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CITY SIZE DYNAMICS IN URBAN SYSTEMS

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Abstract

Systems of urban settlements are characterized by their hierarchical organization. The empirical observation of a large set of cities over almost two centuries shows that this hierarchy evolves very slowly, despite the rapid fluctuations in the growth of individual cities. We suggest to develop a theory of the evolution of urban systems, which would connect the slow dynamic of their city-size distribution with the more rapid dynamic of the individual cities competing for attracting the populations. Both dynamics are shown to be related to the spatial properties of urban systems.

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INTRODUCTION

The distribution of population over a territory always leads to aggregates of various sizes: households, hamlets, villages, towns and cities. There is on the long run a trend towards an increase in the size of the aggregates and an increase in the concentration of the population in the aggregates. This evolution has not always been continuous in the past. However, the process of concentration of the population has been almost continuous and of an unprecedented intensity since at least two centuries in many developed countries: more than 80% of the total population is now concentrated in the largest towns and cities, it was only about 20% before.

Several theories have been developed about the causes and consequences of the urbanization process, mainly understood as the transformation of a rural into an urban population. Explanations have put forward the relationships with economic development, demographic growth, improvement of agricultural productivity, rural depopulation, and technical progresses improving the power of managing larger and larger cities as well as the speed of communications between cities. The distribution of urban growth among cities has been mostly studied in a "comprehensive" way, by establishing relationships between the growth of cities and the diffusion of innovations (Morrill, 1965, Pred, 1966). This was first seen mainly as a "filtering" process down the urban hierarchy (Berry, Pred) and then as a result of more complex network structures in the urban system (Pred, 1977).

We suggest in this paper that it would also be interesting to build up a theory of the historical development of urban systems, which would be perhaps less ambitious, but which could integrate some of their significant dynamic properties, as they have been revealed by the systematic statistical analyses of the distribution of urban growth in a large number of cities and over long periods of time. Such studies are no longer so rare: after the pioneer work by Madden (1955) for the United States and the book by Robson about Great Britain (1973), the work of Vloria on Italia (1979), Pumain (1982) and Guérin-Pace (1990) for France and Matthiesen for Denmark (1985) have increased the required material for comparisons.

In the territorial distribution of urban growth, major regularities can be observed. The most important feature, at the macroscopic scale of the entire system of cities, is the persistency of the spatial and hierarchical configuration of the system: despite of the growth of urban population and of the increases in the number and sizes of cities, the general spatial pattern and the statistical form of the size distribution of cities is preserved over time. Such results suggest that the dynamics of a system of cities could be formalized in using analogies with other open systems situated "far of equilibrium" and whose spatio-temporal dynamic properties have been investigated in physical sciences.

Can we consider the shape of the urban hierarchy as an **attractor** for the state of any urban system? How is this **structural stability** compatible with the permanent **fluctuations** in the size of the individual cities at the meso-level, and with the even more rapid changes among the individuals who compose the urban population at a micro-level? A dynamic theory of the urban systems should connect the **slow dynamic** of their **city-size distribution** with the more **rapid dynamic** of the **individual cities competing for attracting the populations**. But it should also integrate a few specific properties of the urban systems, which are both geographical and historical objects.

1 THE CONCEPT OF A SYSTEM OF CITIES

In opposition to the villages which exploit the resources of their site, cities have been conceptualized as entities which make benefit from their situation, in exchanging and accumulating the wealth of several distant sites. This is possible through the various kinds of flows (materials, persons, informations...) which connect cities to each other. The importance of those relationships for the functioning and the evolution of cities has led to conceive a set of cities, in a regional or in a national territory, or even in a larger framework, as a system of interdependent units.

Archaeology will tell us if from the very beginnings the city existed as an isolated entity or as a node in a network of cities. Whatever the theory about the origins of urban functions, either political and religious control over a society and its territory, or handicraft production (Duby, 1980), or economic trade and exchanges (Bairoch, 1985), it seems very difficult to imagine an isolated city but on the contrary, following Berry (1961), it is necessary to conceive it as "a system within a system of cities". In any case, the specificity of the urban growth of the last two centuries has led to individualize urban systems in describing them as distinct from the rest of the settlement systems.

