A System Dynamics Approach to Sustainable Cities

by

Dr. Michael J. Radzicki
Department of Social Science & Policy Studies
Worcester Polytechnic Institute
Worcester, Massachusetts 01609-2280
United States of America
(508) 831-5767 (Voice)
(508) 831-5896 (Fax)
mjradz@wpi.edu

Dr. W. Scott Trees
Department of Economics
Siena College
Route 9
Loudonville, New York 12211
United States of America
(518) 783-2557 (Voice)
trees%siena.bitnet@vm.its.rpi.edu

> Governments and citizens at local and national levels are taking the United Nations' mandate for "Local Agenda 21s" very seriously. Campaigns are beginning or underway in more than 20 countries. These efforts are producing new tools and innovative approaches for municipal environmental management, urban services provision, and development policy.[1]

Abstract

The idea of sustainable cities has become central to the concept of sustainable economic development. This paper demonstrates that system dynamics modeling can be effectively used to study the forces preventing the sustainable development of cities. The problems being experienced by cities located in both the less industrialized and industrialized nations are examined, and a slate of current policy prescriptions is described. Simulation runs from a system dynamics model created to examine some of the barriers to the sustainable development of cities are presented and their implications for public policy are discussed.

Introduction

In 1992 in Rio de Janeiro, the United Nations Conference on Environment and Development adopted Agenda 21, a document which calls upon the nations of the world to work toward a system of global sustainable economic development (Sitarz 1993). Two years later, delegates met at a follow-up conference in Manchester, England, to discuss the ways in which sustainable economic development could be practically achieved. More specifically, one of the main themes of the Manchester conference was "Sustainable Cities" -- a term reflecting the notion that sustainable economic development can only be achieved through efforts begun at the local level.

The idea of sustainable cities has thus become central to the notion of sustainable economic development. Indeed, many cities have created organizations whose primary goal is to foster sustainable development in their regions (e.g., Sustainable Seattle 1993). While many of these groups have done a splendid job mobilizing volunteers, raising funds, and gathering data, they

[1] Jeb Brugman. 1994. Global Forum '94: Cities and Sustainable Development. p. 1.

appear to lack a method for clarifying thinking, integrating information and, in general, deciding how to use resources wisely.

The purpose of this paper is to show that system dynamics modeling can be effectively used to study the forces preventing the sustainable development of cities. The paper first reviews the various existing definitions of sustainable development and how they are being applied to urban areas. The implications of applying the notion of sustainability to cities located in both the less industrialized and industrialized nations are examined next. The paper then briefly reviews the existing system dynamics literature on the dynamics of cities. Finally, simulation runs from a system dynamics model created to examine some of the barriers to the sustainable development of cities are presented. Some implications for public policy are also discussed.

What is Sustainable Economic Development?

The general concept of sustainable economic development has been in existence for more than two decades.[2] Yet, a precise definition of the concept, that is agreed to by a majority of social and natural scientists, still does not exist. Tisdell (1988), for example, describes the differing views towards sustainability put forth by economists and ecologists,[3] and Barbier (1987), Brown et al. (1987), Lélé (1991), and Viederman (1993) survey a more general list of definitions and disagreements. Herman Daly (1994), arguably one of the "founding fathers" of the sustainability movement, disagrees strongly with any definition of sustainable development that seeks to equate it with the notion of "sustainable growth." Indeed, he finds the idea of "sustainable growth" to be oxymoronic (Daly 1994, p. 1). Notably, this leads Daly to disagree with many proponents of sustainability, who make the "sustainable growth" of the world economy a pillar of their policy recommendations.[4]

Although there are many opinions about the proper meaning of the term sustainable development, one must be chosen (or created) for any sort of analysis to proceed. Thus, in this paper, the definition of sustainable economic development will be taken primarily from the work of Herman Daly (1994). Daly's perspective has been chosen as it is in harmony with much of the work in development economics and urban dynamics that has been done to date by system dynamicists (e.g., Forrester 1969, 1970; Mass 1974; Schroeder et al. 1975; Alfeld and Graham 1976; Meadows, et al. 1972, 1992; Saeed 1991, 1994).

---

[2] Barbier (1987, p. 102) notes that the 1972 United Nations Conference on Human Environment, held in Stockholm, is usually credited with popularizing the concept of sustainable development, but that the idea probably originated at either the 1968 Paris "Biosphere Conference" or the 1968 Washington, D.C. conference on the Ecological Aspects of International Development. Sustainable Seattle (1993, p. 2), on the other hand, argues that the notion of sustainable development came into wide-spread use only after the 1987 publication of the United Nations' World Commission on Environment and Development report -- the so-called "Brundtland Report" (Brundtland 1987). System dynamicists might argue that the concept of sustainable economic development was precisely defined by Forrester in his Urban Dynamics and World Dynamics models, created as early as 1969 and 1970 respectively (see Forrester 1969, 1970).

[3] See also Solow (1993) and Toman et al. (1994).

[4] See for example, Brundland (1987).

In this paper the term sustainable development will mean choosing policies that balance environmental preservation and economic development, so as to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. To illustrate the types of problems associated with this goal, it is useful to refer to Figure 1, which presents a simple overview of the global ecological-economic system. Inspection of Figure 1 reveals that the global ecological-economic system is essentially "closed." This means that, except for the receipt of solar energy from outer space and the dispersion of heat to outer space, the system is self-contained. The people living in the global system use both nonrenewable and renewable resources (which are limited) to produce goods and services that sustain and enhance life on the planet. Unfortunately, the process of creating goods and services also generates pollution that must be dispersed into the land, sea, and air. As shown in Figure 1, the amount of pollution that these "sinks" can absorb is also limited.

For the global system to sustain itself indefinitely, renewable resources must not be used faster than the rate at which they can be regenerated, nonrenewable resources (taking recycling into account, which is also a limited process) must not be used faster than the rate at which they can be substituted for, and pollution must not be generated faster than the rate at which the system can absorb it (Daly 1994).

The Concept of Sustainable Development Applied to Cities

The application of the concept of sustainable development to cities is similar to its application to the global system as a whole. Again referring to Figure 1, it is clear that cities have sources and sinks, and utilize resources and generate pollution, just as the global system does. The main difference between the two entities is that cities are not fully closed systems. That is, unlike the global system, cities can import resources and export pollutants. However, these importing and exporting activities have limits. For example, the trucking of garbage to landfills outside of a city becomes increasingly costly, the farther from the city the landfills are located (Hardoy, et al. p. 141), and the importation of fresh water to replenish a city's depleted aquifers becomes increasingly costly, the greater the distance the water must be piped (Fox 1994, p. 356).

Thus, as with all real social systems, cities have limited carrying capacities. If the carrying capacity of a city is eroded, it becomes increasingly difficult, if not impossible, to create a sustainable environment. As in the case of the global system as a whole, sustainable cities must not use resources faster than they can be replenished or substituted for, nor generate pollution faster than it can be naturally assimilated. Further, the infrastructure (carrying capacity) of a sustainable city must be able to support the current needs of its population -- particularly its poorest citizens. If these criteria are followed, the ability of future generations to meet their needs will not be compromised.

In terms of system dynamics modeling, the notion of sustainability has a very precise definition. More specifically, a system dynamics model of a sustainable city is one that is in a state of dynamic equilibrium. This occurs when all of the model city's stocks are at their desired levels simultaneously and all inflows to its stocks are exactly balanced by outflows from its stocks. Such a state is still "dynamic" in the sense that there are continuous flows of information and material units throughout the model city, yet the model city's stocks are not changing and its state is sustainable far into the future.

