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Do planners cause sprawl?

The impact of characteristic time on developers' behavior

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Abstract

One of the critical variables in decision-making of developers is time. Despite obvious differences in land prices within a particular real estate market, differences in costs and prices are relatively small in comparison to differences in their time incidence. In this paper, we present a simple economic search model of developer that suggests interesting explanation to the spatial sprawl of cities. The central parameter in our model is the characteristic time, which is the period of time from the acquisition of initial property rights in the land and until the first returns on the investment is realized. The model has demonstrated that under certain market and spatial conditions generalization of this parameter generates leapfrogging patterns in cities evolution, mainly during downturn periods. The model also explains the appearance of high-rise buildings in the periphery.

1. Introduction

There is much discussion in the literature concerning urban sprawl. In the most general sense, urban sprawl refers to the expansion of urban built-up area into previously undeveloped land surrounding cities. There are various definitions and measures of sprawl: related to urban form, based on land uses and related to urban density (see Chin (2002), Burchfield et al., (2006) and Kahn (2006)). Besides the agreement that sprawl occurs on the urban fringe in rapidly growing areas there is little consensus. How exactly is it characterized? What is its extent? What causes it?

The literature contains both positive and normative analyses of urban sprawl. On the positive side, there is evidence that urban spatial expansion occurs mainly because of increased population, rising incomes and decline in commuting costs (Brueckner, 2001). There is also evidence that sprawl is the outcome of particular physical or geographical conditions (Burchfield et al., 2006). On the normative side there are economic models supported by empirical evidence explaining that sprawl is not the result of explicit government policies or urban planning, but rather it's the product of car-based living (Glaeser and Kahn, 2003). There are also behavioral models explaining the evolution of sprawl under equilibrium conditions (Turner, 2007).

While its causes seem to be somewhat agreed on, there is little consensus on whether sprawl processes are positive or negative. Much of this confusion is due to the unclear definition of what the term means and what characterizes this pattern. Sprawl's impacts were classified into number of categories indicated by (Chin, 2002): Public and private capital and operating costs, transportation and travel costs, land/natural habitat, quality of life and social issues. The positive impacts of sprawl are lower commuting time and lower congestion (Kahn, 2006) and improved quality of life (Gleaser and Kahn, 2003). The negative impacts are the reduction in quantity of open spaces, extra congestion on roads (Breuckner, 2001) and social problems (Brueckner and Largey, 2006; Gleaser and Kahn, 2003). There is also literature dealing with the effects of growth-management policies on urban sprawl (Brueckner, 2001; Frenkel, 2004).

Classical urban models were concerned with the reasons for spatial agglomeration of people and of activities, the formation of cities and with the dispersion of people and activities within cities from their centers outwards towards urban fringe (Glaeser et al., 2001). The dominant approach presents the growth of cities as a sand pile of people and of activities that develops from its center outwards. As more people and activities are added the center increases in volume. As a result of centrifugal forces activities and people are pushed away from the center and the periphery expands outwards (Alonso, 1964). A stylized moving wave, or front of expansion, is created.

This traditional view of urban expansion was a useful framework for formulating basic models of urban spatial behavior and it did yield a number of very interesting insights. Another approach took into account that the old central business districts are accompanied by secondary centers, at the cities' edge (Garreau, 1992; Krugman, 1996). Theoretical models focused on the examination of equilibrium conditions for the common polycentric urban structures (Fujita, 1982; Fujita, 1990; Henderson, 1974) and empirical work attempted to identify sub-centers (McMillen et al., 2003). These newer analyses are also rather imprecise descriptions of the urban reality.

Urban spatial dynamics are discontinuous in space and non-uniform in time. There is a fair amount of documentation that urban development is characterized as leapfrogging. (Benguigui et al., 2001a; Benguigui et al., 2001b; Heimlich and Anderson, 2001; Newburn and Berck, 2006). Leapfrogging is a discontinuous growth process of urban areas. It can be described as a process, which starts in an initial center, which develops rapidly. Then, secondary centers are created. These centers are not adjacent to the initial center and they develop independently until they agglomerate with each other or with the initial center.

From the early years of the 20th century the study of cities, and in particular of urban growth, has attracted researchers from a variety of disciplines. Urban dynamics and growth have been studied with mechanisms and tools from geography (Krakover, 1985; Portugali, 2000), economics (Fujita et al., 1999) and more. In addition to analytic models, insights were learned by means of computer simulations (Batty, 1998; Batty, 2005) and by means of concepts such as fractals (Benguigui et al., 2000).

