APPENDIX A

MODEL OPERATIONALIZATION

The complete model is structured in four sections: Formal Housing Demand and Supply, Urban Services for Low-quality Housing, Public Housing, and Informal Housing. Also, two additional sectors containing auxiliary variables used to generate output information are included: Total Housing of Formal and Informal Origin, and Total Costs of Provision of Low-income Housing. In this appendix, I describe the operationalization of the variables, parameters, and equations included in the model and describe the quantitative and qualitative information used in this process.

A.1 FORMAL HOUSING DEMAND AND SUPPLY

This sector represents the demand for housing according to category (high-, medium-, and low-quality) as a function of population growth and household size and the supply as a function of the available stock. Its structure is represented in Figure A.1 and its equations are operationalized as follows:

Population growth

(1) Total Population= INTEG (New Population, 335512)
Units: people

(2) New Population=(New Population Normal/Average Time for population)+((Population Growth*New Population Normal)/Average Time for population)
Units: people/Year

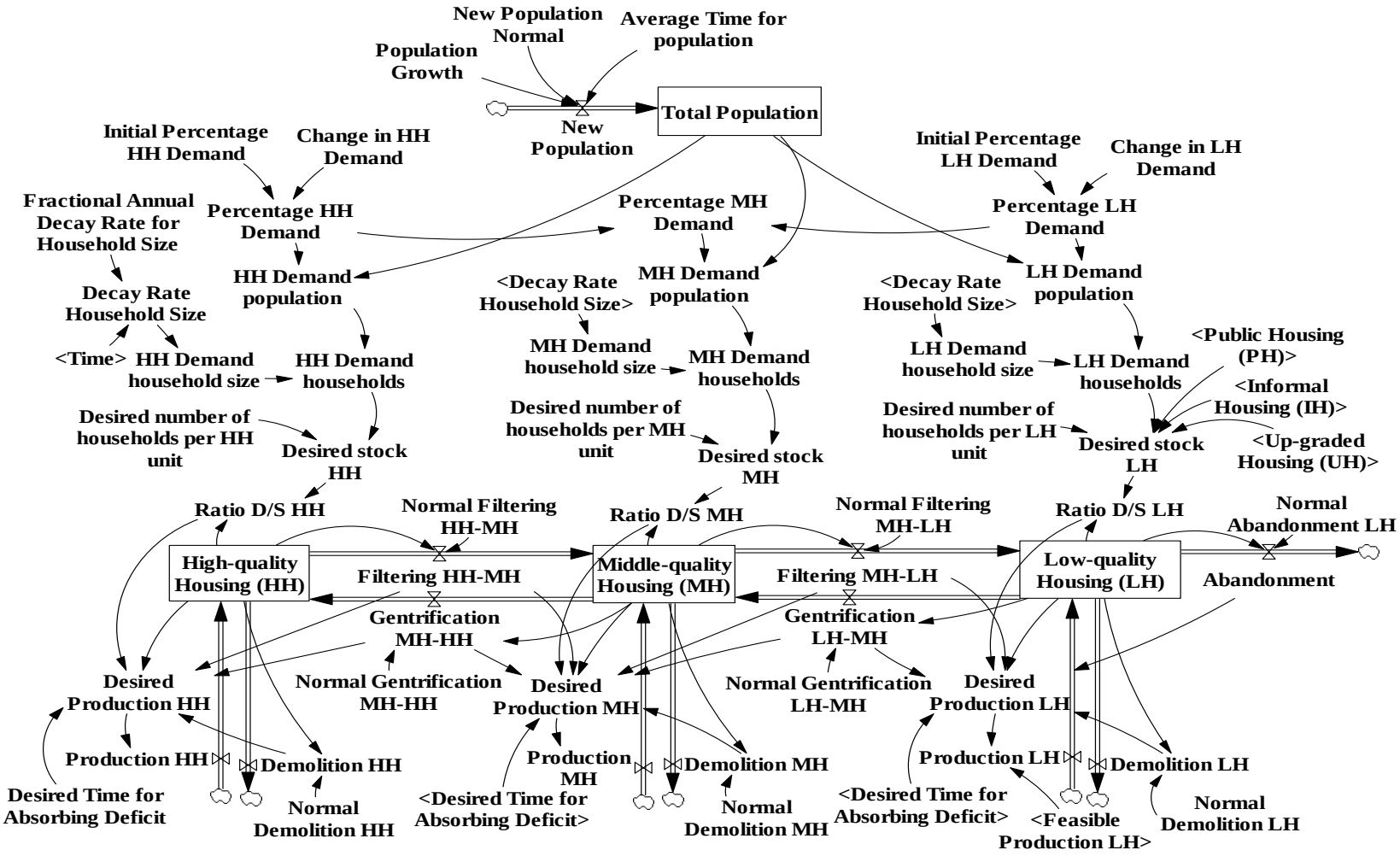


Figure A.1 Formal Housing Demand and Supply Structure

(3) New Population Normal=12000
Units: people

(4) Average Time for population=1
Units: Year

(5) Population Growth=RAMP(0.275, 1938, 1973)
Units: Dmnl

Equation 1 defines Total Population as a stock with initial value of 335,512 which was the population of the city in the census of 1938. Equation 2 represents an inflow to this stock determined by the Normal New Population (Equation 3) which is calculated at 12,000 people per year (Equation 4). Equation 5 defines that this New Population increased at a rate of 0.275 in the period of 1938 to 1973. The values for Equations 4 and 5 were estimated using census data for the years 1905, 1912, 1918, 1928, 1938, 1951, 1964, 1973, 1985, 1993, and 2005. Although this simplified formulation of population growth produces a linear growth for the final years of the simulation, its behavior replicate the historical dynamic as shown in figure 5.4 and since the projected period is relatively short it is not likely to affect the results of the simulation substantially.

Population per category of demand

(6) HH Demand population=Total Population*Percentage HH Demand
Units: people

(7) MH Demand population=Total Population*Percentage MH Demand
Units: people

(8) LH Demand population=Total Population*Percentage LH Demand
Units: people

(9) Percentage HH Demand=Initial Percentage HH Demand+Change in HH Demand
Units: Dmnl

(10) Percentage MH Demand=1-Percentage HH Demand-Percentage LH Demand
Units: Dmnl

(11) Percentage LH Demand=Initial Percentage LH Demand+Change in LH Demand
Units: Dmnl

(12) Initial Percentage HH Demand=0.0501
Units: Dmnl

(13) Initial Percentage LH Demand=0.8757
Units: Dmnl

(14) Change in HH Demand=RAMP(-2.5e-005, 1938, 2038)
Units: Dmnl

(15) Change in LH Demand=RAMP(0.000207, 1938, 2038)
Units: Dmnl

Equations 6 to 8 divide the total population in three categories according to the type of housing demanded. The percentage of Population in the High-quality (HH) Demand category (Equation 9) is assumed to be equal to the percentage of the population in socio-economic strata 5 and 6. The percentage of Population in the Low-quality (LH) Demand category (Equation 11) is assumed to be equal to the percentage of the population in socio-economic strata 1, 2 and 3. The percentage of Population in the Medium- or Middle- quality (MH) category (Equation 10) is assumed as the residual (socio-economic stratum 4).

These strata are defined by the Planning Department since 1983, and by each utility company before that, classifying the population according to income, poverty incidence and the physical characteristics of the neighborhood. The use of strata as a proxy for housing demand or income is fairly common in Colombia (LONJA, 2005; SDP, 2005; Jaramillo, 2004; Molina, 2001) for this model this classification is even more relevant since it determines the levels of cross-subsidization, a central concept in the next sector of the model.

The percentages in each category are assumed to change through time (Equations 12 to 15). This change was estimated by comparing the actual percentages of the stratification in the year 1983 with those in 2005, calculating the linear variation and projecting it for the entire study period. The result is a slow variation with decreases in the HH and MH categories and increase in the LH category. This is congruent with the perception found in the literature about the gradual deterioration of income distribution in the city and in the country. The Gini Coefficient in the seven largest urban areas in Colombia was 0.48 in 1964, 0.52 in 1974, 0.48 in 1984 and 0.50 in 1994. In 2004 the Gini in Bogota was 0.55 (DNP, 2009, *Bogotá cómo vamos*, 2005; Ocampo, 1996). It is important to note that the Gini is not included explicitly in the model because the percentages of population per category were calculated from the percentage of population per stratum.