In many studies, urban systems are supposed to be delimited by the national boundaries, which usually strongly reduce the number of interactions between cities. The delimitation of an urban system remains however a difficult problem, which has not been solved until now in a satisfying way. We know from empirical observation and from urban theory that the sphere of relations of any city is highly dependent upon its size. Small towns may well have relationships of interdependence only at a regional scale, whereas medium-size ones will be more strongly connected at a national level, and large cities at a supranational level. The delimitation of the relevant urban system should therefore vary according to the size of the cities being considered, as well as in the course of time, when interconnections are progressively settled. This kind of variable geometry for the space of reference has not yet been satisfactorily integrated into any model. We will then provisionally consider a set of cities, as defined in a national framework, as an urban system.

In a most formal and parsimonious way, urban systems can be conceptualized as hierarchical open systems (Prigogine, Stengers, 1979). They are hierarchical, in the sense that they can be described at three significant levels: the elements are the individuals, the urban residents (urban households could also be used to define that elementary level); the subsystems are the individual cities, which are defined only by the number of elements that they contain, and this measure of their size strongly differentiates them (usually from a few thousands to several millions of people); the whole system is the total set of cities, where exchanges of elements between subsystems are taking place. Urban systems are also open systems, since they exchange individuals with their environment, for instance migrants to and from rural areas or other countries.

Such a theory is not as poor a description, as it could seem at first sight, for an urban system. In a most general sense, a city can be defined as a permanent agglomeration of many people over a limited space. Of course, this definition is too simple and a minimum size of the aggregate and of its density, which may not always be the same, has also to be considered. On the one hand, when describing a city simply by its number of inhabitants, it becomes less unreasonable to compare cities through

centuries and from one civilization to another. On the other hand, the population size indeed is a very synthetic description of the relative importance of a city as compared with the others, since it is very often rather well correlated with many other social, economic and cultural indicators. It is very often considered as the first "dimension", that is the most important differentiation factor among a set of cities (Parr, Reiner, 1980). A dynamic theory of urban size in urban systems can then induce a progress in the understanding of the whole logic of the urbanization process.

2- THE HIERARCHY OF URBAN SIZES: AN ATTRACTOR?

Usually the cities belonging to the same region or to the same country are strongly differentiated according to their size. There is a strong evidence about a kind of invariance in the statistical distribution of city sizes. The size distribution is highly skewed, with many small towns located close to each other, less and more distant medium-sized cities and only a few very large cities which are located in average far away from each other. The number of cities is roughly in an inverse geometrical progression with their size. This distribution was identified (Le Maître, 1682) and formalized (Auerbach, 1913) a long time ago. It is usually known as the "rank-size rule" as described by Zipf (1949): when plotted on logarithmic coordinates, the population size of a city is a linear function of its rank in the urban hierarchy. The cumulated frequency distribution of the sizes of cities is also similar to a Pareto function (Simon, 1955) or to a lognormal distribution (Gibrat, 1931). The slope of the Pareto distribution, or the dispersion of the lognormal function, are indicators of the degree of concentration of urban populations (in other words, it is a measure of the inequalities in size among cities).

Such types of size distributions for cities can be found everywhere in the world (Zipf, 1949, Rosen and Resnick, 1980, Parr, 1985). They seem to maintain the same shape since a very long time. For instance in France, and despite the numerous difficulties in evaluating the number of their inhabitants, it is hold as highly probable by several historians that such an hierarchical organization of cities exists at least since the Roman Empire. The existence of the hierarchy is not linked with demographic growth, since it has maintained itself even during the regressive periods of the Middle Ages.