It is our perception that much of the spatial-temporal evolution of cities can be understood parsimoniously by reference to the behavior of land developers. In particular, the relevant behavior concerns the choices that developers make of the parcels of land to be developed and the intensity of the development. This is not to say that developers are the only actors in cities. However, their behavior reflects all the relevant information concerning the demand for land and real estate products at various locations and at various times, the corresponding supply of land and the institutional and other constraints that preclude and/or limit the development of land.

According to this view, zoning and other urban planning decisions are considered to be constraints on the developers' behavior, and not the engines of urban evolution (Henderson, 2000). The integration of planning into our behavioural conception of urban spatial evolution is through the concept of "characteristic time" (τ). In this paper we define characteristic time as the duration of the process of land development, from the purchase of land rights by developers until the realization of income from it. The characteristic time of urban development is the central component of a process that includes a number of stages:

- The search time for developable parcels of land,
- The process of purchasing land development rights,

- The entire process of obtaining appropriate zoning for the land - this is the core of the land appreciation process and constitutes the main activity of land developers[1],
- The construction process,
- Marketing and selling.

Characteristic time is a fundamental concept. It governs the behaviour of developers and the consequent evolution of urban areas. The importance of characteristic time stems from the fact that profits of developers are influenced by differences in the spatial incidence of their costs and revenues and by the time incidence of these flows. Despite obvious differences in land prices within a particular real estate market, differences in costs and prices are relatively small in comparison to the differences in their time incidence. The developer maximizes the present value of lands he purchases and it is influences by planning decisions.

The purpose of this paper is to describe economic search model of developer, which can explain certain forces and influence directions in cities' spatial sprawl. In particular, the paper tries to explain dynamic spatial processes in the evolution of high-rise buildings in cities and in its peripheries. The next section consists of documentation and empirical findings of urban leapfrogging processes in cities and examples from the metropolitan space of Tel Aviv, one of the largest cities in Israel. The rest of the paper consists of findings on developer's economic behaviour and its relationship to the concept of characteristic time. The central section presents the economic model and its insights.

[1] It is important to emphasize that developers, as opposed to construction firms, profit from the appreciation of land that they produce. Successful developers create demand for real-estate products by changing zoning of underutilized land.

2. Leapfrogging spatial processes

Leapfrogging is a discontinuous growth process of urban areas. Spatial skipping of developers over adjacent lands creates this phenomenon because developer tries to obtain more attractive locations. The leapfrogging process can be observed in the municipal scale as well as in the metropolis scale. In the municipal scale leapfrogging occurs when new neighborhoods area created in a distance from the existing neighborhoods, while in the metropolis scale it occurs as edge cities and suburbia are developed.

Recently we have studied the evolution of towns within Tel-Aviv metropolis (Benguigui et al, 2001b). In figures 1 and 2 we illustrated the two different patterns of population evolution with data concerning the evolution of adjacent towns within the Tel Aviv metropolis. In figure 1 Holon and Rishon Letzion (a town to the south and to the east of Holon) display a development process in succession. The towns developed successively from the 1950th with different growth rates and different growth patterns. Holon accelerated until 1970th and then slow down. Rishon Letzion developed slowly until the 1970th and then began to accelerate. An illustration to parallel development of adjacent town can bee seen in figure 2 in the case of Holon and Bat Yam (a town to the west and north of Holon).

[Figure 1 about here]

[Figure 2 about here]

It is interesting to consider the map of the three towns (Rishon Letzion, Holon and Bat Yam) in the Year 2003 and after the transition processes (see figure 3). The cities agglomerated to one big populated cluster. And this dynamics of leapfrogging and agglomeration is similar in other cities in Tel Aviv metropolis space.

[Figure 3 about here]

One more interesting aspect of leapfrogging is concerning the height of buildings. As we know from classical urban theories, the heights perform "height gradient" from the CBD outwards. But high-rise buildings appear in reality also in periphery towns. A good example is the high buildings in Ramat Gan, adjacent town to Tel Aviv. Figure 4 is a map of buildings in Tel Aviv and in three adjacent towns: Ramat Gan, Givatym and Bne Berak at the year 2003. The heights of buildings were classified into three classes (high buildings of 25 meters or more, medium heights between 10 and 25 meters and low buildings of 10 meters or less). There are many high buildings in the big city of Tel Aviv but the interesting phenomenon is the appearance of very high buildings in periphery towns like Ramat Gan.

[Figure 4 about here]

The following Sections consists theoretical and practical explanations to the interesting phenomenon of spatial leapfrogging with its different aspects.

3. Characteristic time and the behavior of land developers

The importance of characteristic time stems from the fact that profits of developers are influenced by differences in the spatial incidence of their costs and revenues and by the time incidence of these flows. Despite obvious differences in land prices within a particular real estate market, differences in costs and prices are relatively small in comparison to the differences in their time incidence. This is particularly true in urban areas where the urban fabric is segmented by numerous planning jurisdictions. Indeed, it is a well-recognized fact among practitioners of land development that duration of the development process, and not prices of land and real estate products, constitutes the critical variable in their decision making processes.