Household size and households per category of demand

(16) HH Demand households=HH Demand population/HH Demand household size
Units: household

(17) MH Demand households=MH Demand population/MH Demand household size
Units: household

(18) LH Demand households=LH Demand population/LH Demand household size
Units: household

(19) HH Demand household size=7.6*EXP(Decay Rate Household Size)
Units: people/household

(20) MH Demand household size=7.6*EXP(Decay Rate Household Size)
Units: people/household

(21) LH Demand household size=8.3*EXP(Decay Rate Household Size)
Units: people/household

(22) Fractional Annual Decay Rate for Household Size=-0.012
Units: 1/Year

(23) Decay Rate Household Size=Fractional Annual Decay Rate for Household Size*(Time-1938)
Units: Dmnl

Equations 16 to 18 define that the number households per category is equal to the population per category divided by the household size (the average number of persons per household). Equations 19 to 23 state that household size varies according to category and changes through time. Household size has decreased in Bogotá in the last decades. In 1964 the average household size was 6.2 persons per household (Mohan, 1994), in 1973 it was between 5.04 (Molina, 2001) and 5.2 (Mohan, 1994), in 1985 it was 4.92 (Molina, 2001), in 1993 it was 3.92 (Molina, 2001; SDP, 2005), and in 2005 it was 3.4 (DANE, 2009). This change was modeled as an exponential decay function combining these different data points. The best result indicated a decaying rate of -0.012. The variation per category was calculated by comparing the average household size for the city with the average per category according to information of household size per strata for the year 2001. In that year, the average household in strata 5 and 6 size was 3.6, in stratum 4 it was 3.6, and in strata 1 to 3 was 3.94 (SDP, 2005).

Desired stock per category

(24) Desired stock HH=HH Demand households/Desired number of households per HH unit
Units: housing units

(25) Desired stock MH=MH Demand households/Desired number of households per MH unit
Units: housing units

(26) Desired stock LH=(LH Demand households/Desired number of households per LH unit)-"Informal Housing (IH)"-"Up-graded Housing (UH)"-"Public Housing (PH)"
Units: housing units

(27) Desired number of households per HH unit=1
Units: household/housing unit

(28) Desired number of households per LH unit=1
Units: household/housing unit

(29) Desired number of households per MH unit=1
Units: household/housing unit

Equations 24 to 26 define that the desired stock is equal to the number of households per category of the demand divided by desired number of household per unit, which is assumed to be 1 (Equations 27 to 29). That means that the desired stock per category is equal to the stock needed to accommodate all households in the city without generating deficit. For the case of Low-quality Housing the desired stock is also affected by the stocks of Informal Housing (IH), Up-graded Housing (UH), and Public Housing since these stocks absorb part of the demand easing the pressure of the demand for low-quality housing.

Housing stocks

(30) "High-quality Housing (HH)"= INTEG ("Gentrification MH-HH"+Production HH-Demolition HH-"Filtering HH-MH",2211)
Units: housing units

(31) "Middle-quality Housing (MH)"= INTEG ("Filtering HH-MH"+"Gentrification LH-MH"+Production MH-Demolition MH-"Filtering MH-LH"-"Gentrification MH-HH",3275)
Units: housing units

(32) "Low-quality Housing (LH)"= INTEG ("Filtering MH-LH"+Production LH-Abandonment-Demolition LH-"Gentrification LH-MH",21889)
Units: housing units

(33) "Filtering HH-MH"=("High-quality Housing (HH)"/"Normal Filtering HH-MH")
Units: housing units/Year

(34) "Filtering MH-LH"=("Middle-quality Housing (MH)"/"Normal Filtering MH-LH")
Units: housing units/Year

(35) Abandonment=("Low-quality Housing (LH)"/Normal Abandonment LH)
Units: housing units/Year

(36) "Normal Filtering HH-MH"=40
Units: Year

(37) "Normal Filtering MH-LH"=50
Units: Year

(38) Normal Abandonment LH=60
Units: Year

(39) "Gentrification LH-MH"=("Low-quality Housing (LH)"/"Normal Gentrification LH- MH")
Units: housing units/Year

(40) "Gentrification MH-HH"= ("Middle-quality Housing (MH)"/"Normal Gentrification MH-HH")
Units: housing units/Year

(41) "Normal Gentrification LH-MH"=500
Units: Year

(42) "Normal Gentrification MH-HH"=400
Units: Year

(43) Demolition HH=("High-quality Housing (HH)"/Normal Demolition HH)
Units: housing units/Year

(44) Demolition MH=("Middle-quality Housing (MH)"/Normal Demolition MH)
Units: housing units/Year

(45) Demolition LH=("Low-quality Housing (LH)"/Normal Demolition LH)
Units: housing units/Year

(46) Normal Demolition HH=400
Units: Year

(47) Normal Demolition MH=500
Units: Year

(48) Normal Demolition LH=600
Units: Year

Equations 30 to 31 represent the housing supply as the stocks of High-quality (HH), Middle-quality (MH), and Low-quality (LH). This simplifying assumption about a segmented market is fairly common in the literature of Urban Dynamics (see

Schroeder, Sweeney and Alfeld, 1975; Mass, 1974; Forrester, 1969), Neoclassical Urban Economics (see O'Sullivan, 2009; O'Flaherty, 2005; Mills and Hamilton, 1980) and Marxist Urbanism (see Topalov, 1984). The initial value in each stock was calculated by weighting the formal housing stock in 1938 reported by Jaramillo (1980) in each category according to the percentages of demand. This estimation was made under the assumption that there are no deficits in the high- and middle- categories. This is not only because if there was a deficit the higher categories would displace the demand from the lower category due to their higher purchasing power but also because utilities prioritize the provision for high- and middle-housing since these categories cover the average cost of servicing and, in the first case, generate contributions to provide low-quality housing through the system of cross-subsidization.

These stocks are interrelated by two flows: Filtering and Abandonment in one side (equations 33 and 35) and Gentrification in the other side (equations 39 and 40). Filtering is the general process by which aged housing is downgraded from a higher to a lower quality level evidenced in a decrease in the income level of the occupants over time. Since Low-quality Housing is the lower category of the demand, the process of downgrading from this category is called Abandonment. Gentrification is the particular process by which some housing units are upgraded from a lower to a higher quality level usually caused by a change in location preferences or by a shortage in the supply in the higher level. Also, each stock is affected by two flows: Demolition (equations 41 to 43) and Production (equations 56 to 58 described in the next section).

The rate of Filtering from High- to Middle-quality Housing (equation 33), is defined by the ratio of the value of the stock and the Normal Time that a unit spends in the category. In this case, that time is assumed as 40 years (equation 36). A Normal Time

of 40 years means that under ‘normal’ or average conditions 2.5 percent of the High-income Housing stock is filtered each year. It was not possible to find actual data about this parameter so the assumption was taken from relevant literature: Jaramillo (1980) states that an average life of buildings of 40 years in each market is the standard assumption in these cases. In his model of Urban Dynamics, Forrester (1969) defines the rate of obsolescence as 3 percent for Premium Housing and 2 percent for Worker and Unemployed Housing, which means a normal active life of 33 years in the premium category and 50 years in the other two categories.

The rate of Filtering from Middle- to Low-quality Housing (equations 34 and 37: 2 percent of the stock is filtered each year representing a Normal Time of 50 years) and the rate of Abandonment from Low-quality Housing (equations 35 and 38: 1.6 percent of the stock is filtered each year, or abandoned in this case, representing a Normal Time of 60 years,) are assumed higher not only because in these categories the stock will be used more intensively but also because the production of new Middle- and Low-quality Housing adds years to the expected useful life of these units.

The rates of Gentrification (equations 39 to 42) and Demolition (equations 43 to 48) are defined at 10 percent of the Filtering rate in each category. This reflects the assumption that in ‘normal’ conditions Filtering will be more common than Gentrification or Demolition: if the market is in equilibrium a higher category will prefer new housing produced in its own category over gentrified units. In the other hand, owners will prefer to filter the units over demolition because filtering is cheaper and assures continuity in the income received from the property. That means that in any year in any category for every 10 units that are filtered to a lower category, only 1 is gentrified and 1 is demolished.

Ratio demand/supply and desired production

(49) "Ratio D/S HH"=Desired stock HH/"High-quality Housing (HH)"
Units: Dmnl

(50) "Ratio D/S LH"=Desired stock LH/"Low-quality Housing (LH)"
Units: Dmnl

(51) "Ratio D/S MH"=Desired stock MH/"Middle-quality Housing (MH)"
Units: Dmnl

(52) Desired Production HH=MAX(((("Ratio D/S HH"-1)*"High-quality Housing (HH)")/Desired Time for Absorbing Deficit)+Demolition HH+"Filtering HH-MH"-"Gentrification MH-HH"), 0)
Units: housing units/Year

(53) Desired Production MH=MAX(((("Ratio D/S MH"-1)*"Middle-quality Housing (MH)")/Desired Time for Absorbing Deficit)+Demolition MH+"Filtering MH-LH"+"Gentrification MH-HH"-"Filtering HH-MH" -"Gentrification LH-MH"), 0)
Units: housing units/Year

(54) Desired Production LH=MAX(((("Ratio D/S LH"-1)*"Low-quality Housing (LH)")/Desired Time for Absorbing Deficit)+Abandonment+Demolition LH+"Gentrification LH-MH"-"Filtering MH-LH"), 0)
Units: housing units/Year

(55) Desired Time for Absorbing Deficit=1
Units: Year

(56) Production HH=Desired Production HH
Units: housing units/Year

(57) Production MH=Desired Production MH
Units: housing units/Year

(58) Production LH=MIN(Desired Production LH, Feasible Production LH)
Units: housing units/Year

Equations 49 to 51 capture differences of demand and supply through the calculation of the ratio of these variables. If this ratio is 1, the Desired Stock and the Housing Stock are equal and demand and supply are in equilibrium. If the ratio is more than 1, the Desired Stock is larger than the Housing Stock and there is a shortage of housing

units in the system. And if the ratio is less than 1, the Desired Stock is less than the Housing Stock and there is oversupply of housing.