Global Urbanization Trends

One of the main difficulties in meeting the criteria for sustainable cities throughout the world is the rapid pace of urban population growth. Essentially, urban populations have been growing exponentially and overwhelming the ability of urban infrastructures[5] to handle the demands being placed on them. In terms of Figure 1, the exponential growth of the world's urban populations has led to an exponential growth in the use of renewable and nonrenewable resources in cities and an exponential increase in the dispersion of pollutants to the world's urban environments. These trends have, in turn, led to a situation in which the basic needs of the poorest urban dwellers are not being met and the quality of life for all urban dwellers is being diminished.[6]

To illustrate the extraordinary pace of urban population growth that has taken place during the last four decades, and to provide a look at the likely state of the world's urban centers in the near future, it is useful to examine Tables 1, 2, and 3. Inspection of these tables reveals that the world's population, whether living in the less industrialized or the industrialized nations, is becoming increasingly and significantly urbanized.

Causes of Urban Population Growth

According to Chen and Zlotnik (1994, p. 344 and p. 346), there are three principal causes of urban population growth: 1) natural increase -- i.e., a city's birth rate exceeding its death rate; 2) net rural in-migration; and 3) reclassification of land from rural to urban. Based on limited United Nations' data, it appears that 61% of urban population growth in the less industrialized nations is due to natural increase and 39% is due to a combination of net rural in-migration and reclassification of land. In the industrialized nations, on the other hand, 40% of urban population growth is due to natural increase and 60% is due to net rural migration and land reclassification Chen and Zlotnik (1994, p. 344 and p. 346).

Sustainability Problems Facing Cities Located in the Less Industrialized Nations

As previously mentioned, the fundamental force that is preventing the world's cities from developing sustainably is the exponential growth of urban populations, relative to the limited ability of urban infrastructures to meet the concomitant demands being placed on them. In terms of a more specific list of urban problems that have arisen due to the overwhelming of, and erosion of, the world's urban infrastructures, Hardoy et al. (1992, pp. 125-126) have identified seven problems that "despite [the] great diversity between nations in the scale and nature of urban change...have been shown to be common to most urban centres." These problems are summarized in Table 4. Inspection of the table shows that, quite clearly, urban environmental problems and

---

[5] For example, pollution controls, public services and facilities, land management for housing, and land management for the protection of ecosystems that surround cities (e.g., farmlands, forests, and aquatic ecosystems).

[6] For a similar analysis of the global sustainability problem see Meadows et al. (1972) and Meadows et al. (1992).

urban economic problems are interrelated and directly influence the quality of life of the world's urban citizenry.

Despite the problems they suffer due to their exponentially increasing numbers, Hardoy et al. (1992, pp. 124-125) point out that urban dwellers who live in less industrialized nations are better than urban dwellers who live in industrialized nations vis-à-vis the sustainable use of resources and the global commons. This is because they: 1) have a much lower rate of per capita resource use and waste generation; 2) utilize more recycled materials in their housing construction; 3) use relatively less capital that consumes nonrenewable resources; 4) use public transportation, walking, and bicycling more often; and 5) consume lower amounts of electricity and water per capita. However, Hardoy et al. (1992, pp. 124-125) also note that low per capita levels of, say, water consumption do not meet the definition or spirit of sustainable development if they imply that many urban dwellers lack sufficient water for drinking, cooking, and personal hygiene. Similarly, high rates of urban recycling do not meet the spirit or definition of sustainability if they imply that a majority of urban dwellers reside in substandard housing, created out of materials such as cardboard.

Sustainability Problems Facing Cities Located in the Industrialized Nations

In many respects, the sustainability problems faced by urban dwellers who live in the industrialized nations are similar, if not identical, to those faced by urban dwellers who live in the less industrialized nations. This is because, although the rate of urban population growth is significantly less in cities located in the industrialized nations, the per capita use of resources and the per capita generation of pollution are significantly greater. Many urban policy makers and citizens groups, such as the Truckee Meadows Regional Planning Agency (Life in the Truckee Meadows 1994) and Sustainable Seattle (1993), have recognized this fact and have attempted to measure the dynamic behavior of various economic, environmental, and cultural variables that they feel help to define their city's "quality of life."[7] These groups have also recognized that many "linkages" exist between the variables they have identified, and that specifying the linkages helps to define a "whole system" view of a city -- i.e., a view that takes into account the interactions within and among human and natural systems (Sustainable Seattle 1993, p. 5).

Proposed Solutions to the Urban Sustainability Problem

Urban policy makers have been studying the problems of cities for years and have arrived at many recommendations for improving the quality of urban life and, more recently, for fostering sustainable urban development. Chen and Zlotnik (1994, p. 349), for example, note that despite their deficiencies in infrastructure and services, cities are still the core of modern economic activity, particularly in the less industrialized nations. The challenge, they argue, is to harness the economic dynamism to fuel sustainable development more generally.

Hardoy, et al. (1992, pp. 142-148) have specified the details of an "alternative urban future" for cities in less industrialized nations which can be created, they argue, if the following changes are instituted: 1) low income groups organize and win a political voice; 2) technical help is

[7] The group Sustainable Seattle (1993, p. 2) defines sustainability as "long-term cultural, economic, and environmental health and vitality."

received from international development agencies; 3) collaboration between local governments and community organizations is established to install and maintain urban infrastructure and services; 4) local governments provide cheap and well-located sites for low income housing and cheap materials for building low income housing; 5) nongovernmental organizations (NGOs) are established to give advice and make loans to low income households; 6) local governments start internalizing spillover costs -- particularly those associated with pollution; 7) local governments provide services such as fresh water at rates that reflect their true costs -- i.e., eliminate subsidies; 8) local governments guarantee urban dwellers sufficient nutritional intake and health care; 9) local governments work actively on preventive health care via the creation and maintenance of safe and sufficient water supplies, sanitation systems, drainage systems, garbage collection programs, and paved roads.

This list of policy recommendations can be supplemented with Chen and Zlotnik's (1994) observation that rural development programs must go hand and hand with urban development programs, or the flow of rural-to-urban immigrants cannot be reduced. More specifically, Chen and Zlotnik argue that providing rural populations only with education and linkages to cities, raises expectations and prompts more migration to cities. What is needed, therefore, are comprehensive rural development programs which include (in addition to education) increased health care and family planning services, increased agricultural productivity, increased rural employment opportunities, and increased linkages to small and medium sized cities.

The Urban Dynamics Literature

Most system dynamicists will recognize that many of the problems related to urban sustainability, as well as many of the proposed solutions, have already been addressed in the "urban dynamics literature."[8] For example, the fundamental reason for the growth, stagnation, and decline of cities in the urban dynamics literature is the exponential growth of the urban population (due mainly to net in-migration) in the limited physical space of the cities, and the erosion of the cities' carrying capacities (i.e., their business/employment sectors) due to the rules governing urban land use. Essentially the cities change from attractive places to move to and live in, to unattractive places, characterized by unemployed, low income households, trapped in low income housing. Extensions to the basic urban dynamics story have included such issues as the dynamics of arson and home insurance (Homer 1979a, 1979b) and the quality of life in "bedroom communities" that are attractive primarily for not having significant employment opportunities (Radzicki and Seville 1994).

One observation that can be made with respect to Hardoy et al's (1992) policy recommendations, based on a knowledge of the urban dynamics literature, is that they probably won't work unless successful rural development programs, such as those suggested by Chen and Zlotnik (1994), are simultaneously enacted. This is because Hardoy et al's programs will make cities more attractive places to live and hence attract additional migrants who will undermine the policy initiatives and push the system away from a sustainable state.

