=
          0.35
Units: Dmnl

Mature Business Structures= INTEG (
          +new business obsolescence-mature business obsolescence,300)
Units: unit

MI jobs from deteriorating struct=
          Deteriorating business structures*Middle income jobs per deteriorating business structure
Units: jobs

MI jobs from mature struct=
          Mature Business Structures*Middle income jobs per mature business structure
Units: jobs

MI jobs from new struct=
          Middle income jobs per new business structure*New Business structures
Units: jobs

Middle Income Births=
          Middle Income Population*Births normal
Units: persons/Year

Middle Income Deaths=
          Middle Income Population*Deaths normal
Units: persons/Year

Middle Income Household size=
          4
Units: persons/household

Middle Income household to housing ratio=
          Middle Income households/(Middle Income Housing Density*(Middle Income Houses-
          Section 8 houses))
Units: Dmnl

Middle Income households=
          Middle Income Population/Middle Income Household size
Units: household

Middle Income Houses= INTEG (
          Middle Income Housing Construction+Upper income Housing Obsolescence-
          Middle Income Housing Demolition-Middle Income Housing Obsolescence,6400)
Units: housing units

Middle Income Housing Density=
          1
Units: household/housing units

Middle Income In migration=
          Middle Income Population*In migration normal*Attractiveness multiplier for middle income pop
Units: persons/Year

Middle Income Jobs=
>   **MI jobs from deteriorating struct+MI jobs from mature struct+MI jobs from new struct**

Units: jobs

Middle income jobs per deteriorating business structure=
>   **5**

Units: jobs/unit

Middle income jobs per mature business structure=
>   **8**

Units: jobs/unit

Middle income jobs per new business structure=
>   **12**

Units: jobs/unit

Middle Income Out migration=
>   **Middle Income Population*Out migration normal**

Units: persons/Year

Middle Income Population= INTEG (
>   **Middle Income Births+Middle Income In migration-Middle Income Deaths-**
>   **Middle Income Out migration,25000)**

Units: persons

Middle Income to Job ratio=
>   **Middle Income Population*Labor participation fraction/Middle Income Jobs**

Units: persons/jobs

New Business structures= INTEG (
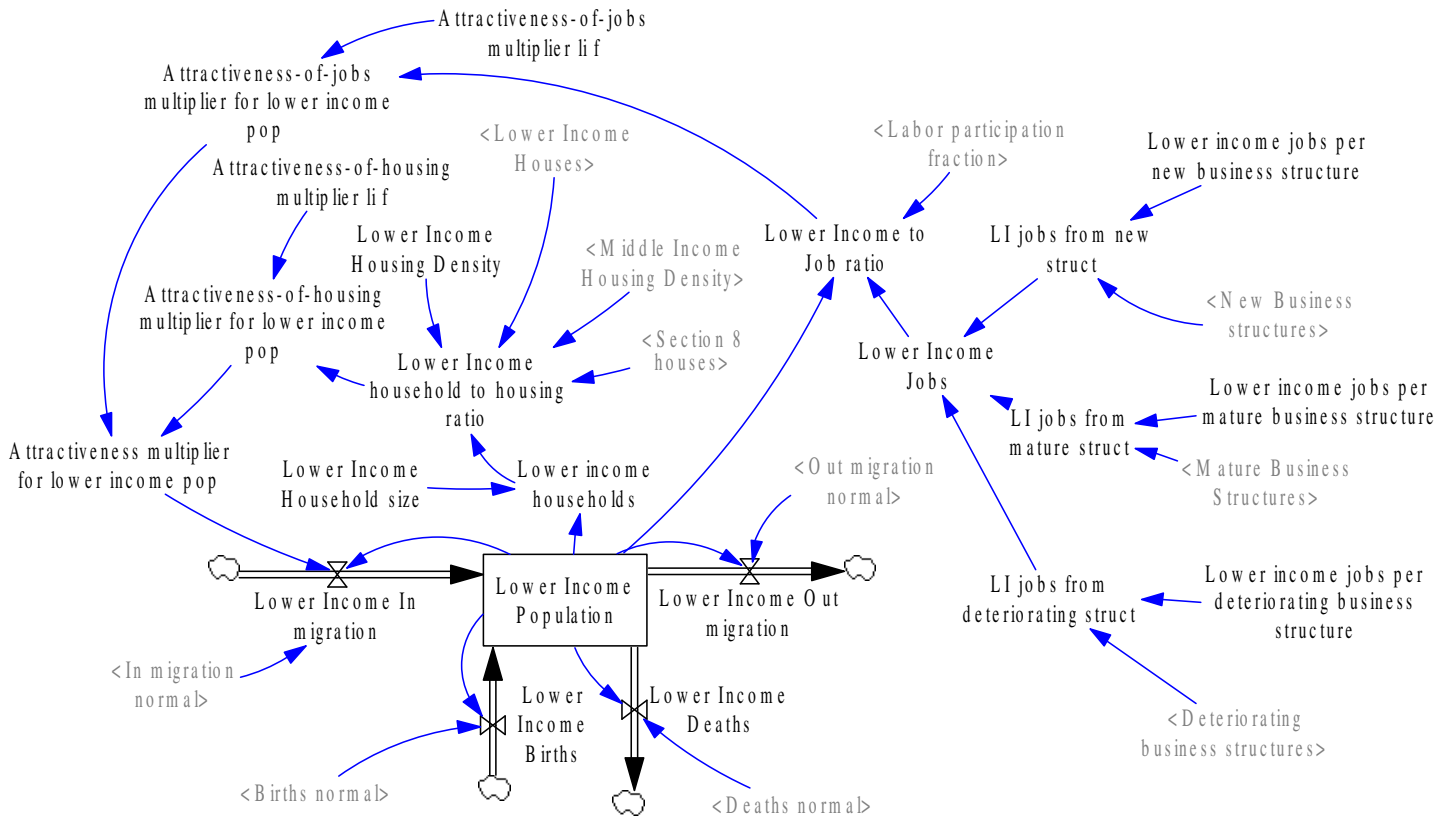>   **New Business Construction-new business obsolescence,600)**