To achieve equilibrium of demand and supply the system should produce enough units per year to offset the increase in the demand and the net change in the supply. For that reason the annual Desired Production in every category (equations 52 to 54) should cover the difference of demand (Desired Stock) and supply (Housing Stock) in a specific period of time assumed at 1 year (equation 55). Also, it should cover the units lost through Filtering and Demolition minus the units gained through Gentrification. This is because Filtering and Demolition are negatively related to the supply (they decrease the stock in the category), and Gentrification is positively related to the supply (it increases the stock). To avoid a negative Desired Production a control in the inflow is included in the form of a maximum between the simulated value and zero.

Equations 56 to 58 represent the actual production of housing per category. In the case of high- and middle-quality housing the production is equal to the desired production because the provision of public services, which as described in the second sector of the model is assumed to be the main constraint of housing production, is prioritized for these categories due to the system of cross-subsidization. In the case of low-quality housing the production is the minimum of the desired and the feasible according to the availability of urban services.

A.2 URBAN SERVICES FOR LOW-QUALITY HOUSING

This sector represents the process of provision of urban services for low-quality housing describing the system of cross-subsidization. Its structure is represented in Figure A.2 and its equations are operationalized as follows:

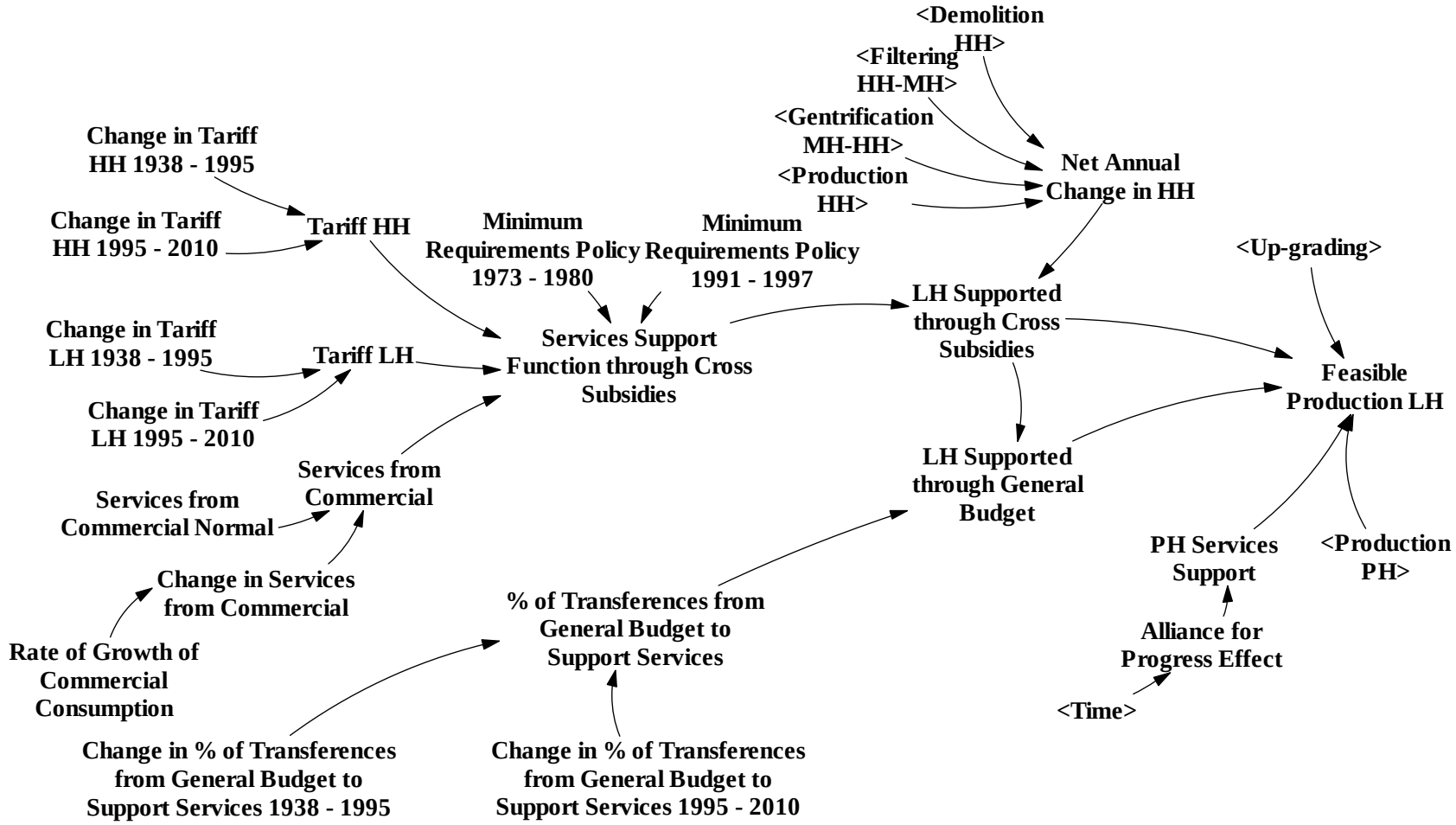


Figure A.2 Urban Services for Low-Quality Housing

Tariffs for high- and low-quality housing

(59) Tariff HH=1.79+"Change in Tariff HH 1938 - 1995"+"Change in Tariff HH 1995 - 2010"
Units: LTAC/housing units

(60) "Change in Tariff HH 1938 - 1995"=RAMP(0.0072, 1938, 1995)
Units: LTAC/housing units

(61) "Change in Tariff HH 1995 - 2010"=RAMP(-0.0667, 1995, 2010)
Units: LTAC/housing units

(62) Tariff LH=0.87+"Change in Tariff LH 1938 - 1995"+"Change in Tariff LH 1995 - 2010"
Units: LTAC/housing units

(63) "Change in Tariff LH 1938 - 1995"=RAMP(-0.01, 1938, 1995)
Units: LTAC/housing units

(64) "Change in Tariff LH 1995 - 2010"=RAMP(0.0267, 1995, 2010)
Units: LTAC/housing units

The provision of public services in Bogotá has been characterized by a system of cross-subsidization in which occupants of high-quality housing pay tariffs that are higher to the long term average cost of provision to finance (or, in the language of the model, 'support') occupants of low-quality housing who pay lower tariffs. Equations 59 to 61 represent the evolution of the tariff per high-quality housing units in terms of the number of long term average cost (LTAC) that it covers. Equation 59 states that this tariff was 1.79 times the long term average cost of provision in 1938 and that from that year it increased linearly at a rate of 0.0072 until 1995 (equation 60) and then it decreased linearly at a rate of -0.0667 until 2010 (equation 61).

These changes (equations 60 and 61) represent the evolution of the system of cross-subsidization characterized by a period of increasing contributions and redistribution from 1938 to 1995 and a change to a system in which tariffs are expected to be as

close as possible to the long term average cost of provision introduced by the Law 142 of 1994. The initial tariff and the rates of change were calculated by following the evolution of the ratio of the tariffs for the higher strata and the medium strata for telephone and telecommunications from the year 1950 to 2010 and projecting the trend linearly to 1938.

Since the system of cross-subsidization has been designed on the assumption that the tariff for the medium strata should be equal to the long term average cost of provision (i.e. this category does not subsidize, and it is not subsidized by, other categories) this ratio could be considered the tariff for high-quality housing in terms of average costs. For instance, a ratio of 1.79 in 1938 means that each housing unit pays the average cost caused by its own provision and contributes and additional 79 percent of the average cost for the provision of low-quality housing.

The service of telecommunications was selected because it provided the longest historical data series of tariffs per strata. The data for the period 1950-2000 was taken from the “Historical Statistics of Bogotá” published by SDP (2000). This information was complemented with data for years after 2000 from other sources (SUI, 2010; SDP, 2005b). To avoid a bias due to the service selected, the resulting ratio was compared to other services such as water and sewerage, electricity, and garbage collection for the years in which the information was available. The results showed that the ratio calculated using only the telephone service was representative of the ratio for the rest of services for the period 1938 to 1995. After 1995, the ratio was similar to that of electricity but lower than the ratio in water and sewerage. This is because this service received a special provision in Law 142 of 1994 that allowed higher tariffs. For that reason, for the years 1995 to 2010 the ratio was corrected using a composite of the tariffs for all services.

Equations 62 to 64 follow the same logic to represent the tariff for low-quality housing in terms of the average long term cost of provision. In this case the ratio is calculated as the tariff for this category compared to the tariff of middle-quality housing. The initial value of 0.87 (equation 62) means that in 1938 each housing unit covered 87 percent of the cost that its provision generated and the rest was financed through cross subsidies. The tariff for low-quality housing decreased at a rate of -0.01 from 1938 to 1995 (equation 63) and then it increased at a rate of 0.0267 until 2010 (equation 64).