[8] See for example Forrester (1969), Mass (1974), Schroeder, et al. (1975), Alfeld and Graham (1976), Homer (1979a, 1979b), and Radzicki and Seville (1994).

The Need for a System Dynamics Approach to the Study of Sustainable Cities

Given that the system dynamics approach allows for a "whole system" analysis of cities, that it can provide a precise definition of sustainability, and that it has already been used to address the question of sustainability in a variety of social systems, it would appear that it is an ideal tool to use in the study of sustainable cities. Obvious immediate uses for system dynamics would be to: 1) help groups such as Sustainable Seattle model the variables they are currently measuring and the linkages they are currently specifying; 2) analyze the interactions between urban resource use, urban pollution generation, and urban economic activity; 3) analyze the interactions between urban resource use, urban pollution generation, urban economic activity, and other "quality of life indicators" that have been identified as crucial to the well-being of cities (e.g., "neighborhood cohesiveness" (see Homer 1979a, 1979b)); and 4) examine the long and short-term effects of proposed policy changes on the ability of cities to develop sustainably.

A System Dynamics Model for the Study of Sustainable Cities

In order to illustrate how the system dynamics method can be used to address the issues surrounding sustainable cities, a generic system dynamics model of a city, located in a less industrialized nation, will now be presented. An overview of the model's structure is described first, and some base run simulations of the model are presented next.

Figure 2 is a sector diagram of the sustainable city model. Inspection of the figure reveals that the model has five interacting sectors: demographic, business, housing, pollution, and government. Each of these sectors also influence a "quality of life" variable that tracks the combined behavior of a variety of system variables. Taken together, the five sectors describe the basic stock-flow-feedback loop structure of an urban area, and contain the variables and linkages that are seen by policy makers as crucial to understanding urban sustainability. The model is an extension of the URBAN2 model, originally created by Alfeld and Graham (1976).

Demographic Sector

Consistent with the Urban Dynamics literature, the demographic sector of the sustainable city model divides the urban population into three income groups: low, middle, and high. Each of these groups is disaggregated into four age categories: 0-14, 15-46, 46-65, and 66 Plus. This is done so that some important urban dynamics, including: in- and out-migration, which differs by age and income group (Greenwood 1975), and the dependency ratio (i.e., the ratio of the nonworking to the working), which is an important measure of the economic support available to the city's population (Todaro 1994, pp. 186-187), can be simulated. Figure 3 is a stock-flow diagram of the low income sub sector of the sustainable city model.

Business Sector

Figure 4 is a stock-flow diagram of the business sector of the sustainable city model. Inspection of the figure reveals that the model distinguishes between new, mature, and deteriorating business structures. New structures age into mature structures which, in turn, age into deteriorating structures. Further, each simulated year, some of the mature and deteriorated business structures are rehabilitated, either partially or fully. As in the URBAN2 model,

construction of new business structures is influenced by the availability of land and labor, and the ability of firms to utilize existing, mature, business structures.

Housing Sector

Figure 5 is a stock-flow diagram of the housing sector of the sustainable city model. Inspection of the figure reveals that the housing stock is divided into low, middle, and high income dwellings and that the high income dwellings age into middle income dwellings which, in turn, age into low income dwellings. Further, a distinction is made between middle income dwellings that are built as middle income dwellings, and those that age into middle income dwellings, and between low income dwellings that are built as low income dwellings, and those that age into low income dwellings. Low income dwellings that are built as low income dwellings are the cardboard and scrap (recycled) homes that house the majority of the poor in the less industrialized nations. Finally, as with the business sector of the model, a portion of low income dwellings that were originally built as high or middle income dwellings, and a portion of middle income dwellings that were originally built as high income dwellings, are rehabilitated each year. This basic housing structure has been adapted from Homer (1979a, 1979b).

Pollution Sector

The pollution sector of the sustainable city model divides the waste generated by the city's businesses and dwellings into that which makes its way into the water (particularly sewage), that which makes its way into the air (particularly industrial emissions, auto emissions, and emissions from bio-mass stoves), and that which makes its way into the land (particularly garbage). Feedbacks from pollution affect the death rates of the population and the overall quality of life in the city.

Government Sector

The government sector of the sustainable city model receives property tax revenue from business and private home owners and spends property tax revenue on health care, pollution abatement, low cost housing, and city infrastructure and services. The particular allocation of tax revenue has significant consequences for the city's development as, if it successfully improves the quality of urban life, it also stimulates rural-to-urban migration.

Base Run of the Sustainable City Model

Figures 6, 7, and 8, present the base run of the sustainable city model. Inspection of the figures reveals that the fundamental behavior of the model is spectacular growth followed by stagnation and decline. Two important points follow directly from this behavior. The first is that the behavior is consistent with the behaviors generated by various urban dynamics models created over the years. The second is that the behavior is not sustainable. That is, the city stagnates and declines into a polluted and congested area, with a large proportion of its citizens in the low income group, residing in low income houses.

Implications for Public Policy

Although experimentation with the model continues, an important policy recommendation is emerging. Specifically, many government programs that successfully address sustainability

problems are self-defeating, as they end-up making the city more attractive to rural migrants. A combined set of rural and urban policies seems to be required.

References

Alfeld, L. E. and A. K. Graham 1976. Introduction to Urban Dynamics. Cambridge, MA: Productivity Press.

Barbier, E. B. 1987. "The Concept of Sustainable Economic Development." Environmental Conservation 14(2): 101-110.

Brown, B. J., M. E. Hanson, D. M. Liverman, and R. W. Merideth, Jr. 1987. "Global Sustainability: Toward Definition." Environmental Management 11(6): 713-719.

Brundtland, G. H. 1987. Our Common Future: Report of the World Commission on Environment and Development. Oxford: Oxford University Press.

Chen, N. Y. and H. Zlotnik. 1994."Urbanization Prospects for the 21st Century." pp. 343-358. In Laurie Ann Mazur, ed. Beyond the Numbers: A Reader on Population, Consumption, and the Environment. Washington, D. C.: Island Press.

Daly, H. E. 1994. "Sustainable Growth: An Impossibility Theorem." Clearinghouse Bulletin 4(4): 1-2, 4, 7.

Forrester, J. W. 1969. Urban Dynamics. Portland, Oregon: Productivity Press.

Forrester, J. W. 1970. World Dynamics. Portland, Oregon: Productivity Press.

Fox, R. W. 1994. "Consequences of Rapid Urban Growth: the Example of Mexico City." pp. 356-357. In Laurie Ann Mazur, ed. Beyond the Numbers: A Reader on Population, Consumption, and the Environment. Washington, D. C.: Island Press.

Global Forum '94: Cities and Sustainable Development. Conference Announcement. Manchester City Council. Room 3034. Town Hall Extension. Manchester. M60 2LA. United Kingdom.

Greenwood, M. J. 1975. "Research on Internal Migration in the United States: A Survey." Journal of Economic Literature 13(June): 397-433.

Hardoy, J., D. Mitlin, and D. Satterthwaite. 1992."The Future City." pp. 124-156. In Making Development Sustainable: Redefining Institutions, Policy, and Economics. Johan Holmberg, ed. Washington, D. C.: Island Press.

Homer, J. B. 1979a. "Home Insurance in a Changing Residential Community: A System Dynamics Approach and Case Study." D-3180. System Dynamics Group. MIT.

Homer, J. B. 1979b. "INSUR1: A Dynamic Model of Property Insurance Coverage in an Urban Neighborhood." D-3120. System Dynamics Group. MIT.

Lélé, S. M. 1991. "Sustainable Development: A Critical Review." World Development 19(6): 607-621.