Units: unit

Out migration normal=
>   **0.07**

Units: 1/Year

Section 8 houses=
>   **Actual LI households in section8 housing/Middle Income Housing Density**

Units: housing units

Appendix D – Lower Income Population Sector

Attractiveness multiplier for lower income pop=
    "Attractiveness-of-housing multiplier for lower income pop"*
    "Attractiveness-of-jobs multiplier for lower income pop "
Units: Dmnl

"Attractiveness-of-housing multiplier for lower income pop"=
    "Attractiveness-of-housing multiplier li f"(Lower Income household to housing ratio)
Units: Dmnl

"Attractiveness-of-housing multiplier li f"(
    [(0,0)-(2,2)],(0,1.4),(0.2,1.4),(0.4,1.35),(0.6,1.3),(0.8,1.15),(1,1),(1.2,0.8),(1.4,0.65),
    (1.6,0.5),(1.8,0.45),(2,0.4))
Units: Dmnl

"Attractiveness-of-jobs multiplier for lower income pop "=
    "Attractiveness-of-jobs multiplier li f"(Lower Income to Job ratio)
Units: Dmnl

"Attractiveness-of-jobs multiplier li f"(
    [(0,0)-(2,2)],(0,2),(0.2,1.95),(0.4,1.8),(0.6,1.6),(0.8,1.35),(1,1),(1.2,0.5),(1.4,0.3),(1.6,0.2),(1.8,0.15),(2,0.1))
Units: Dmnl

Births normal=
    0.03
Units: 1/Year

Deaths normal=
  0.015
Units: 1/Year

Deteriorating business structures= INTEG (
  +mature business obsolescence-deteriorating business structures demolition,100)
Units: unit

In migration normal=
  0.1
Units: 1/Year

Labor participation fraction=
  0.35
Units: Dmnl

LI jobs from deteriorating struct=
  Deteriorating business structures*Lower income jobs per deteriorating business structure
Units: jobs

LI jobs from mature struct=
  Mature Business Structures*Lower income jobs per mature business structure
Units: jobs

LI jobs from new struct=
  Lower income jobs per new business structure*New Business structures
Units: jobs

Lower Income Births=
  Lower Income Population*Births normal
Units: persons/Year

Lower Income Deaths=
  Lower Income Population*Deaths normal
Units: persons/Year

Lower Income Household size=
  3
Units: persons/household

Lower Income household to housing ratio=
  Lower income households/((Lower Income Houses*Lower Income Housing Density)+
  (Section 8 houses*Middle Income Housing Density))
Units: Dmnl