The long duration to approval is due to the fact that the characteristic time includes both the time prior to the formal deposition of a plan and the time after the deposition and until approval, or final rejection. In some countries, a typical plan undergoes the pre and post deposition process through two or three planning boards, depending on whether it impinges on local, regional or national plans (Ginat, 2001).

In the case of one regional planning board in Israel, the typical pre-deposition duration was 10 years (Fialkoff, 1985). While 97 percent of deposited plans are eventually approved, the approval process may last many years. In the case of one local planning board, the median time to approval of a simple housing project involving no more than 2 land parcels is 18 months from deposition. Rejected plans took 4.5 years from deposition. The median time of all the stages is estimated at 10 years (Sofer, 1994).

The following simple illustration based on realistic apartment price variation in the Tel-Aviv metropolitan area strengthens the assertion concerning the importance of characteristic time. The apartment prices vary from US$ 500 to US$ 6,000 per square meter (sqm). The minimal characteristic time is more than 4 years (Sofer, 1994)[2]. Assuming a discount rate that reflects the typical expected gross return of 20 percent, it is obvious that the present value of building one sqm of an apartment of the built apartment is influenced greatly by characteristic times. The characteristic time influences the developers' decisions significantly more than the differences in the prices of the real-estate products.

Our approach to modeling the behavior of developers is typical of economic models[3]. Many developers are functioning in cities. Their behavior is similar to that of the typical developer that we chose to describe. The interest of the typical developer is to maximize the present value of his profits. Since the cost of producing real-estate products varies minimally over space within the same geographic market, developers' profits are defined as the discrepancy between the future value of the developed land and the price of the undeveloped land he acquired for development. Thus, the developer's problem can be defined as a search problem for developable land. His objective is to maximise the present value of land acquired for the purpose of development and sale to consumers of real-estate products. The land parcels

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[2] This is because there is no building permit that can be obtained in the city of Tel-Aviv in less than two years and because the typical building process is more than two years.

[3] There are some descriptive models in the urban studies literature and very simple models in the economics literature concerning the behavior of developers. For example: (Edelson, 1975; Eckart, 1985 and Dendrinos, 2000).

purchased by developers have two attributes: price of real-estate products that can be produced on the land and the expected duration until planning authorities will grant a permit to develop the land as the developer envisages. Both attributes vary over time and space.

The size of the developer relative to the market is such that the developer can sell all the real-estate products that he produces. Suppose we consider locations that are in fact parts of the same real-estate market. For example, if we consider housing services the choice of sites for building housing is from among sites that are in competition from the perspective of prospective buyers. The differences in location attributes of the sites are reflected in the willingness-to-pay for housing services, or the prices that the developer will receive for the developed land. It is noteworthy that differences in accessibility within a particular housing market are small and are reflected in the consumers' willingness-to-pay for housing as well. The differences are insignificant from the developers' perspective.

Thus, the developer's choice of the fraction of his investible funds, α, allocated to housing at each location, i, is governed by the future value of land, p, discounted for the time it will take him to develop the land, τ, at each location. Thus, his return from all the parcels that he will develop can be defined as:

$$\sum_i \left[\alpha_i \left(\frac{p_i}{\tau_i} \right) \right] \qquad (1)$$

s.t. $\left(\sum \alpha_i = 1 \right)$.

The developer's decisions are continuous and the fraction of investments allocated at each location changes as the price that he expects for the developed land and the time it takes to develop land change.

Changes in the expected future prices of real-estate products are a reflection of the relative attractiveness of a location. As time passes, economies of scale and urbanisation augment the willingness-to-pay for real-estate products. The amount of developable land decreases as cities grow. The relative scarcity of land affects the competition for developable land among developers and it makes for a relative scarcity of developed land.

The time evolution of a particular city is governed by the shape of two related functions: (p), which is the average price of housing and (τ) representing the characteristic time. The (τ) function is exogenous to the model. It reflects changes in planning philosophy and the reaction of planning authorities to changes in a variety of conditions in the particular town. The other function is partly endogenous. Among other things, it reflects changes in immigration to the city and the outward expansion of the city's boundary. It is a non-linear function of the other variables in the model.

The developers in the urban space decide when and where to build and decide on the intensity of development (or the heights of buildings). They did it in specific periods and their decisions are a function of the duration times and prices characterized the locations in urban space. Their decisions change the spatial conditions by changing durations and prices. This process is multi-period process and eventually it leads to the spatial evolution of the city. Schematically, this dynamic process is presented in figure 5, where x indicate the location's choice of developers and h indicates the height of buildings.