Life in the Truckee Meadows: 1994 Quality of Life Index Report. 1994. Truckee Meadows Regional Planning Agency. 1400-Awedekind Road. Reno, Nevada. 89512.

Mass, N. J. 1974. Readings in Urban Dynamics: Volume 1. Portland, Oregon: Productivity Press.

Meadows, D. H., D. L. Meadows, and J. Randers. 1992. Beyond the Limits. Post Mills, VT: Chelsea Green.

Meadows, D. H., D. L. Meadows, J. Randers, and W. W. Behrens, III. 1972. The Limits To Growth. New York: Universe Books.

Radzicki, M. J. and D. A. Seville. 1994. "An Institutional Dynamics Model of Sterling, Massachusetts: Indicative Planning at the Local Level." Journal of Economic Issues 27(2): 481-492.

Saeed, K. 1994. Development Planning and Policy Design. Brookfield, VT: Ashgate.

Saeed, K. 1991. Towards Sustainable Development. Lahore, Pakistan: Progressive Publishers.

Schroeder, W.W., III, R. E. Sweeney, and L. E. Alfeld. 1975. Readings in Urban Dynamics: Volume 2. Portland, Oregon: Productivity Press.

Sitarz, D. 1993. Agenda 21: The Earth Summit Strategy To Save Our Planet. Boulder, CO: Earth Press.

Solow, R. M. 1993. "Sustainability: An Economist's Perspective." pp. 179-187. In Economics of the Environment: Selected Readings. 3rd Edition. R. Dorfman and N. S. Dorfman, eds. New York: W. W. Norton.

Sustainable Seattle. 1993. "The Sustainable Seattle 1993 Indicators of Sustainable Community: A Report to Citizens on Long-Term Trend in Our Community." Available from Sustainable Seattle. c/o Metrocenter YMCA. 909 Fourth Avenue. Seattle, WA, 98104. (206) 382-5013.

Tisdell, C. 1988. "Sustainable Development: Differing Perspectives of Ecologists and Economists, and Relevance to LDCs." World Development 16(3): 373-384.

Todaro, M. P. 1994. Economic Development. 5th Edition. White Plains, NY: Longman.

Toman, M. A., J. Pezzy, and J. Krautkraemer. 1994. "Neoclassical Economic Growth Theory and 'Sustainability.'" Discussion Paper ENR 93-14 Rev. Resources for the Future. Washington, D. C.

Viederman, S. 1993. "Sustainable Development: What Is It and How Do We Get There?" Current History (April): 180-185.

Walter, B., L. Arkin, and R. Crenshaw. 1992. Sustainable Cities: Concepts and Strategies for Eco-City Development. Los Angeles, CA: Eco-Home Media.

Worcester Telegram and Gazette. 1994. "World's Cities Swelling" (September 20): A5.

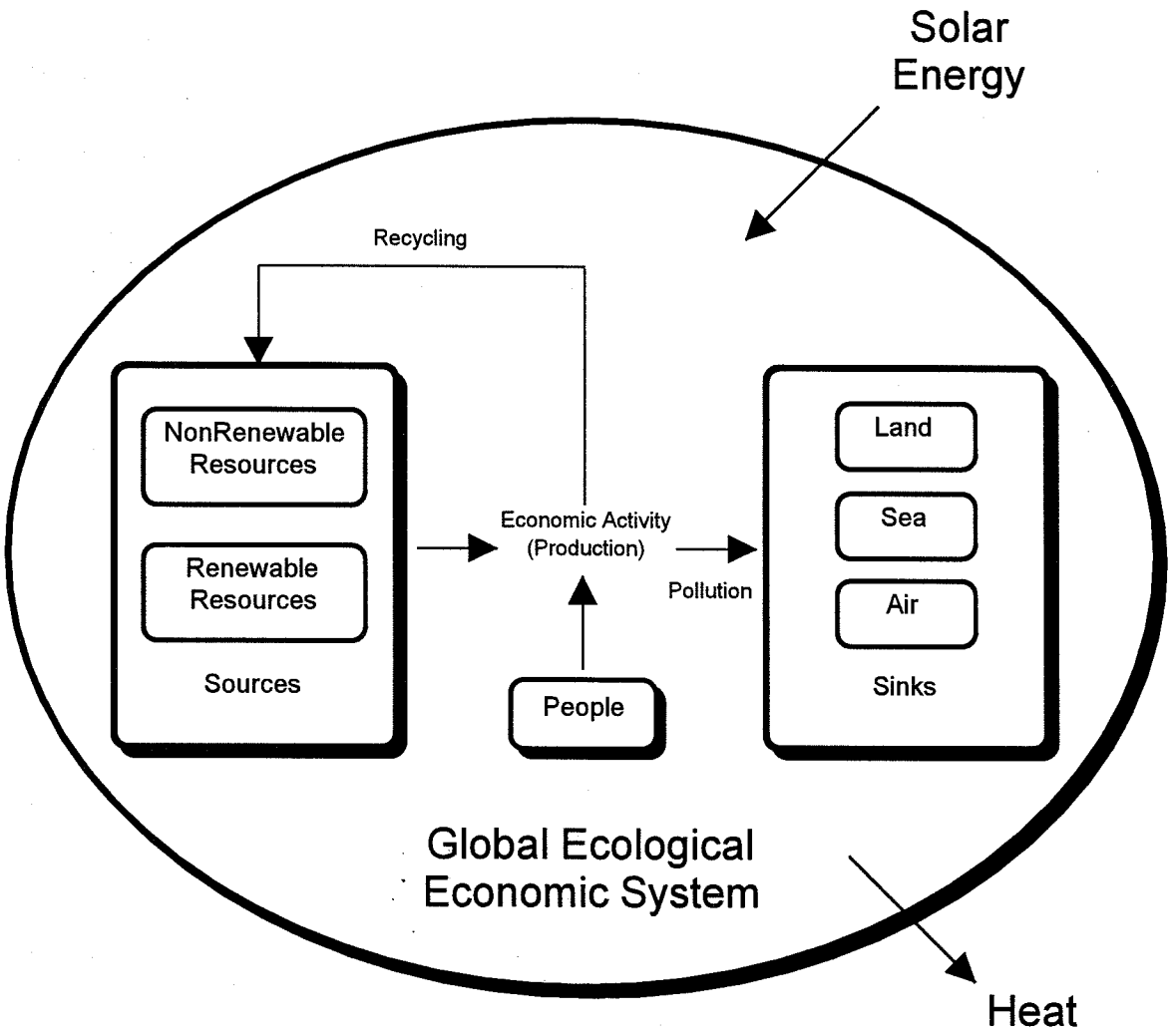

Figure 1: The Global Ecological-Economic System and Its Relationship to Sustainable Development

* Over the past 40 years, the number of urban dwellers has more than tripled -- from 737 million in 1950 to 2.5 billion in 1993 (Chen and Zlotnik 1994, p. 344).
* About 60 million people join the world's urban population each year (Chen and Zlotnik 1994, p. 344).
* By the year 2000 there will be 391 cities with more than 1 million residents, up from 288 in 1990. Of those, 26 will be megacities with more than 10 million people (Worcester Telegram and Gazette 1994).
* By the year 2005, for the first time in history, more than half the world's population will live in urban areas (Chen and Zlotnik 1994, p. 343).