Lower income households=
  Lower Income Population/Lower Income Household size
Units: household

Lower Income Houses= INTEG (
  Lower Income Housing Construction+Middle Income Housing Obsolescence-
  Lower Income Housing Demolition,3200)
Units: housing units

Lower Income Housing Density=
  1.5
Units: household/housing units

Lower Income In migration=
  Lower Income Population*In migration normal*Attractiveness multiplier for lower income pop
Units: persons/Year

Lower Income Jobs=
>   **LI jobs from deteriorating struct+LI jobs from mature struct+LI jobs from new struct**
Units: jobs

Lower income jobs per deteriorating business structure=
>   **5**
Units: jobs/unit

Lower income jobs per mature business structure=
>   **6**
Units: jobs/unit

Lower income jobs per new business structure=
>   **9**
Units: jobs/unit

Lower Income Out migration=
>   **Lower Income Population*Out migration normal**
Units: persons/Year

Lower Income Population= INTEG (
>   **Lower Income Births+Lower Income In migration-Lower Income Deaths-
>   Lower Income Out migration,12500)**
Units: persons

Lower Income to Job ratio=
>   **Lower Income Population*Labor participation fraction/Lower Income Jobs**
Units: persons/jobs

Mature Business Structures= INTEG (
>   **+new business obsolescence-mature business obsolescence,300)**
Units: unit

Middle Income Housing Density=
>   **1**
Units: household/housing units

New Business structures= INTEG (
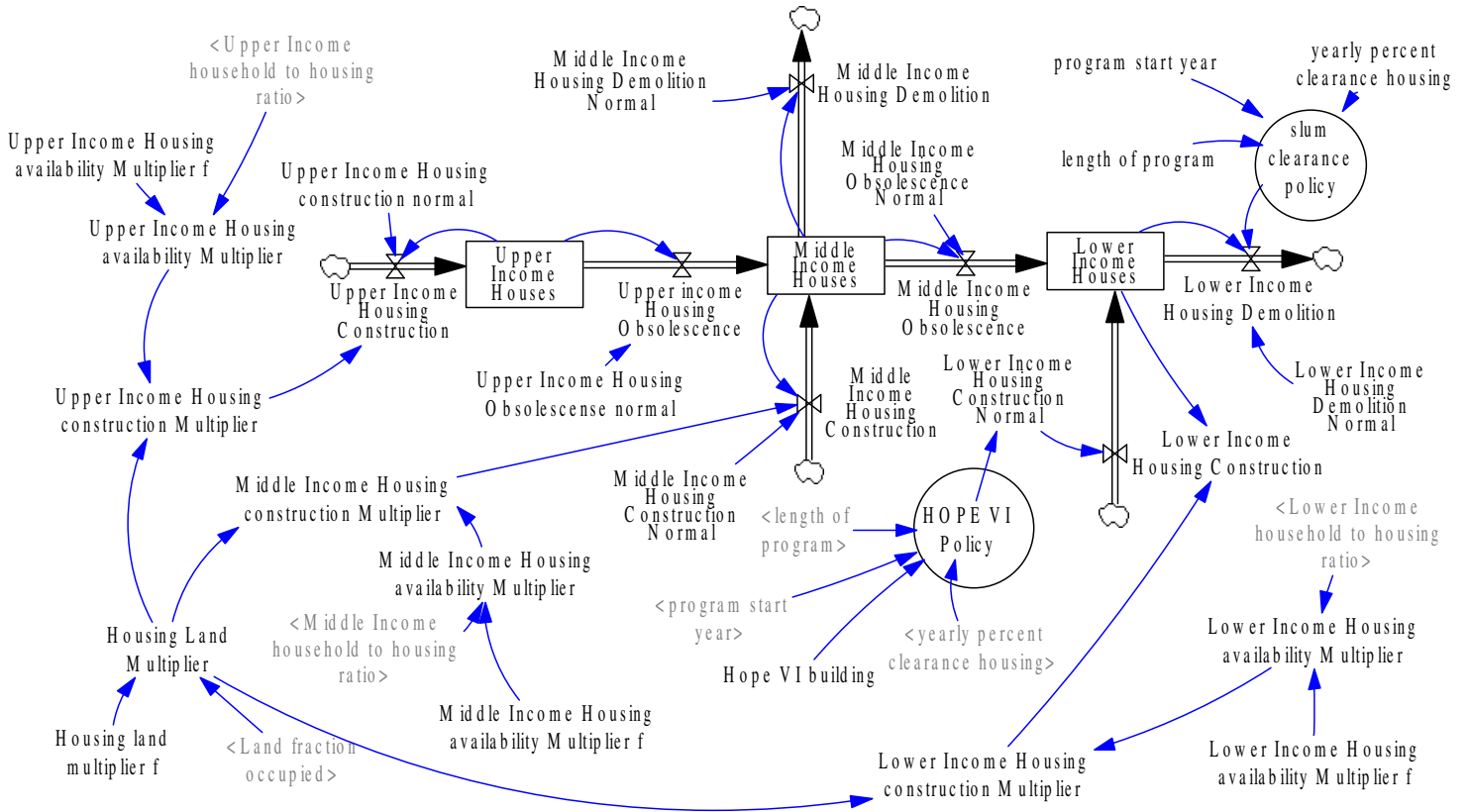>   **New Business Construction-new business obsolescence,600)**
Units: unit