[Figure 5 about here]

In the next section we present the mathematical development of these ideas in the case of a single town and one developer on a linear space. The quantitative development of these ideas provides a more precise meaning to the concept of characteristic time and the way that it shapes spatial evolution. The model provides theoretical justification for leapfrogging processes and in particular the leapfrogging of high-rise buildings to the periphery.

4. The economic search model

The basic assumption of this paper is that developer's behavior can be understood by reference to the present value of their cash flow. Developers are profit maximizers and they try to find optimal location (x) and optimal height (h) to their buildings subject to spatial and zoning limitations. Our search model assumes linear space (see Figure 6). The linear location space is bounded on one side by the city at "0" and on the other side "P" by the periphery. The developers locate their buildings at some distance (x) from the city. The assumption of linear space is retained in this paper in order to simplify the mathematical development of the model.

[Figure 6 about here]

The decision of developers in the model is at specific period and it is based on the characteristic time of locations (τ) and on the willingness to pay (WTP) in those locations. Every period the spatial conditions are changed and developers respond to those changes. The city's evolution is the outcome of many decisions of developers in many periods.

There are more assumptions in the model. The developer has only two costs: the cost of purchasing the land, which is the initial investment (I) and "overnight costs" (c), which represents all the other multi period costs (building costs for example). The realization of income from the building's project is taken place in one future period and after the characteristic time (τ). The "overnight costs" are function of building's height c(h). The initial investment (I) and prices of land (p) are assumed to be decreasing function of (x) ("Rent gradient"). In the model, price (p) represents the market price of height unit, which is one floor. One more assumption is that characteristic time is increasing function of building's height.

The cash flow of the building's project is very simple and it is presented in table 1. At period t=0 there is only initial investment and after (τ) periods there are revenues p(*x*)h and "overnight costs" (-c(*h*)).

[Table 1 about here]

The developer is a profit maximizer and he try to maximize the present value or future value of his cash flow. His decision variables are location (x) and height (h) and interest rate is indicated by (r). The objective function can be seen in expression 2.

$$\underset{x,h}{Max}\; FV(t=\tau) = -I(x)(1+r)^{\tau} - c(h) + p(x)h \qquad (2)$$
$$s.t \quad \tau = \tau(x,h)$$

The first order conditions (in expressions 3 and 4) are obtained from derivation according to distance (x) and height (h) and equalizing to zero.

$$\frac{\partial FV}{\partial x} = -(1+r)^{\tau}\frac{dI(x)}{dx} - I(x)(1+r)^{\tau}\tau_x \ln(1+r) + h\frac{dp(x)}{dx} = 0 \qquad (3)$$

$$\frac{\partial FV}{\partial h} = -I(x)(1+r)^{\tau}\tau_h \ln(1+r) - \frac{dc(h)}{dh} + p(x) = 0 \qquad (4)$$

From the resulting first-order conditions it is possible to identify the optimal height in expression 5.

$$h = \frac{(1+r)^{\tau} I'(x) + I(x)(1+r)^{\tau}\tau_x \ln(1+r)}{p'(x)} \quad where \quad h \geq 0 \qquad (5)$$

The derivative of the height (h) according to characteristic time (τ) is presented in expression 6.

$$\frac{\partial h}{\partial \tau} = \frac{I'(x)}{p'(x)}(1+r)^{\tau} \ln(1+r) + \frac{I(x)\tau_x}{p'(x)}(1+r)^{\tau} \ln^2(1+r) \tag{6}$$

If height (h) is increasing with characteristic time (τ) and if (τ) is an increasing function of distance (x) than by transitivity argument the height is increasing with distance (x). This relation presented in expression 7 is a basic foundation to the leapfrogging phenomenon of heights.

$$if \quad \frac{\partial h}{\partial \tau} > 0 \quad and \quad \frac{\partial \tau}{\partial x} > 0 \quad then \quad \frac{\partial h}{\partial x} > 0 \tag{7}$$

The rent gradient assumption means that $I'(x) < 0, \quad p'(x) < 0$. This assumption accompanied with the mathematical results is the baseline to the leapfrogging condition. There are two distinct possibilities for the sign of the derivative of (τ) according to distance (x). If $\tau_x > 0$ then the sign of the derivative of (h) according to (τ) is not clear as can be seen in expression 8.

$$\frac{\partial h}{\partial \tau} = \frac{I'(x)}{p'(x)}(1+r)^{\tau} \ln(1+r) + \frac{I(x)\tau_x}{p'(x)}(1+r)^{\tau} \ln^2(1+r) \gtrless 0 \tag{8}$$

$$= \frac{(-)}{(-)} \circ (+) \circ (+) \quad + \quad \frac{(+) \circ (+)}{(-)} \circ \ (+) \circ (+) \quad \gtrless 0$$