Table 1: Global Urbanization Trends

* Urban populations in the less industrialized nations have grown five fold since 1950 (Chen and Zlotnik 1994, p. 343).
* 39% of the world's urban population lived in the less industrialized nations in 1950; 61% did in 1990 (Chen and Zlotnik 1994, p. 344).
* Urban populations in the less industrialized nations grew by 910 million from 1970-1993 (Chen and Zlotnik 1994, p. 344).
* In 1970, 25% of the population of the less industrialized nations was urban; 36% was urban in 1993; and 50% is expected to be urban in 2015 (Chen and Zlotnik 1994, p. 346).
* By the year 2000, 17 of the world's 20 largest cities will be in the less industrialized nations (Chen and Zlotnik 1994, p. 343).
* By the year 2015, cities in less the industrialized nations are expected to gain 1.6 billion people (Chen and Zlotnik 1994, p. 344).
* By the year 2025, the less industrialized nations will have four times as many urban dwellers as the industrialized nations (Chen and Zlotnik 1994, p. 344).

Table 2: Urbanization Trends in Less Industrialized Nations

* Urban populations in the industrialized nations grew by 208 million from 1970-1993 (Chen and Zlotnik 1994, p. 344).
* The annual rate of urban population growth in the industrialized nations is low, relative to the less industrialized nations (1.1%), but is still higher than the growth rate of their populations as a whole (.7%) (Chen and Zlotnik 1994, p. 353).
* Rural populations in the industrialized nations are decreasing at an annual rate of .3% (Chen and Zlotnik 1994, p. 353).
* In 1970, 67% of the population of the industrialized nations was urban; 74% was urban in 1993; and 81% is expected to be urban in 2015 (Chen and Zlotnik 1994, p. 346).
* During the last three decades, large urban areas in the industrialized nations were losing population to smaller urban areas (or at least not growing as fast). Recent data indicates that this trend may be reversing (Chen and Zlotnik 1994, p. 353).
* By the year 2015, cities in the industrialized nations are expected to gain 200 million people (Chen and Zlotnik 1994, p. 344)

Table 3: Urbanization Trends in Industrialized Nations

* A high proportion of people with incomes too low to allow them to meet their basic needs for food, water, clothing, shelter, and health care.
* An estimated 600 million people living in life and health-threatening environments in very poor-quality housing with little or no provision for infrastructure and services essential for health.
* Little or no protection for workers from unsafe workplaces (where exposure to toxic chemicals is common) and over-long working hours.
* High levels of air and water pollution and inadequate controls over industrial wastes, including the collection and disposal of toxic and hazardous wastes.
* A haphazard, unplanned pattern of urban expansion in which poorer groups are often denied access to safe, legal housing sites on which such housing can be built (and as a result, large concentrations of low-income groups construct shelters on floodplains, hillsides prone to landslides, and other unsuitable sites).
* A high proportion of infants and children in the population (usually close to half the population), but with enormous inadequacies in the services essential for child health and development such as primary health care (including a strong focus on immunization and preventive measures), emergency services, schools, nurseries, crèches, and safe and easily accessible play facilities.
* A physical decay in infrastructure such as roads and drainage systems, public buildings and services such as public transport, schools, hospitals, and health centers.