Cross-subsidies from other uses

(65) Services from Commercial=Services from Commercial Normal+(Services from Commercial Normal*Change in Services from Commercial)
Units: Dmnl

(66) Services from Commercial Normal=3.34
Units: Dmnl

(67) Change in Services from Commercial=RAMP(Rate of Growth of Commercial Consumption, 1938, 2038)
Units: Dmnl

(68) Rate of Growth of Commercial Consumption=0.0431
Units: 1/Year

Apart from contributions from the high-quality housing, services for low-quality housing are also financed with contributions from the other uses such as commercial, industrial, and official (labeled in figure A.2 just as commercial but including all these different uses in the actual model). Equations 65 to 68 represent this source of contributions as a function of the evolution of the tariff and consumption of these other uses.

Since this support is included in the calculation of cross-subsidies as a multiplier of the contributions generated by high-quality housing (see equation 71 in the next section), it is calculated by comparing the tariffs and consumption for other uses to

those of the higher category (calculating, in effect, the extra-support from other services per unit of support from high-quality housing).

The ‘normal’ extra-support (equation 66) was calculated as the ratio of the tariff for other uses to the tariff of high-quality housing (1.67) multiplied by the ratio of consumption in these two categories (2) estimated according to data from SDP (2000). This extra-support is assumed to increase for the entire period of the simulation at the rate of growth of commercial consumption (equation 67). This rate is assumed to be equal to the rate of economic growth, calculated as the real average rate of economic growth for 1960 – 2005 as reported by GRECO (2002), since the consumption in these uses depend on the evolution of the economic output (equation 68).

Minimum requirements and services support function

(69) Services Support Function through Cross Subsidies=((Tariff HH-1)/(1-Tariff LH)*Services from Commercial)+("Minimum Requirements Policy 1973 - 1980"*((Tariff HH-1)/(1-Tariff LH))*Services from Commercial)+("Minimum Requirements Policy 1991 - 1997"*((Tariff HH-1)/(1-Tariff LH))*Services from Commercial)
Units: Dmnl

(70) "Minimum Requirements Policy 1973 - 1980"=RAMP(0.0428, 1973, 1980)
Units: Dmnl

(71) "Minimum Requirements Policy 1991 - 1997"=RAMP(-0.05, 1991, 1997)
Units: Dmnl

Equations 69 to 71 define the Services Support Function through Cross Subsidies, a representation of the number of low-quality units that can be serviced per high-quality unit, as a function of the relation of the tariffs, the extra-support from other uses, and the policy of minimum requirements. The first part of equation 69 defines that the number of low-quality units supported depends on the ratio of the contribution from high-quality housing in terms of long term average cost of service provision (which is

equal to the tariff minus 1) and the amount of subsidy per low-quality unit (which is equal to 1 minus the tariff). This ratio is then multiplied by the extra-support from other uses to define the 'normal' total support.

The second part of the equation shows the effect of the minimum requirements policy by representing its impact in the long term average cost of service provision. This impact was calculated by comparing the proportion of the costs of provision of trunk services to that of total services (including trunk and domestic) in a minimum requirement development (estimated using information from Mohan [1994] at 0.29 percent) and the same proportion in a traditional development (estimated using information from Roda [2000] at 0.42 percent). Since the proportion in the case of minimum requirements is about 70 percent that of a traditional development, it can be inferred that this policy decreased the average long term cost of service provision by 30 percent and, therefore, it increased the support in the same proportion since the amount of subsidy per low-quality unit decreased. However, it was assumed that this change did not happen immediately after the law was enacted in 1972 because the implementation of the policy during the first years was very slow and it required another complementing law in 1979 (Ceballos, 2005; Mohan 1994). Likewise, the dismantling of the policy was also a gradual process that started in 1990 and was completed in 1997 (Ceballos, 2005). Equations 70 and 71 capture the gradual implementation and dismantling of the policy of minimum requirements.

Low-quality housing supported by cross-subsidies

(72) LH Supported through Cross Subsidies=Services Support Function through Cross Subsidies*Net Annual Change in HH
Units: housing units/Year

(73) Net Annual Change in HH=Production HH+"Gentrification MH-HH"-"Filtering HH-MH"-Demolition HH
Units: housing units/Year

Equations 72 to 73 calculate the total number of low-quality housing units supported in a given year by cross-subsidies as the support per high-quality unit times the net annual change of the number of high-quality units.

Low-quality housing supported by general budget

(74) "% of Transferences from General Budget to Support Services"=0.15+"Change in % of Transferences from General Budget to Support Services 1938 - 1995" +"Change in % of Transferences from General Budget to Support Services 1995 - 2010"
Units: Dmnl

(75) "Change in % of Transferences from General Budget to Support Services 1938 - 1995"=RAMP(-0.00175, 1938, 1995)
Units: Dmnl

(76) "Change in % of Transferences from General Budget to Support Services 1995 - 2010"=RAMP(0.03, 1995, 2010)
Units: Dmnl

(77) LH Supported through General Budget=MAX((("% of Transferences from General Budget to Support Services"/(1-"% of Transferences from General Budget to Support Services")*LH Supported through Cross Subsidies)), 0)
Units: housing units/Year

Equations 74 to 77 represent another source of funding to support the provision of services for low-quality housing: the transferences from the general budget. Equations 74 to 76 capture the historical evolution of the proportion of transferences to the total revenue of utility companies in Bogotá. This estimation was made using information of the total budget of the Water Company in Bogotá obtained from Jaramillo (1988) for the period before 1985 and from SHD (2010) for the period after 1995. The data for the years in which no information found was estimated according to the trends. The general pattern shows that the proportion of these transferences decreased from 15 percent of the total revenue in 1938 to 5 percent in 1995 (equation 75) and then increased to 50 percent in 2010 (equation 76). This last value is realistic considering

that the transferences from the general budget to the Water Company reached 47.52 percent of the current revenues in 2007. The historical trend follows the logic of the system of financing of public services in Colombia which historically was supposed to be self-sustainable through cross-subsidization without substantial help from the general budget. This changed in 1994 when Law 142 stated that tariffs should be close to the long term average cost and that any deficit produced by subsidization should be covered with resources of the general budget (Gilbert, 2007).

Equation 77 calculates the 'extra-support' achieved through these resources of the general budget in terms of the number of additional housing units per year that can be provided with services. It is important to note that extra-resources in the utility companies' budgets produced by capital resources were not taken into account in this estimation because, in any case, these credits need to be repaid with revenue from tariffs or transferences in a period of 20 years or less (which is shorter than the period of simulation). For instance, Jaramillo (1988) provides evidence that an increase in credit during the 1970s was balanced with an increase in tariffs in 1980s showing that in the long term the capacity of servicing depends only on the revenues generated by utility companies and the transferences from the general budget.

Feasible production of low-quality housing

(78) Feasible Production LH=MAX(LH Supported through Cross Subsidies+LH Supported through General Budget-(2*"Up-grading")-(PH Services Support*Production PH), 0)
Units: housing units/Year

(79) PH Services Support=2.33*Alliance for Progress Effect
Units: Dmnl

(80) Alliance for Progress Effect=IF THEN ELSE (Time>=1960:AND:Time<=1973, 0.7, 1)
Units: Dmnl

Equation 78 defines the Feasible Production of Low-quality Housing per year as the number of units supported by cross subsidies and general budget minus the number of up-graded units and the public units produced in the same period. This is because up-grading and public housing provision consume resources from the utility companies displacing low-quality units. Since these two policies are more expensive, then, each up-graded and public unit will crowd-out more than one low-quality unit.

In the case of up-grading this number is estimated as 2 because according to different sources the cost of up-grading in Bogotá is about 3 times more expensive than a planned urbanization[1] (Cities Alliance 2006; Aristizabal and Gomez, 2002; Roda, 2000) but usually the community is asked to pay at least a third part of these costs through monetary contributions, labor, and land (Gilbert and Ward, 1985, 1982).

In the case of public housing the number of crowded-out units is estimated in 2.33 (equation 79) because the utilities have to provide not only the trunk service but also the secondary or domestic connection, which in the case of private development according to Colombian law is covered by the developer. This represents an extra cost over the trunk service provision of 133 percent per unit for a ratio of 1 to 2.33 (Roda, 2000). It is important to note that other costs of public housing provision such as housing subsidies and written-off debts are not included in this calculation because they are paid from the budget of the housing authorities and not by public utilities. The cost of provision of public housing decreased during the 1960s (equation 80) thanks to a policy implemented by the Alliance of Progress that tested, as a pilot case, the main

[1] In effect, according to the information of Cities Alliance (2006) the cost of up-grading an informal unit represents 3.5 times the cost trunk service provision for a formal privately produced unit and 3.78 for a unit produced by NGO's. Aristizabal and Ortiz (2002) estimate that the cost of up-grading per square meter is 2.7 times the cost of servicing a square meter of a formal development. Roda (2000) calculates that the cost of intervention per hectare of the up-grading program (*Programa de Desmarginalización*) is about 2.5 the cost of trunk service provision for a formally produced unit.

features of the minimum requirement policy that was going to be implemented at large scale in the 1970s.