In this case it is easy to calculate the condition for positive derivative, which is the leapfrogging condition. The condition after reduction is presented in expression 9.

$$\frac{\partial h}{\partial \tau} > 0 \quad or \quad \frac{\partial h}{\partial x} > 0 \quad if \ r \approx 0 \tag{9}$$

This condition means that leapfrogging of high buildings to periphery can occur even though characteristic time in periphery is higher than characteristic time in central city. It can happen mainly in recession periods and this is not surprising because low interest rates (r close to zero) means that developers are almost indifferent between present and future because they don’t lost too much from long delays in the realization of their revenues. On the other hand if $\tau_x < 0$ then with the aforementioned assumptions it is clear that the sign of the derivative of height (h) according to (τ) is positive as can be seen in expression 10.

$$\frac{\partial h}{\partial \tau} = \frac{I'(x)}{p'(x)}(1+r)^{\tau}\ln(1+r) + \frac{I(x)\tau_x}{p'(x)}(1+r)^{\tau}\ln^2(1+r) > 0 \qquad (10)$$

$$= \frac{(-)}{(-)} \circ (+) \circ (+) \quad + \quad \frac{(+)\circ(-)}{(-)} \circ \ (+)\circ(+) \quad > 0$$

This result is very obvious and intuitive because developers prefer short characteristic times to long duration times and therefore they locate high buildings in those low duration time's regions. The above results are interesting and they also robust. By releasing the “rent gradient” assumption there is no change in the final expressions and outcomes.

5. Some words about housing market, prices and land-use regulations

The developers are important actors in the housing market and their decisions influence directly the supply of new buildings. There are interesting works describing the rise of housing prices caused by the declining in supply of new homes (Glaeser et al, 2005; Glaeser and Ward, 2006). According to these studies, reductions in supply don’t reflect a real lack of land, and the increase in housing prices don’t reflects rising housing qualities or rising of construction costs. The increase in prices reflects the increasing difficulty of obtaining regulatory approval for building new homes and there are evidences to the large increase in the number of new regulations and other man-made restrictions on development.

Our simple model (presented in previous section) supports the strong insights about the behavior of developers in the housing market. It is easily demonstrated by derivation of the price function (p) in expression (4) according to (τ) (the characteristic time). The result is presented in expression 11.

$$\frac{\partial p}{\partial \tau} = I(x)(1+r)^{\tau} \ln \tau \geq 0 \qquad (11)$$

The expression shows that prices of housing units are increasing function of (τ). The characteristic time represents the long duration time of obtaining regulatory approval for building new homes and it cause directly a declining of housing supply by developers and increasing of housing prices as can be seen in figure 7.

[Figure 7 about here]

6. Conclusions

In this paper we explored the relationship between time and space within a metropolitan area. Land-use regulations and the consequence long durations of building projects' approvals have direct influence on decisions of land developers. The critical ingredient in our paper is characteristic time. It is the period of time from the acquisition of initial property rights in the land and until the first return on the investment is realized. It reflects the planning decisions and it affects the decisions of developers.

The evolution of cities can be the result of decisions of many developers in many periods and leapfrogging pattern is one spatial form of this evolution and spatial sprawl. Leapfrogging has few aspects: the population increase in the adjacent towns or locations, the physical change in building's area of those towns and the last is leapfrogging of high-rise buildings to the periphery.

Our simple search model suggests that leapfrogging pattern can be the result of realistic decisions of developers, who decide where to locate their buildings and what is their intensity (or height). The model has demonstrated that leapfrogging pattern of high buildings can be the result of certain conditions:

1. Decreasing of (τ) with distance (x) from the city can leads to leapfrogging of heights because developers try to find low (τ) locations for their high buildings.

2. Downturn periods with negligible interest rate can lead also to leapfrogging of heights even if (τ) is increasing with distance. The reason is simply the indifference of developers between present and future in the time incidence of their revenues at recession periods.

There are two major issues that are not addressed in this paper and can be considered in future studies:

1. **Spatial mapping of characteristic times** - The spatial mapping of (τ) can be important input to behavioral models. A part of this work was done by (Sofer, 1994), but the measurement of duration times was in low resolution of the national and district levels. It is interesting to measure (τ) in high-resolution levels of specific locations in cities and their periphery.

2. **Empirical study of leapfrogging patterns in recession periods** - one of the interesting outcomes of our model is that low interest rates can lead to leapfrogging of heights to the periphery. This conclusion has to be tested empirically.

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Tables

Period	t=0	...	t= τ
Flow	-I(x)		-c(h)+p(x)h

Table 1: The cash flow of the building's project.