Table 4: Problems Common to Most Urban Centers

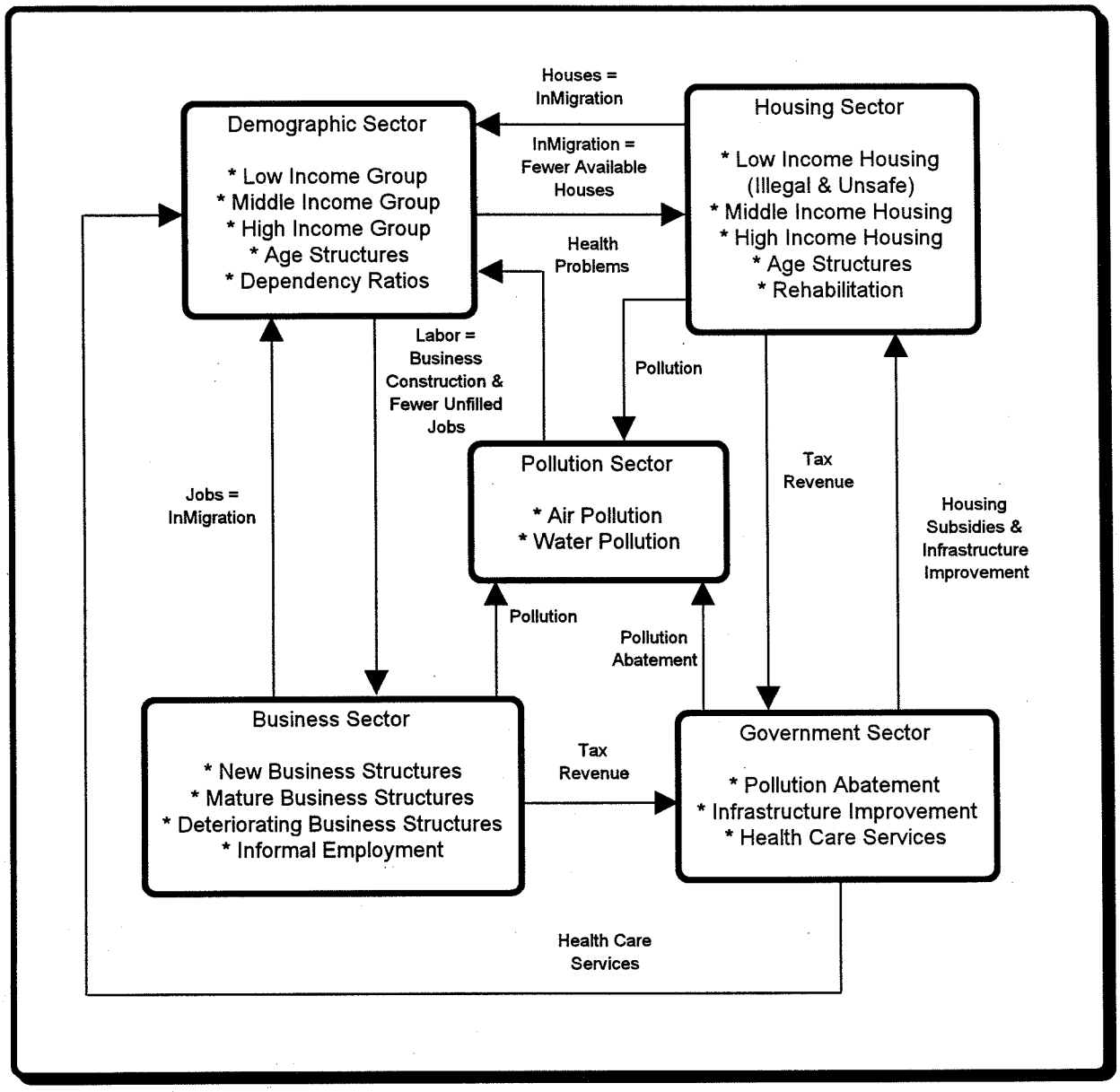

Figure 2: Sector Diagram of Sustainable City Model

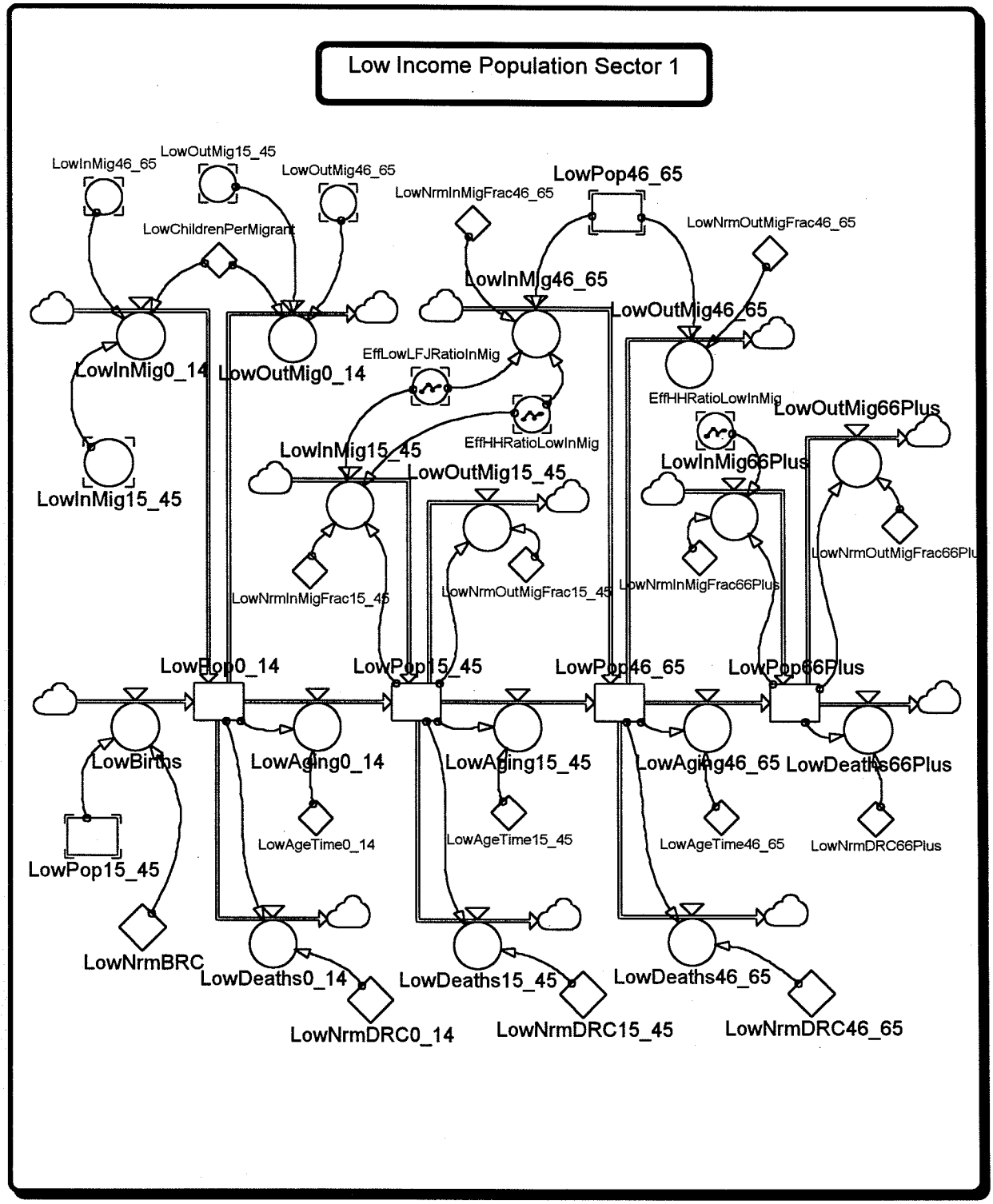

Figure 3: Low Income Population Sector of Sustainable City Model