Equation 78 includes a control that prevents the Feasible Production from becoming negative. This does not state that up-grading and public housing cannot be higher than the support of services for low-quality units produced by cross-subsidies and the general budget. Rather, it defines that utilities will cover the cost of provision of services through up-grading and public housing until it is viable for the companies without generating deficit. From that point on, the cost will be covered by the general budget.

This is consistent with the role of the public utilities in Bogota since they have always protected their commercial orientation and their financial sustainability requiring politicians and residents to cover part of the cost of up-grading (Gilbert and Ward, 1985, 1982). The up-graded and publicly provided units that are not covered by the utilities through their own revenues will appear later as a cost for the general budget in the last sector of the model since there the total costs of provision of services for low-quality housing are consolidated. The description of the last sector at the end of this appendix includes detailed information on the costs of different interventions.

A.3 PUBLIC HOUSING

This sector represents the evolution of the provision of public housing in the city. Its structure is represented in Figure A.3 and its equations are operationalized as follows:

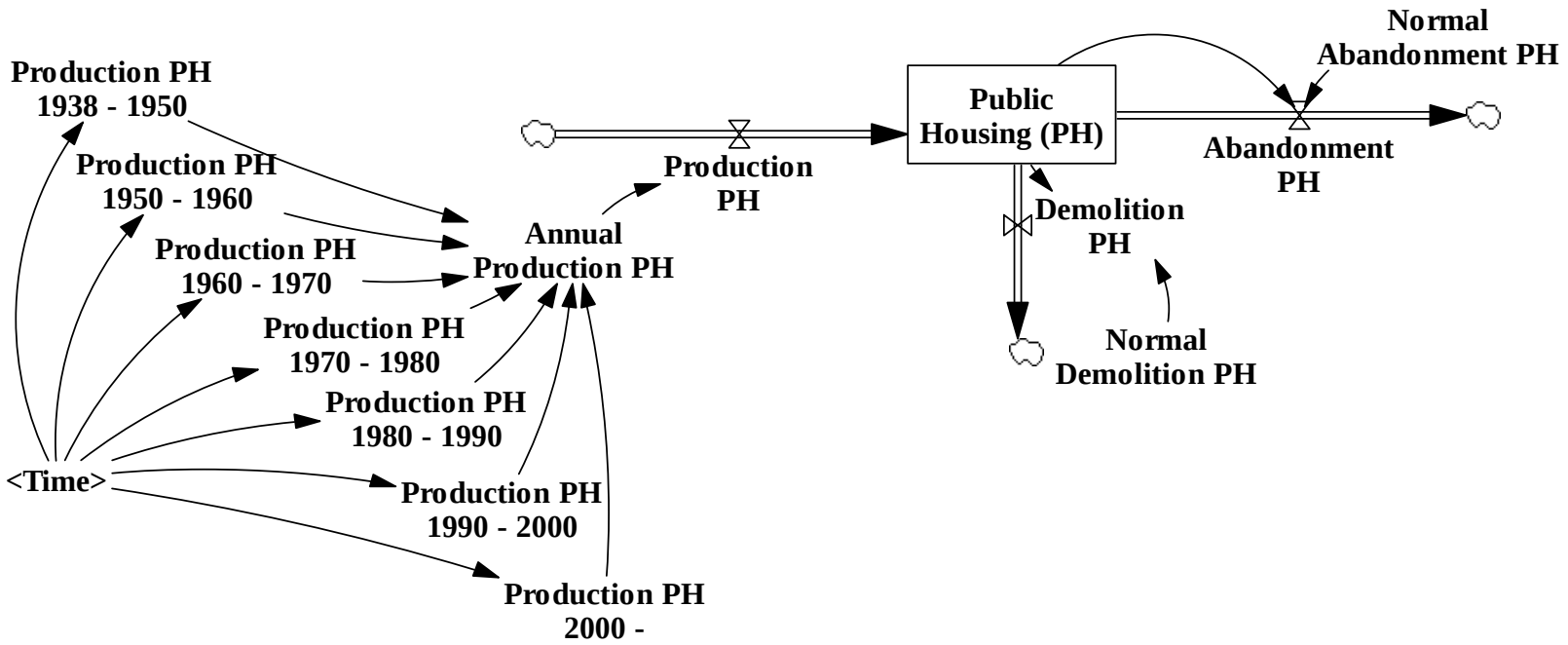


Figure A.3 Public Housing

Annual public housing production

(81) Annual Production PH="Production PH 1938 - 1950"+"Production PH 1950 - 1960"+"Production PH 1960 - 1970"+"Production PH 1970 - 1980" +"Production PH 1980 - 1990"+"Production PH 1990 - 2000"+"Production PH 2000 -"
Units: housing units/Year

(82) "Production PH 1938 - 1950"=IF THEN ELSE(Time<1950, 264, 0)
Units: housing units/Year

(83) "Production PH 1950 - 1960"=IF THEN ELSE(Time>=1950:AND:Time<1960, 581, 0)
Units: housing units/Year

(84) "Production PH 1960 - 1970"=IF THEN ELSE(Time>=1960:AND:Time<1970, 3696, 0)
Units: housing units/Year

(85) "Production PH 1970 - 1980"=IF THEN ELSE(Time>=1970:AND:Time<1980, 6262, 0)
Units: housing units/Year

(86) "Production PH 1980 - 1990"=IF THEN ELSE(Time>=1980:AND:Time<1990, 2860, 0)
Units: housing units/Year

(87) "Production PH 1990 - 2000"=IF THEN ELSE(Time>=1990:AND:Time<2000, 539, 0)
Units: housing units/Year

(88) "Production PH 2000 -"=IF THEN ELSE(Time>=2000, 2372, 0)
Units: housing units/Year

Equations 81 to 88 represent the evolution of public housing in Bogotá. This inflow was estimated aggregating historical data from a variety of sources (*Secretaría del Habitat and Universidad Piloto de Colombia*, 2008; ICT, 1997; Saldarriaga, 1996). Since it was not possible to find annual data, the production per decade for the different public housing authorities was calculated and, then, the annual average was computed. In this calculation, I included the production of ICT (*Instituto de Credito*

Territorial), CVP (*Caja de la Vivienda Popular*), and METROVIVIENDA. Other public offices involved in the production of housing such as FAVIDI (*Fondo de Vivienda Distrital*), CVM (*Caja de la Vivienda Militar*), FNA (*Fondo Nacional del Ahorro*) and BCH (*Banco Nacional Hipotecario*), were not considered in this estimation because they were oriented to middle- and high-quality housing since they produced units for public employees and members of the army. Table A1 summarizes the information related to the production of public housing in Bogotá.

Table A.1 Public Housing in Bogotá 1938 - 2005

Period	ICT	CVP	Metro-vivienda	Total per decade	Annual Average
1938-1950	2,098	1,074		3,172	264
1950-1960	5,776	30		5,806	581
1960-1970	34,389	2,567		36,956	3,696
1970-1980	52,337	10,283		62,620	6,262
1980-1990	23,214	5,387		28,602	2,860
1990-2000		5,387		5,387	539
2000-2005		2,694	9,167	11,860	2,372
Total per Housing Authority	**117,814**	**27,423**	**9,167**	**154,403**	**2,305**

Sources: *Secretaría del Habitat and Universidad Piloto de Colombia*, 2008; ICT, 1997; Saldarriaga, 1996

Public housing stock

(89) "Public Housing (PH)"= INTEG (Production PH-Abandonment PH-Demolition PH,0)
Units: housing units

(90) Production PH=Annual Production PH
Units: housing units/Year

(91) Demolition PH="Public Housing (PH)"/Normal Demolition PH
Units: housing units/Year