Figures

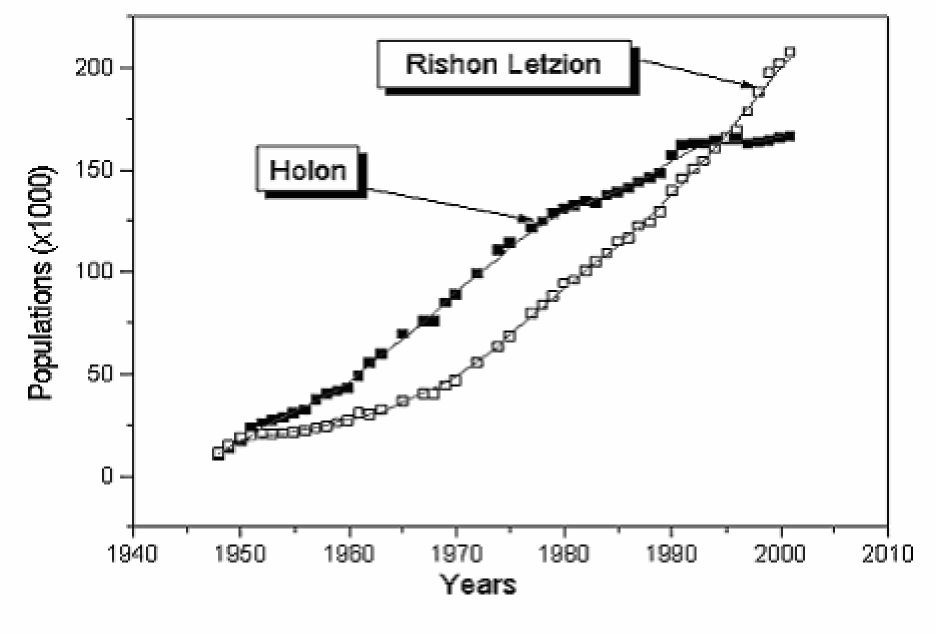

Figure 1: Variation of the populations of two adjacent towns Rishon Letzion and Holon in the Tel Aviv metropolis showing a case of successive development of the towns.

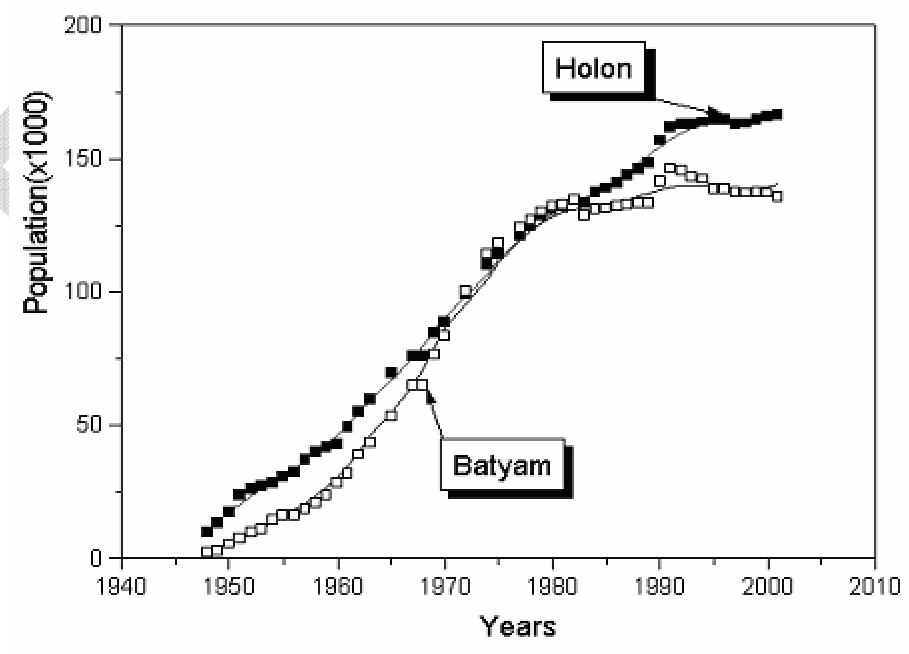

Figure 2: Variation of the populations of two adjacent towns Bat Yam and Holon in the Tel Aviv metropolis showing a case of parallel development of the towns.