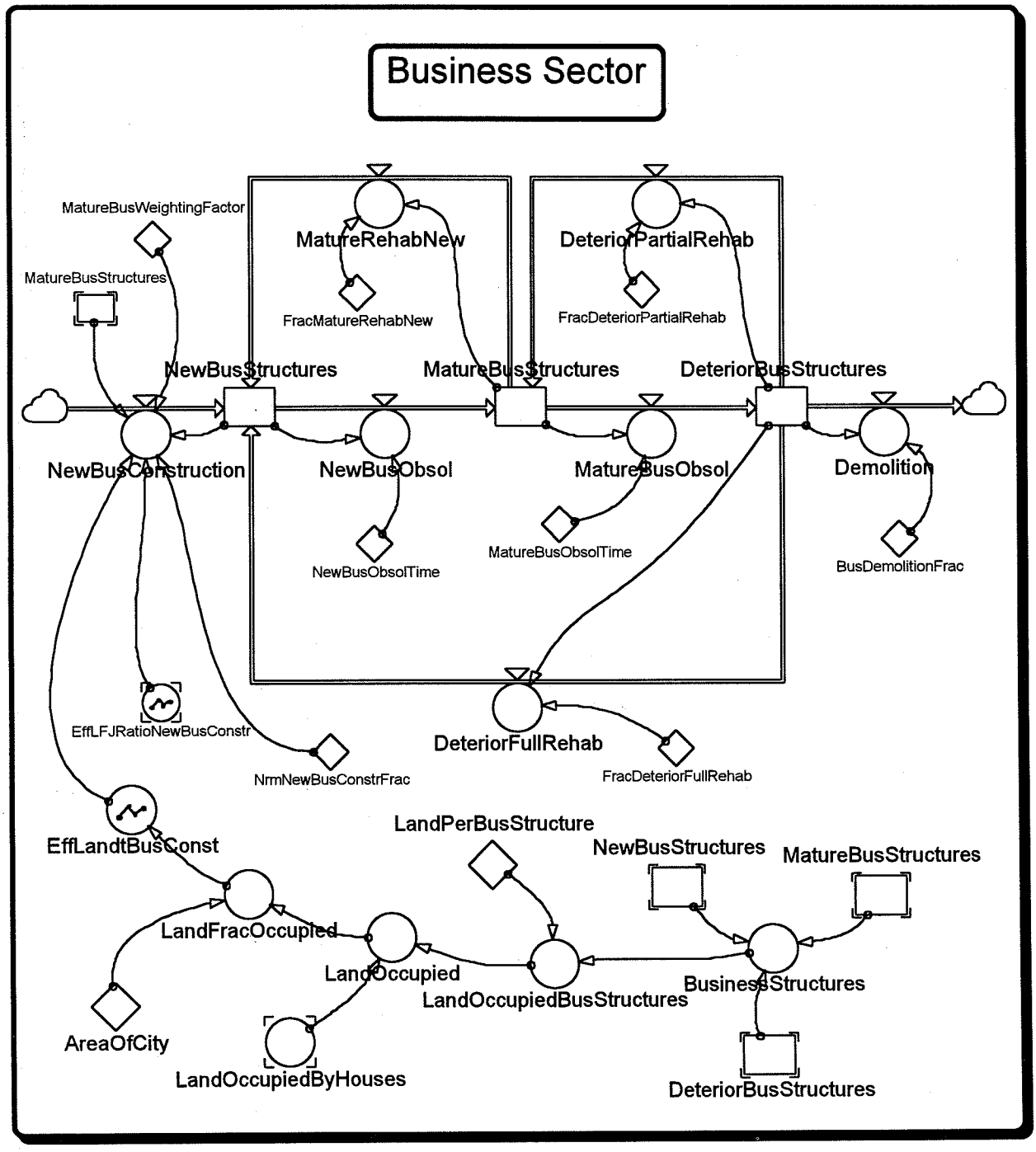

Figure 4: Business Sector of Sustainable City Model

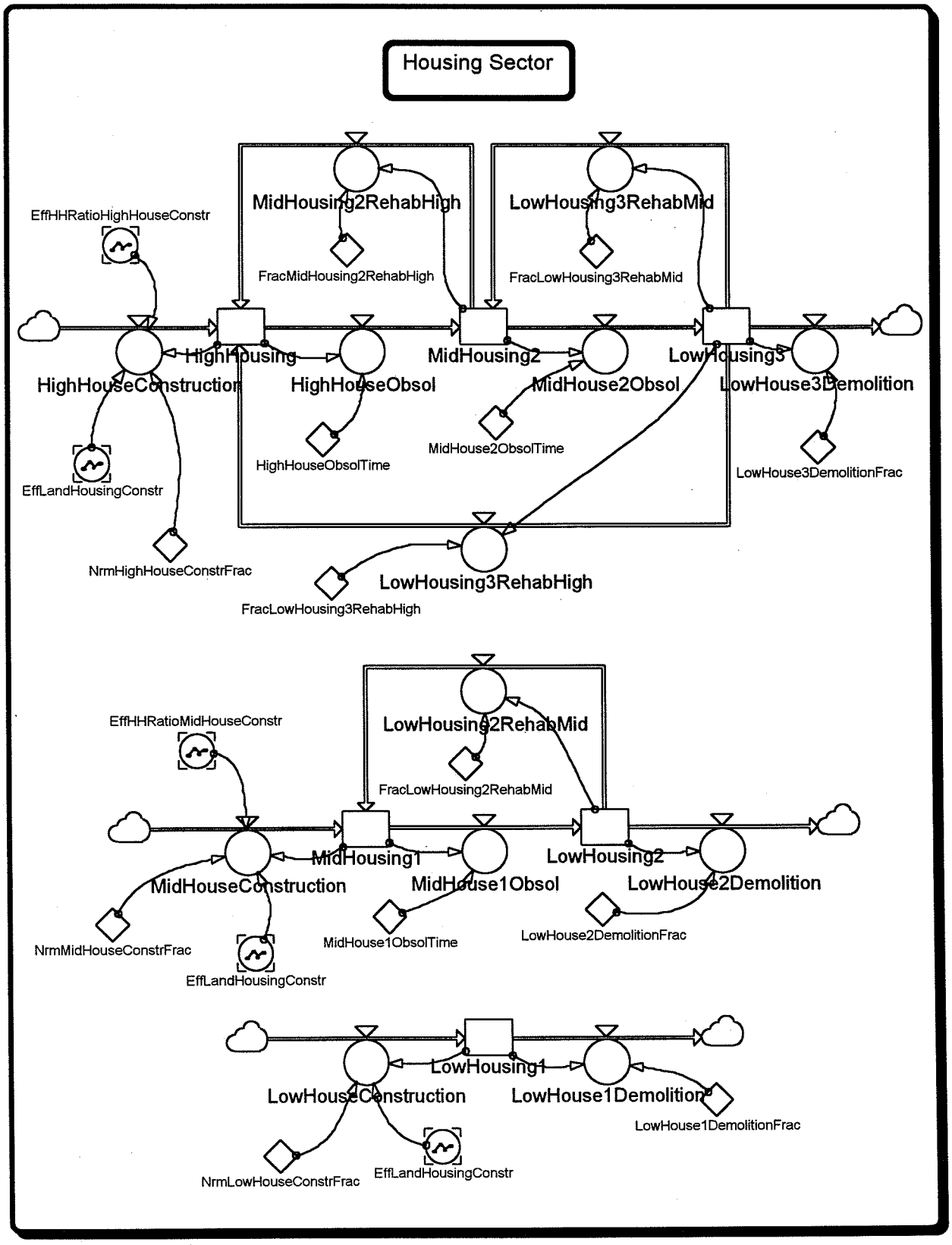

Figure 5: Housing Sector of Sustainable City Model

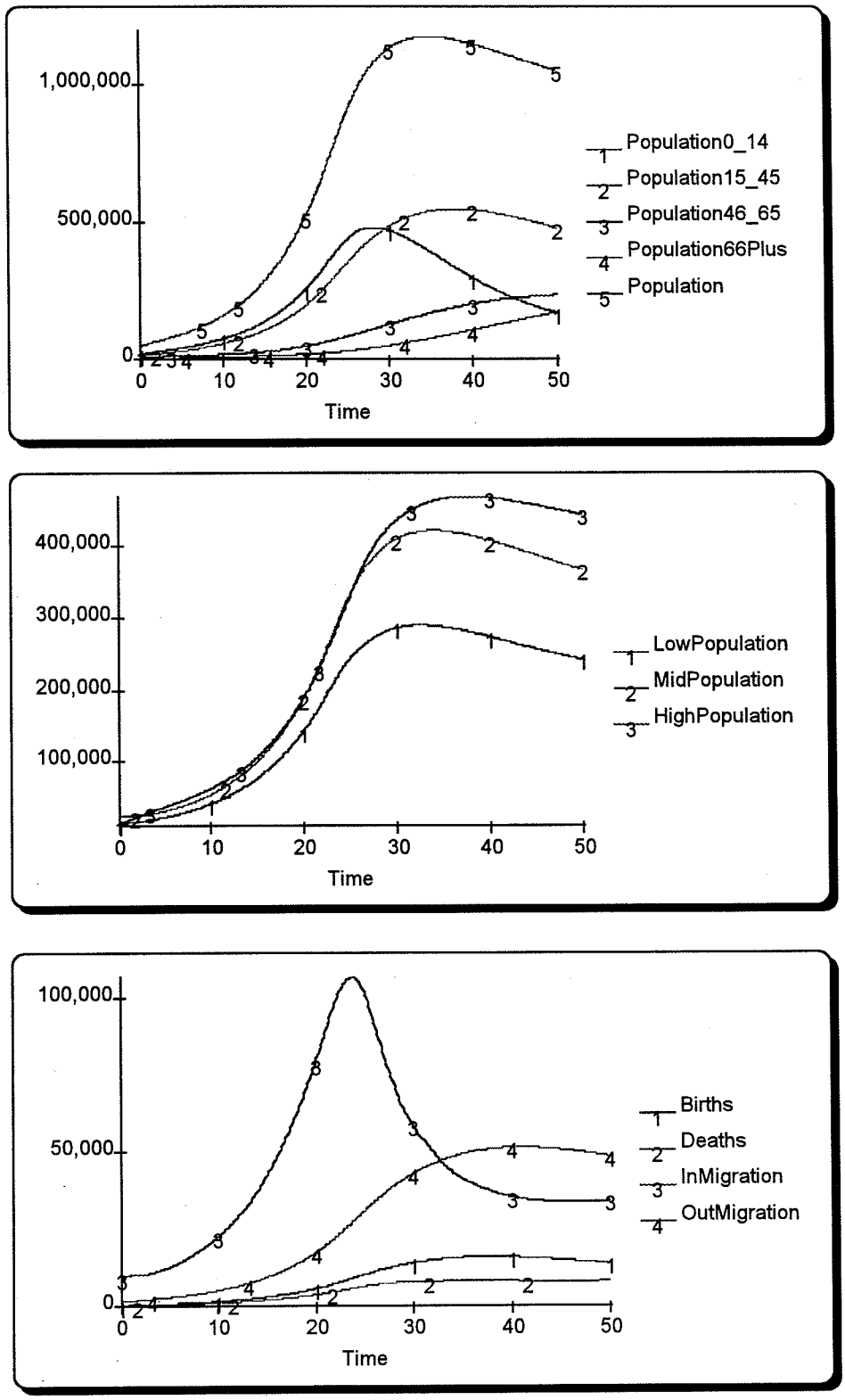

Figure 6: Base Run of the Demographic Sector of the Sustainable City Model