(92) Normal Demolition PH=600
Units: Year

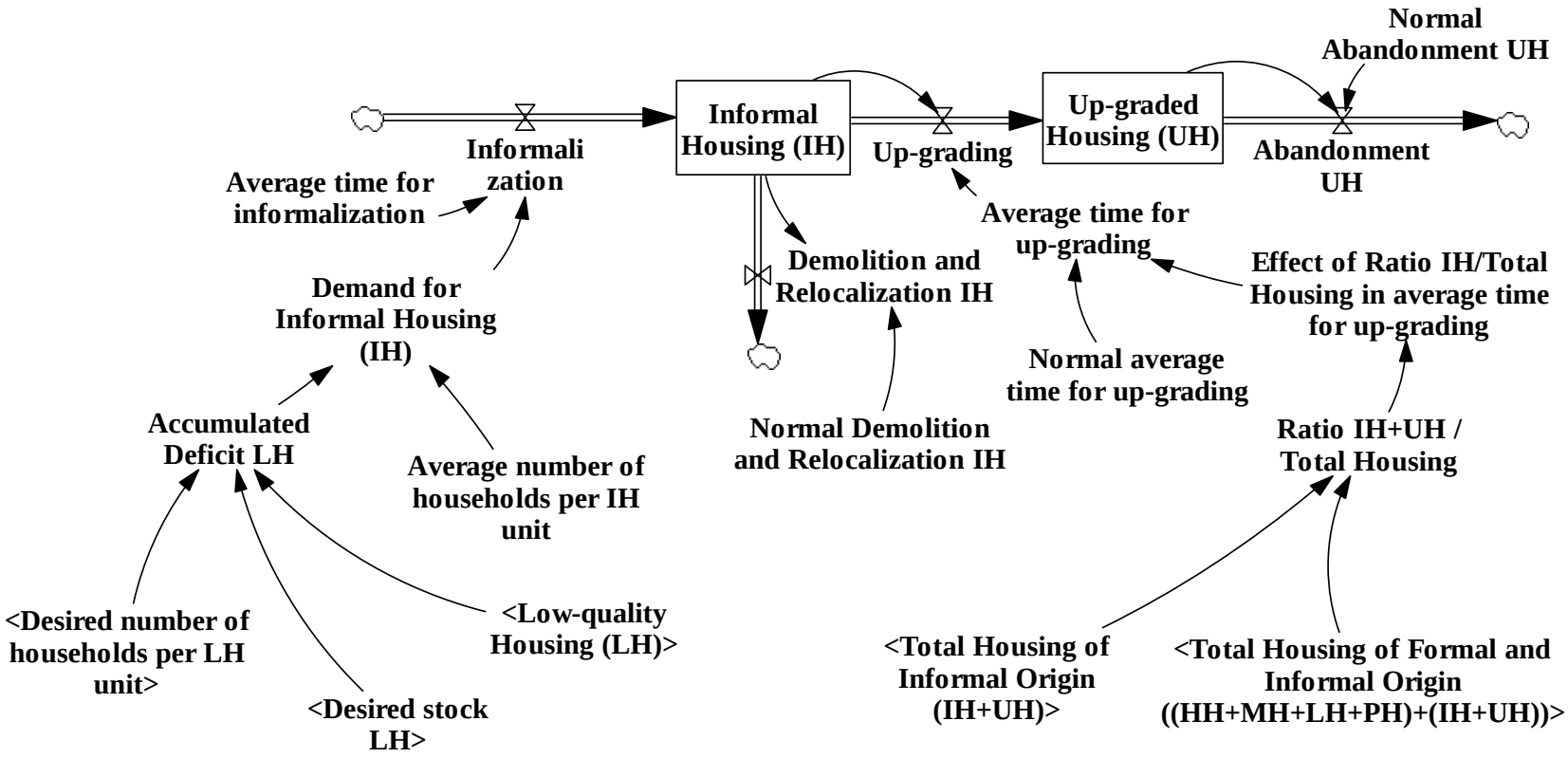
(93) Abandonment PH="Public Housing (PH)"/Normal Abandonment PH
Units: housing units/Year

(94) Normal Abandonment PH=120
Units: Year

Equations 89 to 94 represent the stock of public housing. Equation 90 states that the only inflow to this stock is the annual production (described in the last section). Equations 91 and 92 define the outflow of demolition which is assumed to be equal to the demolition of low-quality housing units (the normal demolition time is the same) since there are not reasons to think that these flows should behave differently. Equations 93 and 94 represent the outflow of abandonment which is assumed to be less likely than the abandonment of low-quality housing (the normal abandonment time is twice that of low-quality housing) this is because the relative scarcity of public housing units and the fact that their price and mortgages are subsidized.

A.4 INFORMAL HOUSING

This sector represents the process of informalization and the evolution of the stock of informal housing in the city. It includes the operationalization of two policies, up-grading and relocalization. Its structure is represented in Figure A.4 and its equations are operationalized as follows:



FigureA.4 Informal Housing

Informalization

(95) "Demand for Informal Housing (IH)"=Accumulated Deficit LH/Average number of households per IH unit
Units: housing units

(96) Accumulated Deficit LH=(Desired stock LH-"Low-quality Housing (LH)")*Desired number of households per LH unit
Units: household

(97) Average number of households per IH unit=1.5
Units: household/housing unit

(98) Informalization=MAX("Demand for Informal Housing (IH)"/Average time for informalization, 0)
Units: housing units/Year

(99) Average time for informalization=1
Units: Year

(100) "Informal Housing (IH)"= INTEG (Informalization-Demolition and Relocalization IH-"Up-grading",2670)
Units: housing units

(101) Demolition and Relocalization IH="Informal Housing (IH)"/Normal Demolition and Relocalization IH
Units: housing units/Year

(102) Normal Demolition and Relocalization IH=600
Units: Year

Equations 95 to 99 represent the process of informalization. Equation 95 defines the demand for informal housing as the ratio of the deficit for low-quality housing to the number of households per informal unit. In essence, this condition is stating that informality will depend on the failure of the production of formal housing to absorb the increases in demand (equation 96). Equation 97 defines the average number of households per IH unit as 1.5. This number is higher than in the case of formal low-quality housing, which was assumed as 1, because crowding will be a rational response to the conditions of housing deficit households.

This is also related to one of the most important characteristics of informal housing: the 'urbanistic freedom' associated with the non-compliance of planning requirements that allows the expansion of the accommodations to generate extra-income through rental and commercial activities (Abramo, 2007). According to Gilbert (1999) two thirds of informal settlers in Bogotá obtain supplementary income from their houses and according to Doebele (1977) one third of informal units have rooms that are rented to other households. Extrapolating this information, it can be calculated that the average number of households per unit in the informal market is between 1.33 and 1.67. For the simulation an average of 1.5 was selected taking into account these descriptions and the fact that the average number of households in strata 1 and 2 is 1.54 (SDP, 2005).

This demand for informal housing is transformed in an inflow of informalization by dividing it by the average time of informalization (equation 98). This equation includes a control to prevent the inflow from becoming negative under the extreme condition that there is surplus of housing in the lower category. Equation 99 defines the average time of informalization as one year because most accounts describe that informal settlers occupy the land immediately after its acquisition and start the process of self-construction very quickly: according to Doebele (1977), 94 percent of informal settlers begin construction within a year as a way to reassure occupation. Equation 100 represents the stock of informal housing as the accumulation of informalization. The initial value of 2,670 units is taken from the estimation of Jaramillo (1980) about the informal stock in 1938. Equations 101 and 102 operationalize one of the two outflows affecting the stock of informal housing: the demolition and relocalization of informal units. The normal rate of this outflow is defined as being equal to the demolition of formal low-quality and public housing (the average time in all these cases is 600).

This is because, relocalization and eviction of informal housing in Bogotá are uncommon in part because of the prevalence of the system of 'pirate subdivision' in which legal owners subdivide and sell peripheral land to informal settlers. In this system, as opposed to the pattern of 'invasion' of public or private land which is widely found in other Latin American cities, the transaction can be considered legitimate because it is consensual, although it cannot be considered completely legal since the subdivision and urbanization are not approved by the planning department. For these reasons, forced evictions, which are common in the cases of invasion, and squatting, are rare in the overall picture of informality in Bogotá since the number of housing units produced through these processes is less than 0.7 percent of the total stock (Gilbert, 1981). In general, relocalization only takes place when the informal units are located in zones of hazard risk (Roda, 2000).

Up-grading

(103) "Up-grading"="Informal Housing (IH)"/"Average time for up-grading"
Units: housing units/Year

(104) "Average time for up-grading"="Normal average time for up-grading"*"Effect of Ratio IH/Total Housing in average time for up-grading"
Units: Year

(105) "Normal average time for up-grading"=30
Units: Year

(106) "Ratio IH+UH / Total Housing"=
"Total Housing of Informal Origin (IH+UH)"/"Total Housing of Formal and Informal Origin ((HH+MH+LH+PH)+(IH+UH))"
Units: Dmnl

(107) "Effect of Ratio IH/Total Housing in average time for up-grading" = WITH LOOKUP("Ratio IH+UH / Total Housing",([(0,0)-(1,1)],(0,1),(0.25,0.75),(0.5,0.5),(0.75,0.25),(1,0.0001)))
Units: Dmnl

(108) "Up-graded Housing (UH)"= INTEG ("Up-grading"-Abandonment UH, 0)
Units: housing units

(109) Abandonment UH="Up-graded Housing (UH)"/Normal Abandonment UH
Units: housing units/Year

(110) Normal Abandonment UH=240
Units: Year

Equations 103 to 110 represent the process of up-grading. Since this process entails the provision of services to informal settlements a posteriori, it has been defined as an outflow from the stock of informal housing (equation 103) that creates a stock of up-graded housing (equation 108), which, although its informal origin, is qualitatively different from the informal stock. The rate of up-grading is defined by the average time for up-grading (equation 104). In the initial conditions of the model in 1938 this time is defined as 30 years (equation 105). This is because qualitative information suggests that in Bogotá before 1950 the average period between the origination of an informal settlement and its legalization, a process related to up-grading, was more than 24 years (*Secretaría del Habitat and Universidad Piloto de Colombia*, 2008).