Out migration normal=
>   **0.07**
Units: 1/Year

Section 8 houses=
>   **Actual LI households in section8 housing/Middle Income Housing Density**
Units: housing units

Appendix E – Housing Sector

Hope VI building=
      0
Units: Dmnl

HOPE VI Policy=
      PULSE(program start year, length of program)*yearly percent clearance housing*Hope VI building
Units: 1/Year

Housing Land Multiplier=
      Housing land multiplier f(Land fraction occupied)
Units: Dmnl

Housing land multiplier f(
      [(0,0)-(1,2)],(0,0.4),(0.1,0.7),(0.2,1),(0.3,1.25),(0.4,1.45),(0.5,1.5),(0.6,1.5),(0.7,1.4),(0.8,1),(0.9,0.5),(1,0))
Units: Dmnl

Land fraction occupied=
      (land occupied by businesses+land occupied by housing)/Area
Units: Dmnl

length of program=
      50
Units: Year

Lower Income household to housing ratio=
      Lower income households/((Lower Income Houses*Lower Income Housing Density)+
      (Section 8 houses*Middle Income Housing Density))
Units: Dmnl

Lower Income Houses= INTEG (
        Lower Income Housing Construction+Middle Income Housing Obsolescence-
        Lower Income Housing Demolition,3200)
Units: housing units

Lower Income Housing availability Multiplier=
        Lower Income Housing availability Multiplier f(Lower Income household to housing ratio)
Units: Dmnl

Lower Income Housing availability Multiplier f(
        [(0,0)-(2,2)],(0,1),(0.2,1),(0.4,1),(0.6,1),(0.8,1),(1,1),(1.2,1),(1.4,1),(1.6,1),(1.8,1),(2,1))
Units: Dmnl

Lower Income Housing Construction=
        Lower Income Houses*Lower Income Housing Construction Normal*
        Lower Income Housingconstruction Multiplier
Units: housing units/Year

Lower Income Housing construction Multiplier=
        Housing Land Multiplier*Lower Income Housing availability Multiplier
Units: Dmnl

Lower Income Housing Construction Normal=
        HOPE VI Policy
Units: 1/Year

Lower Income Housing Demolition=
        Lower Income Houses*(Lower Income Housing Demolition Normal+slum clearance policy)
Units: housing units/Year

Lower Income Housing Demolition Normal=
        0.04
Units: 1/Year

Middle Income household to housing ratio=
        Middle Income households/(Middle Income Housing Density*(Middle Income Houses-
        Section 8 houses))
Units: Dmnl

Middle Income Houses= INTEG (
        Middle Income Housing Construction+Upper income Housing Obsolescence-
        Middle Income Housing Demolition-Middle Income Housing Obsolescence,6400)
Units: housing units

Middle Income Housing availability Multiplier=
        Middle Income Housing availability Multiplier f(Middle Income household to housing ratio)
Units: Dmnl

Middle Income Housing availability Multiplier f(
        [(0,0)-(2,2)],(0,0.2),(0.2,0.25),(0.4,0.35),(0.6,0.5),(0.8,0.7),(1,1),(1.2,1.35),(1.4,1.6),(1.6,1.8),(1.8,1.95),(2,2))
Units: Dmnl