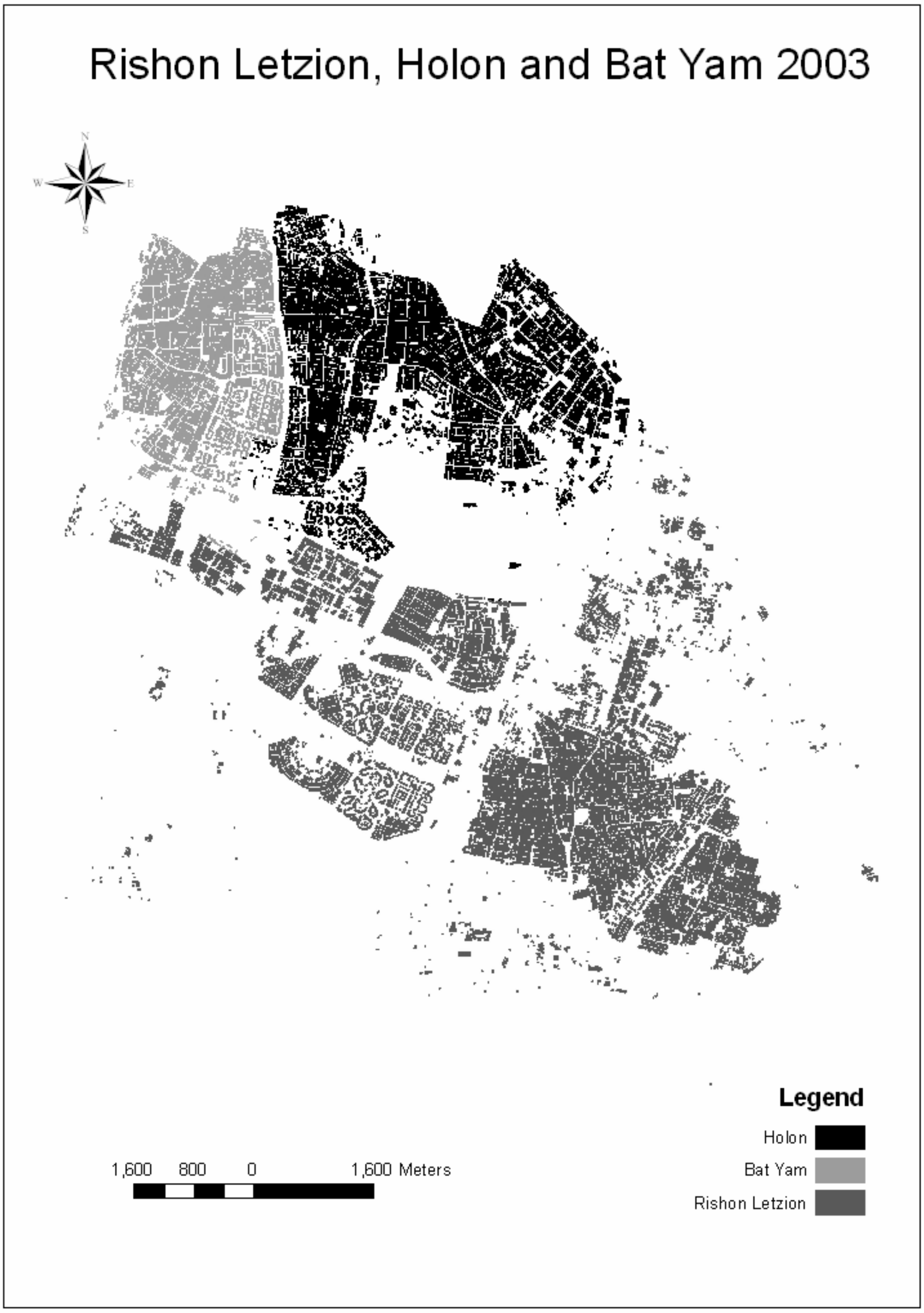

Figure 3: Map of Rishon Letzion, Holon and Bat Yam in the year 2003

year 2003, where the building's heights where classified into 3 classes (high, medium and low).

Figure 4: Map of Tel Aviv and suburbia towns: Ramat Gan, Givatym and Bne Berak in the year 2003, where the building's heights where classified into 3 classes (high, medium and low).