This initial 'normal' time is assumed to be affected by the incidence of informality in the city: if a higher proportion of the built space is informal there will be more pressure to up-grade these units since the negative externalities produced by the lack of services will start to affect formal areas. Likewise, as the up-graded stock grows the situation for non-up-graded informal settlers will become less bearable and there will also be more pressure for up-grading. This process is captured in equations 106 and 107 that transform the proportion of housing of informal origin, the informal and up-graded stocks, to the total stock into an effect that decreases the average time for up-grading as the incidence of informality increases.

Equation 107 represents this effect through a 'table function' (a relation of independent and dependent variables) as a perfectly linear relation stating that when

the proportion of informal settlements to the total stock is zero the effect is null and that for each percentage point increase in the proportion, the normal initial time decreases in one percentage point. This linear relation was assumed since it was not possible to find information that suggested other type of relation. The table function excludes an effect equal to zero to prevent a mathematical error in the extreme condition that 100 percent of the stock is informal.

Equation 108 defines the stock of up-graded housing as the accumulation of up-grading. Equation 109 defines abandonment as an outflow from this stock. In equation 110 a lower rate of abandonment than in the formal stocks is assumed (the time for abandonment is four times that of low-quality housing and twice that of public housing) since up-graded units have the advantages of 'urbanistic freedom' that allow the expansion and adaptation of the space (Abramo, 2007).

A.5 TOTAL HOUSING OF FORMAL AND INFORMAL ORIGIN

This sector aggregates the information produced in the model into auxiliary variables that are comparable to the historical data of the housing stocks in Bogotá that serve as reference mode in this model. Its structure is represented in Figure A.5 and its equations are operationalized as follows:

(111) "Total Housing of Formal Origin (HH+MH+LH+PH)"="High-quality Housing (HH)"+"Middle-quality Housing (MH)"+"Low-quality Housing (LH)"+"Public Housing (PH)"
Units: housing units

(112) "Total Housing of Informal Origin (IH+UH)"="Informal Housing (IH)"+"Up-graded Housing (UH)"
Units: housing units

(113) "Total Housing of Formal and Informal Origin ((HH+MH+LH+PH)+(IH+UH))"="Total Housing of Formal Origin (HH+MH+LH+PH)"+"Total Housing of Informal Origin (IH+UH)"
Units: housing units

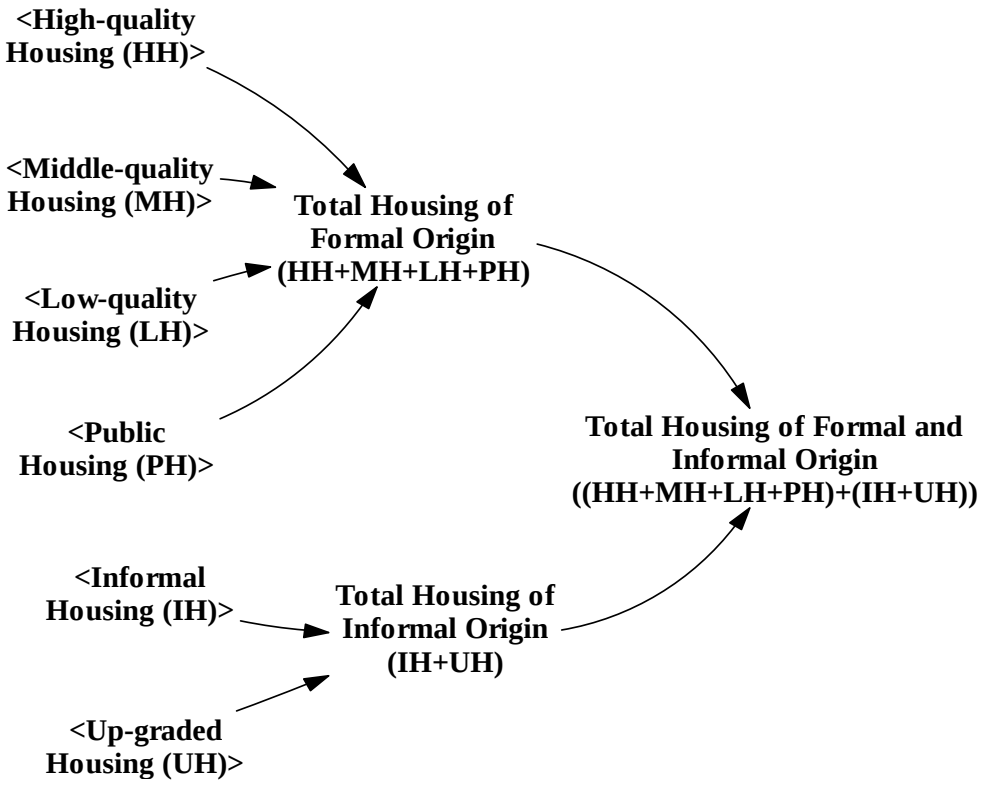


Figure A.5 Total Housing of Formal and Informal Origin

Equation 111 defines the stock of housing of formal origin as the sum of high-, medium-, and low-quality stocks plus the stock of public housing. Equation 112 states that the stock of total housing of informal origin is equal to the informal and up-graded stocks. Equation 113 aggregates all these stocks to calculate the total housing stock in the city.

A.6 TOTAL COSTS OF PROVISION OF LOW-INCOME HOUSING

This sector represents the total cost of provision of low-income housing calculating auxiliary variables that capture the cost of provision of services as well as the costs of interventions such as public housing and relocalization. To represent the redistributive dimension of the provision of low-income housing the costs are disaggregated in public costs paid through contributions or from the general budget and cost paid by the low-income households. The structure of this sector is represented in Figure A.6 and its equations are operationalized as follows:

Cost of service provision for low-quality housing

(114) Cost of Production LH=Normal Cost of Production LH*(1-"Minimum Requirements Policy 1973 - 1980"-"Minimum Requirements Policy 1991 - 1997")
Units: LTAC/housing units

(115) Normal Cost of Production LH=1
Units: LTAC/housing units

(116) Annual Public Cost of Production LH=Production LH*(Cost of Production LH-Tariff LH)
Units: LTAC/Year

(117) Accumulated Public Cost of Production LH= INTEG (Annual Public Cost of Production LH,0)
Units: LTAC

(118) "Annual Cost of Production LH for Low-income Households"=Production LH*Tariff LH
Units: LTAC/Year

(119) "Accumulated Cost of Production LH for Low-income Households"= INTEG ("Annual Cost of Production LH for Low-income Households",0)
Units: LTAC