Middle Income Housing Construction=
        Middle Income Houses*Middle Income Housing Construction Normal*
        Middle Income Housingconstruction Multiplier
Units: housing units/Year

Middle Income Housing construction Multiplier=
        Housing Land Multiplier*Middle Income Housing availability Multiplier
Units: Dmnl

Middle Income Housing Construction Normal=
  0.04
Units: 1/Year

Middle Income Housing Demolition=
  Middle Income Houses*Middle Income Housing Demolition Normal
Units: housing units/Year

Middle Income Housing Demolition Normal=
  0.01
Units: 1/Year

Middle Income Housing Obsolescence=
  Middle Income Houses*Middle Income Housing Obsolescence Normal
Units: housing units/Year

Middle Income Housing Obsolescence Normal=
  0.03
Units: 1/Year

program start year=
  150
Units: Year

slum clearance policy=
  PULSE(program start year, length of program)*yearly percent clearance housing
Units: 1/Year

Upper Income household to housing ratio=
  Upper Income Households/(Upper Income Housing Density*Upper Income Houses)
Units: Dmnl

Upper Income Houses= INTEG (
  Upper Income Housing Construction-Upper income Housing Obsolescence,4400)
Units: housing units

Upper Income Housing availability Multiplier=
  Upper Income Housing availability Multiplier f(Upper Income household to housing ratio)
Units: Dmnl

Upper Income Housing availability Multiplier f(
  [(0,0)-(2,2)],(0,0.2),(0.2,0.25),(0.4,0.35),(0.6,0.5),(0.8,0.7),(1,1),(1.2,1.35),(1.4,1.6),(1.6,1.8),(1.8,1.95),(2,2))
Units: Dmnl

Upper Income Housing Construction=
  Upper Income Houses*Upper Income Housing construction normal*
  Upper Income Housing construction Multiplier
Units: housing units/Year

Upper Income Housing construction Multiplier=
  Housing Land Multiplier*Upper Income Housing availability Multiplier
Units: Dmnl

Upper Income Housing construction normal=
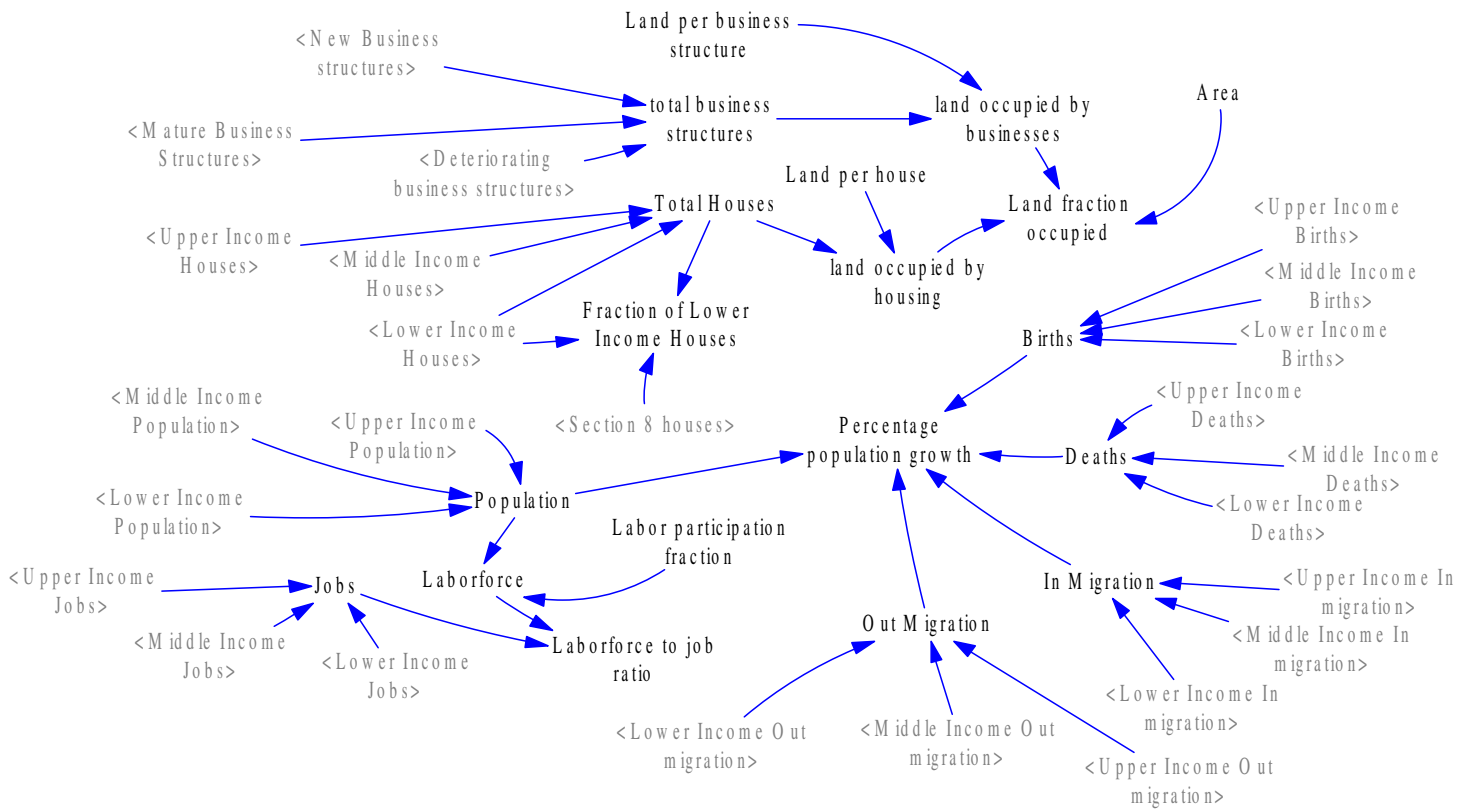 **0.05**
Units: 1/Year