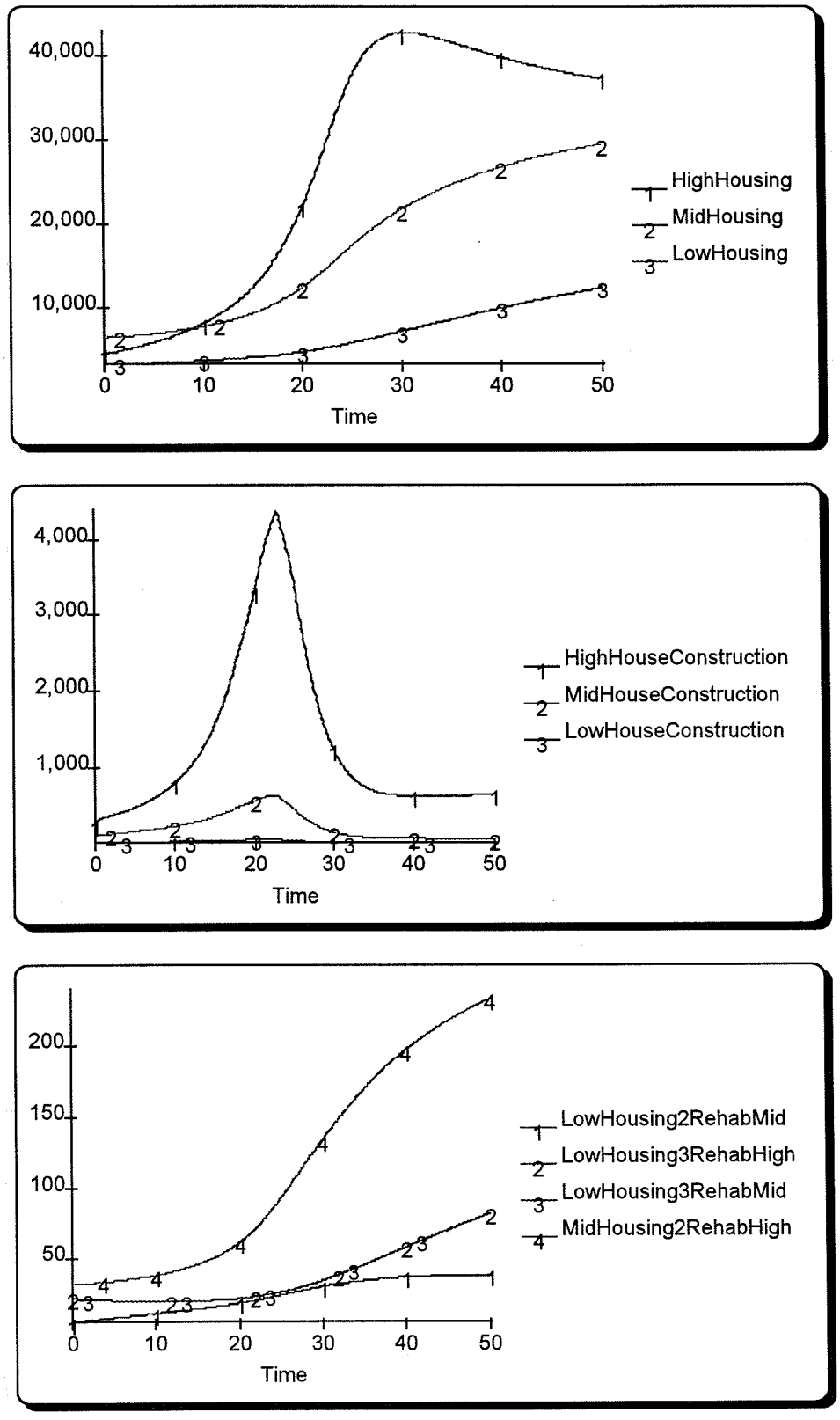

Figure 7: Base Run of the Housing Sector of the Sustainable City Model

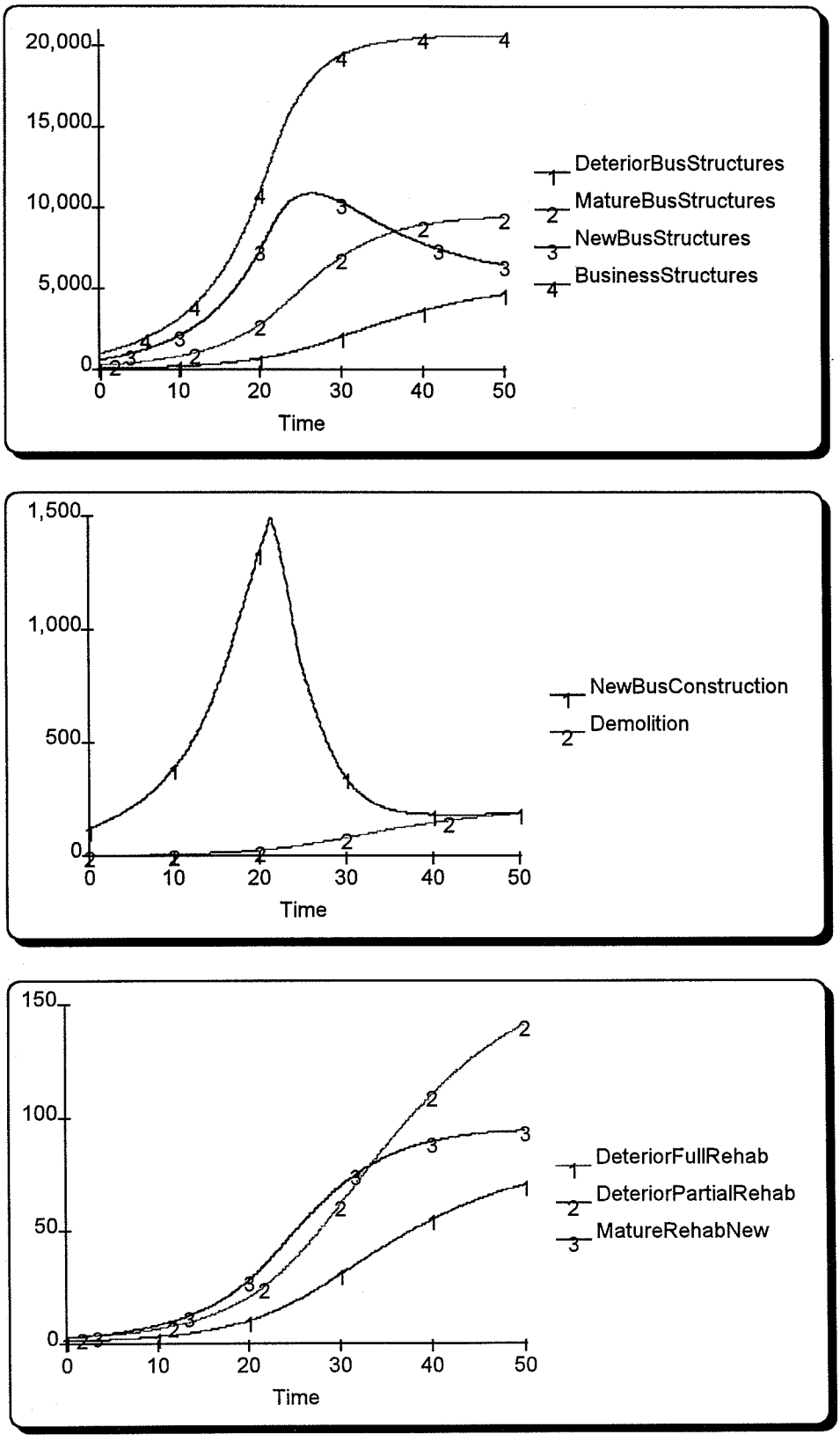

Figure 8: Base Run of the Business Sector of the Sustainable City Model