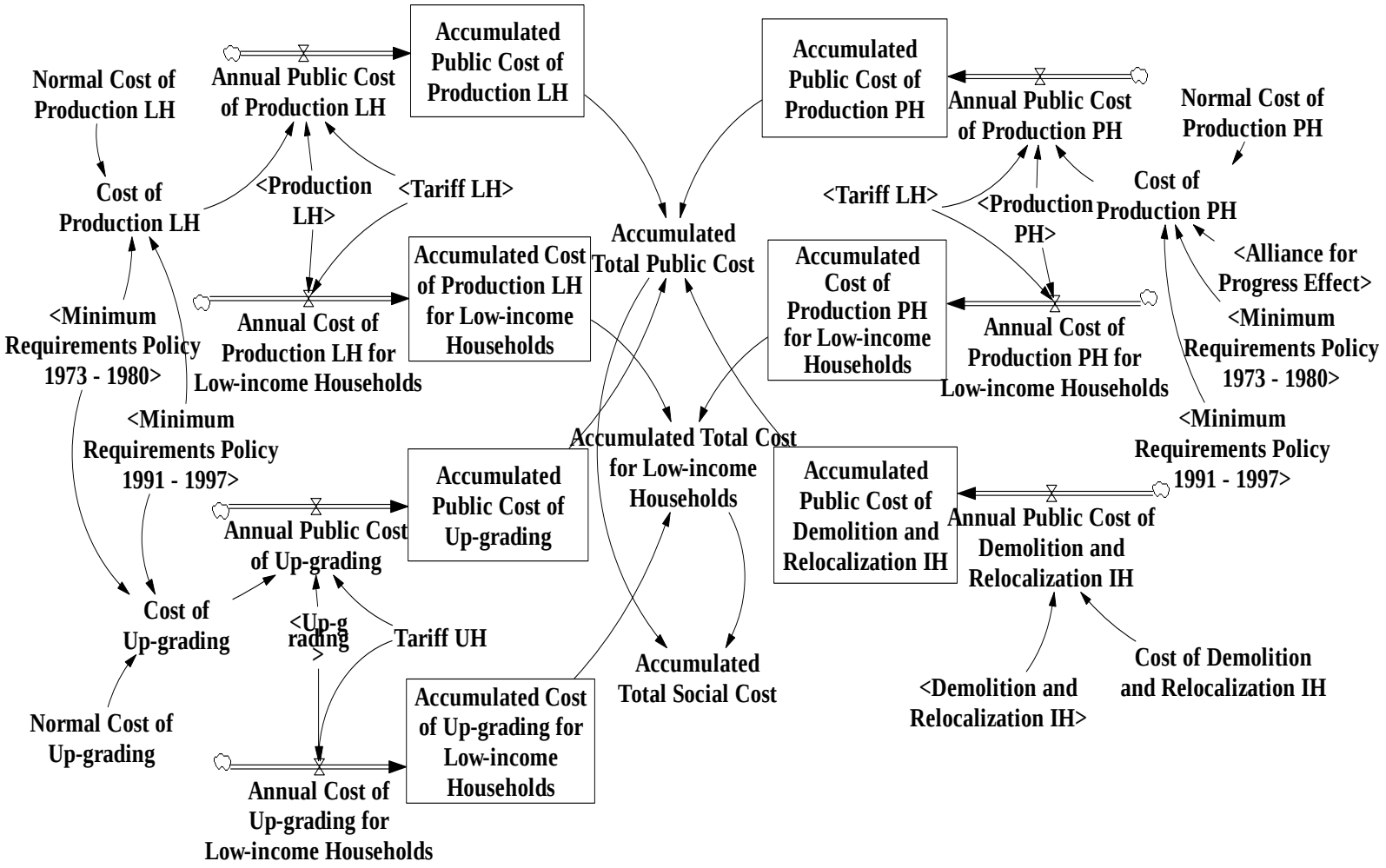


Figure A.6 Total Cost of Provision of Low-income Housing

Equations 114 and 115 represent the cost to provide services to low-quality housing. In normal conditions this cost per unit is equal to the average long term cost of service provision (equation 115) but it decreases with the policy of minimum requirements since this intervention lowers the average cost for this type of housing (equation 114). Part of this cost is paid by the same households occupying low-quality housing through the tariff, so the annual cost for low-income households in a given year is the tariff times the production (equation 118) and the accumulated cost is its integral (equation 119). The other part is paid through cross-subsidies from contributions and through transferences from the general budget. Equation 116 represents the annual public cost as the difference between the costs of provision and the tariff (i.e. the subsidy) times the production of low-quality housing. Equation 117 represents the accumulation of this public cost.

Cost of service provision for up-graded housing

(120) "Cost of Up-grading"="Normal Cost of Up-grading"*(1-"Minimum Requirements Policy 1973 - 1980"-"Minimum Requirements Policy 1991 - 1997")
Units: LTAC/housing units

(121) "Normal Cost of Up-grading"=3
Units: LTAC/housing units

(122) "Annual Public Cost of Up-grading"="Up-grading"*("Cost of Up-grading"-Tariff UH)
Units: LTAC/Year

(123) Tariff UH=1
Units: LTAC/housing units

(124) "Accumulated Public Cost of Up-grading"= INTEG ("Annual Public Cost of Up-grading",0)
Units: LTAC

(125) "Annual Cost of Up-grading for Low-income Households"="Up-grading"*Tariff UH
Units: LTAC/Year

(126) "Accumulated Cost of Up-grading for Low-income Households"= INTEG ("Annual Cost of Up-grading for Low-income Households",0)
Units: LTAC

As it was explained in the description of the second sector of the model, the cost of up-grading a unit was estimated at 3 times the cost of providing a formal unit, which is equivalent to 3 long term average costs (equation 121). This cost is affected by the policy of minimum requirements (equation 120). One third of it is paid by the households through tariffs and contributions in money and time (equation 123) and two thirds are paid by the public sector through cross-subsidies and transferences from the general budget (equation 122). The total annual costs for the public and the low-income households are obtained using these weights and the total production per year (equations 122 and 125) and the accumulated costs are the integral of the annual costs (equations 124 and 126).

Cost of service provision for public housing

(127) Cost of Production PH=Normal Cost of Production PH*(1-"Minimum Requirements Policy 1973 - 1980"-"Minimum Requirements Policy 1991 - 1997")*Alliance for Progress Effect
Units: LTAC/housing units

(128) Normal Cost of Production PH=6
Units: LTAC/housing units

(129) Annual Public Cost of Production PH=Production PH*(Cost of Production PH-Tariff LH)
Units: LTAC/Year

(130) Accumulated Public Cost of Production PH= INTEG (Annual Public Cost of Production PH,0)
Units: LTAC

(131) "Annual Cost of Production PH for Low-income Households"=Production PH*Tariff LH
Units: LTAC/Year

(132) "Accumulated Cost of Production PH for Low-income Households"= INTEG ("Annual Cost of Production PH for Low-income Households",0)
Units: LTAC

The total costs per public unit include not only the costs of trunk and secondary service provision paid by the utilities but also the costs of housing subsidies and written-off debts paid from the budget of the housing authorities. According to information from Roda (2000) this total cost per public unit was estimated at 6 times the cost of providing trunk services to a formal unit, which is equivalent to 6 long term average costs (equation 128). This cost is affected not only by the policy of minimum requirements but also by the pilot tests of this policy conducted in the projects funded by the Alliance for Progress (equation 129). Part of this cost is covered by the households through tariffs for public services, which in this case are equal to the tariff paid in low-quality housing. Therefore, the annual cost for low-income households is equal to the production times the tariff at any given year (equation 131) and the accumulated cost is equal to the integral of the annual production (equation 132). The rest is paid by the public sector through cross-subsidies and transferences (equations 129 and 130).

Cost of demolition and relocalization

(133) Cost of Demolition and Relocalization IH=5.5
Units: LTAC/housing units

(134) Annual Public Cost of Demolition and Relocalization IH=Demolition and Relocalization IH*Cost of Demolition and Relocalization IH
Units: LTAC/Year

(135) Accumulated Public Cost of Demolition and Relocalization IH= INTEG (Annual Public Cost of Demolition and Relocalization IH,0)
Units: LTAC

The costs for relocalization of informal housing involve a payment from the municipality recognizing the improvements achieved through the process of self-

construction. In addition, in more than 70 percent of the cases it involves technical assistance, a subsidy, and access to credit to facilitate the process of finding an alternative accommodation in the formal market. Using information from Roda (2000) and weighting these factors the average cost of relocalization was estimated at 5.5 the cost of providing trunk services to formal unit, or 5.5 long term average costs (equation 133). The annual cost of relocalization is the cost per unit times the number of relocalized units (equation 134) and the aggregate cost is integral of the annual cost (equation 135).

Total costs for public sector and low-income households

(136) "Accumulated Total Cost for Low-income Households"="Accumulated Cost of Production LH for Low-income Households"+"Accumulated Cost of Production PH for Low-income Households"+"Accumulated Cost of Up-grading for Low-income Households"
Units: LTAC

(137) Accumulated Total Public Cost=Accumulated Public Cost of Production LH+Accumulated Public Cost of Production PH+"Accumulated Public Cost of Up-grading"+Accumulated Public Cost of Demolition and Relocalization IH
Units: LTAC

(138) Accumulated Total Social Cost=Accumulated Total Public Cost+"Accumulated Total Cost for Low-income Households"
Units: LTAC

The accumulated total cost for low-income households is the sum of the accumulated costs for low-quality, up-graded, and public housing that are paid by the households (equation 136). The accumulated total cost for the public sector is the sum of the accumulated costs for low-quality, up-graded, and public housing plus the cost of demolition and relocalization, costs that are paid by the utilities with monies from contributions and by transferences from the general budget (equation 137). The total cost for society is the sum of the costs for the households and the public sector (equation 138).

Table A.2 summarizes the costs according to the type of intervention. This table presents a description of the intervention, the monetary cost per housing unit in Colombian Pesos (COP) of the year 2000, the cost in terms of long term average cost (LTAC), and the information source. It is important to note that the costs of maintaining the infrastructure are assumed to be proportional to the cost of the investment. Therefore, the number of LTAC per intervention is calculated by dividing its cost by the cost of providing trunk services for a formal low-quality unit.

Table A.2 Costs of Different Public Interventions in Bogotá

Intervention	Description	Cost in COP	Cost in LTAC	Source
Service Provision	Includes trunk infrastructure	$1,350,000	1	Roda (2000)
Public Housing	Includes trunk and secondary infrastructure, and housing subsidy	$7,879,200	6	Roda (2000)
Service Provision for Public Housing	Includes trunk and secondary infrastructure	$3,150,000	2.33	Roda (2000)
Demolition and Relocalization (simple: 29 percent of cases)	Includes payment recognizing the improvements of self-construction	$3,000,000		Roda (2000)
Demolition and Relocalization (complete: 71 percent of cases)	Includes payment recognizing the improvements plus technical assistance, and housing and credit subsidy	$9,090,000		Roda (2000)
Demolition and Relocalization (aggregated)	Weighted average of the costs of relocalization according to the incidence per type (simple and complete)	$7,323,000	5.5	Roda (2000)
Up-grading	Includes trunk infrastructure (and in some cases secondary infrastructure) a posteriori		(2,5 to 3,78)	Roda (2000), Aristizabal and Gomez (2002), Cities Alliance (2006)

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