Upper income Housing Obsolescence=
  Upper Income Housing Obsolescense normal*Upper Income Houses
Units: housing units/Year

Upper Income Housing Obsolescense normal=

0.03
Units: 1/Year

yearly percent clearance housing=
        0
Units: 1/Year

Appendix F – Sector Interactions

Area=
        10000
Units: Acre

Births=
        Lower Income Births+Middle Income Births+Upper Income Births
Units: persons/Year

Deaths=
        Lower Income Deaths+Middle Income Deaths+Upper Income Deaths
Units: persons/Year

Deteriorating business structures= INTEG (
        +mature business obsolescence-deteriorating business structures demolition,100)
Units: unit

Fraction of Lower Income Houses=
        (Lower Income Houses+Section 8 houses)/Total Houses
Units: Dmnl

In Migration=
> **Lower Income In migration+Middle Income In migration+Upper Income In migration**

Units: persons/Year

Jobs=
> **Lower Income Jobs+Middle Income Jobs+Upper Income Jobs**

Units: jobs

Labor participation fraction=
> **0.35**

Units: Dmnl

Laborforce=
> **Population*Labor participation fraction**

Units: persons

Laborforce to job ratio=
> **Laborforce/Jobs**

Units: persons/jobs

Land fraction occupied=
> **(land occupied by businesses+land occupied by housing)/Area**

Units: Dmnl

land occupied by businesses=
> **total business structures*Land per business structure**

Units: Acre

land occupied by housing=
> **Total Houses*Land per house**

Units: Acre

Land per business structure=
> **0.2**

Units: Acre/unit

Land per house=
> **0.1**

Units: Acre/housing units

Lower Income Births=
> **Lower Income Population*Births normal**

Units: persons/Year

Lower Income Deaths=
> **Lower Income Population*Deaths normal**

Units: persons/Year

Lower Income Houses= INTEG (
> **Lower Income Housing Construction+Middle Income Housing Obsolescence-**
> **Lower Income Housing Demolition,3200)**

Units: housing units

Lower Income In migration=
> **Lower Income Population*In migration normal*Attractiveness multiplier for lower income pop**

Units: persons/Year

Lower Income Jobs=
> **LI jobs from deteriorating struct+LI jobs from mature struct+LI jobs from new struct**

Units: jobs

Lower Income Out migration=

Lower Income Population*Out migration normal
Units: persons/Year

Lower Income Population= INTEG (
       Lower Income Births+Lower Income In migration-Lower Income Deaths-
       Lower Income Out migration,12500)
Units: persons