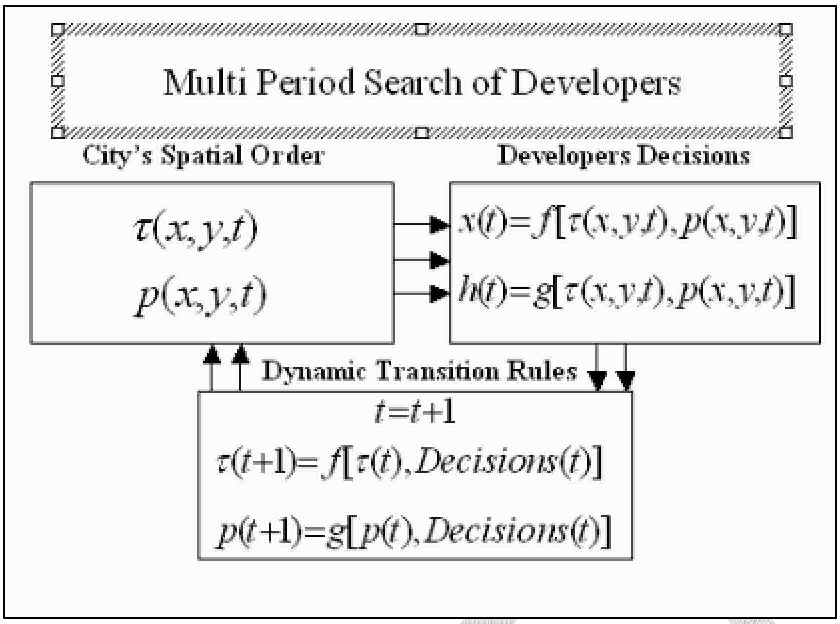

Figure 5: Multi-period search of developers and the spatial evolution of the city.

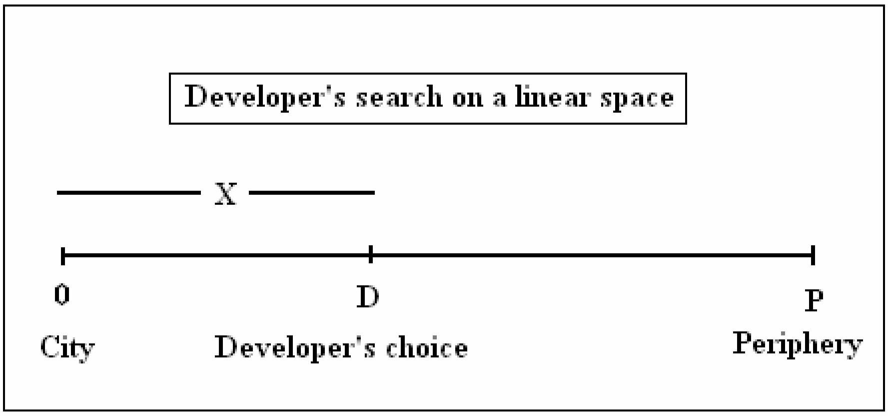

Figure 6: Developer's search on a linear space in the economic model.

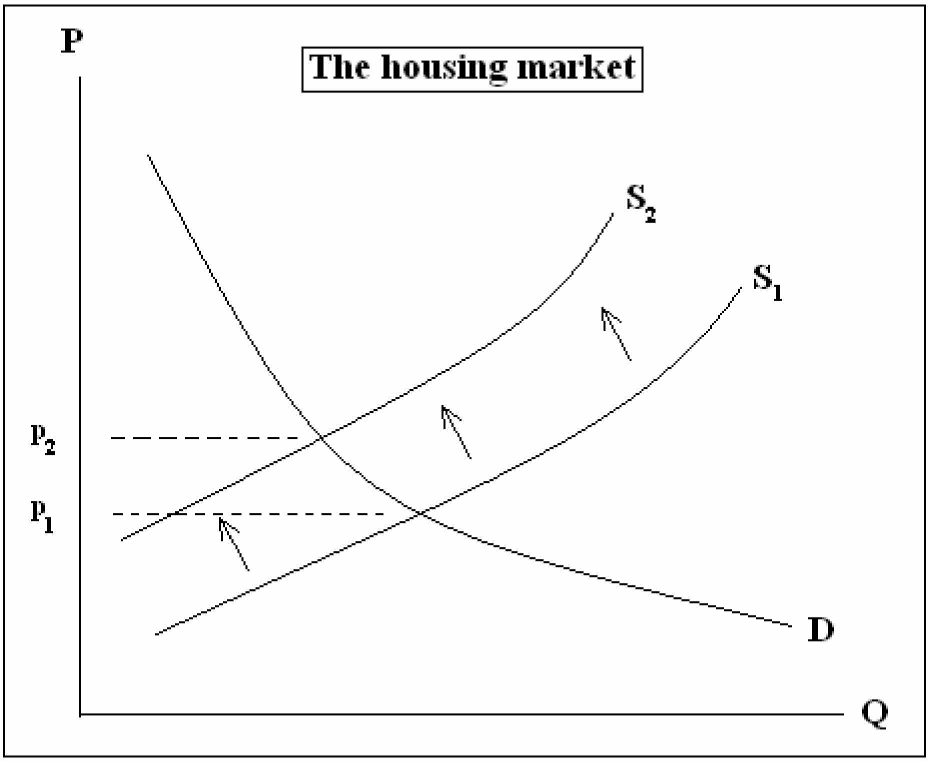

Figure 7: Declining supply and increasing prices in housing market.