Mature Business Structures= INTEG (
       +new business obsolescence-mature business obsolescence,300)
Units: unit

Middle Income Births=
       Middle Income Population*Births normal
Units: persons/Year

Middle Income Deaths=
       Middle Income Population*Deaths normal
Units: persons/Year

Middle Income Houses= INTEG (
       Middle Income Housing Construction+Upper income Housing Obsolescence-
       Middle Income Housing Demolition-Middle Income Housing Obsolescence,6400)
Units: housing units

Middle Income In migration=
       Middle Income Population*In migration normal*Attractiveness multiplier for middle income pop
Units: persons/Year

Middle Income Jobs=
       MI jobs from deteriorating struct+MI jobs from mature struct+MI jobs from new struct
Units: jobs

Middle Income Out migration=
       Middle Income Population*Out migration normal
Units: persons/Year

Middle Income Population= INTEG (
       Middle Income Births+Middle Income In migration-Middle Income Deaths-
       Middle Income Outmigration,25000)
Units: persons

New Business structures= INTEG (
       New Business Construction-new business obsolescence,600)
Units: unit

Out Migration=
       Lower Income Out migration+Middle Income Out migration+Upper Income Out migration
Units: persons/Year

Percentage population growth=
       (Births+In Migration-Deaths-Out Migration)/Population
Units: 1/Year

Population=
       Lower Income Population+Middle Income Population+Upper Income Population
Units: persons

Section 8 houses=
       Actual LI households in section8 housing/Middle Income Housing Density
Units: housing units

total business structures=
> **New Business structures+Mature Business Structures+Deteriorating business structures**
Units: unit

Total Houses=
> **Lower Income Houses+Middle Income Houses+Upper Income Houses**
Units: housing units

Upper Income Births=
> **Upper Income Population*Births normal**
Units: persons/Year

Upper Income Deaths=
> **Upper Income Population*Deaths normal**
Units: persons/Year

Upper Income Houses= INTEG (
> **Upper Income Housing Construction-Upper income Housing Obsolescence,4400)**
Units: housing units

Upper Income In migration=
> **Upper Income Population*In migration normal*Attractiveness multiplier for upper income pop**
Units: persons/Year

Upper Income Jobs=
> **UI jobs from deteriorating struct+UI jobs from mature struct+UI jobs from new struct**
Units: jobs

Upper Income Out migration=
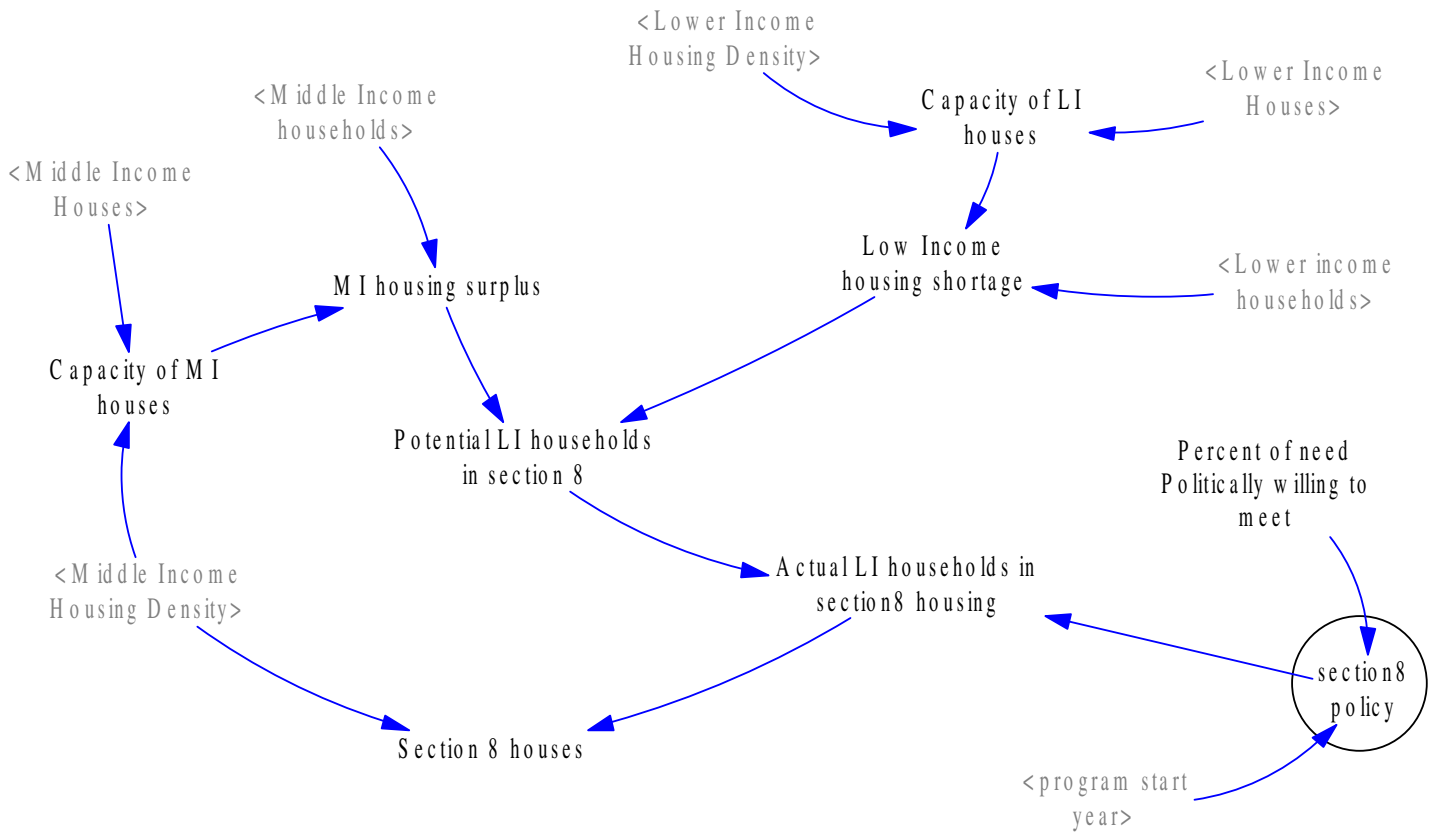> **Upper Income Population*Out migration normal**
Units: persons/Year

Upper Income Population= INTEG (
> **Upper Income Births+Upper Income In migration-Upper Income Deaths-Upper Income Out migration, 12500)**
Units: persons

Appendix G – Section 8 Policy

<Lower Income Housing Density>

<Middle Income households>

<Lower Income Houses>

<Middle Income Houses>

Capacity of LI houses

<Lower income households>

MI housing surplus

Low Income housing shortage

Capacity of MI houses

Potential LI households in section 8

Percent of need Politically willing to meet

<Middle Income Housing Density>

Actual LI households in section8 housing

section8 policy

Section 8 houses

<program start year>

Actual LI households in section8 housing=
        Potential LI households in section 8*section8 policy
Units: household

Capacity of LI houses=
        Lower Income Houses*Lower Income Housing Density
Units: household

Capacity of MI houses=
        Middle Income Houses*Middle Income Housing Density
Units: household

Low Income housing shortage=
        MAX(0, Lower income households-Capacity of LI houses)
Units: household

Lower income households=
        Lower Income Population/Lower Income Household size
Units: household

Lower Income Houses= INTEG (
        Lower Income Housing Construction+Middle Income Housing Obsolescence-
        Lower Income Housing Demolition,3200)
Units: housing units

Lower Income Housing Density=
        1.5

Units: household/housing units

MI housing surplus=
  MAX(0, Capacity of MI houses-Middle Income households)
Units: household

Middle Income households=
  Middle Income Population/Middle Income Household size
Units: household

Middle Income Houses= INTEG (
  Middle Income Housing Construction+Upper income Housing Obsolescence-
  Middle Income Housing Demolition-Middle Income Housing Obsolescence,6400)
Units: housing units

Middle Income Housing Density=
  1
Units: household/housing units

Percent of need Politically willing to meet=
  0
Units: Dmnl

Potential LI households in section 8=
  MIN(MI housing surplus, Low Income housing shortage)
Units: household

program start year=
  150
Units: Year

Section 8 houses=
  Actual LI households in section8 housing/Middle Income Housing Density
Units: housing units

section8 policy=
  STEP(Percent of need Politically willing to meet, program start year)
Units: Dmnl