It would be of the highest importance, for a dynamic theory of the settlement systems, to know if other types of distributions can be observed. This is a question to archeology: is it possible for instance to imagine a normal distribution of settlement size? Such a distribution would suggest that there is an optimal size for human settlement, depending upon the availability of ressources in a given distance for a group, and/or upon the internal management capacities of the group. It would imply that under those circumstances a permanent settlement is not viable below or above a given threshold of size.

If such patterns of settlements could be found, for instance for agricultural communities, the explanation of the distribution of city sizes would have to be searched in the specificity of the urban functions. If it is impossible to find evidence for any normal distribution of settlement sizes, the explanation of the lognormal distribution can be more general and may be limited to the study of the aggregation of the population over a territory. In any cases, the universality of this configuration leads to think of it as a very strong and stable attractor in the dynamics of the urbanization process.

3 FROM STATIC TO DYNAMIC INTERPRETATIONS

Several kinds of explanations have been put forward to explain the distribution of city size in urban systems (for a review, see Pumain, 1982 or Sheppard, 1982). This distribution was at first considered as expressing an **equilibrium**. Zipf considered the "rank-size distribution" as an equilibrium between two counterbalancing forces, a "force of concentration" and a "force of diversification". Both forces resulted from the "law of least effort" tending either to concentrate people and activities on the same place of production and consumption in order to avoid transportation costs, or to locate production and consequently the consumption in the vicinity of the natural resources to be exploited, resources whose distribution is likely to be rather dispersed. His explanation of why the two forces equilibrate in order to produce the perfect regular size distribution of cities was however not really argued.

Tentative explanations of city size distribution as the most probable state of an urban system are not convincing either. Berry and Garrison (1958) have suggested without demonstration that the Pareto distribution would correspond to a state of maximum entropy within the urban system. Curry (1964) has derived a skewed distribution of city sizes from the principle of entropy maximization (in the sense of information theory) in a process of allocation of individual cities among the various possible city sizes. Many weaknesses have been found however in his interpretation: the theoretical resulting distribution is rather different from the observed ones (Haran, Vining, 1973), the model supposes a closed urban system (Chapman, 1970), and the explanation is only shifted from the size distribution toward the constraints which have to be defined to get it as a result of the process (Pumain, 1982).

Central place theory - whose inventor may not be W. Christaller (1933) but J. Reynaud (1841, as discovered by Robic, 1982) - provides a static explanation for the size, spacing, and hierarchical functional organization of cities. "Sociability" according to J. Reynaud, "centrality", according to W. Christaller, are the key concepts for understanding the grouping of population and of non-agricultural activities in the most accessible, central, places. A regular pattern of nested urban levels is considered as an equilibrium between supply and demand of goods and services. Supply is limited by a minimum threshold in the number of consumers which is required for its profitability, whereas demand is limited in extent by a decreasing accessibility around the centers and a corresponding increase in the relative transportation cost.

In this model, the theoretical distribution of city sizes is supposed to be discontinuous, like a staircase where each level corresponds to a specific bunch of urban functions. Several authors have tried to make it compatible with a rank-size distribution by introducing stochastic variations in the hierarchical levels (Beckmann, 1958, Beguin, 1979). One may indeed argue that several independent and random factors are blurring the size limits of each level and smoothing the size distribution: the location of industrial functions, which does not depend on city size, and the local variations in the demand per capita and in the elasticity of supply according to profit are the main explanatory factors for such a randomization of the model. However, Parr (1970) argues that the rank-size distribution has a larger validity, because it contains all the plausible hierarchical distributions, whereas all hierarchical structures which are derived from central place theory are not compatible with the actual size distributions of cities.

An interesting development has been proposed by Allen and Sanglier (1979), with a dynamic model of a central place system. When experimented over fictitious data,

this model produces satisfying results, especially as far as the distribution of city sizes is concerned. However, this type of model would require a large work of data collection to be tested on the historical development of a real urban network. This is a well-known problem for complex dynamic models (Pumain, 1987). If we still believe in experimentation as a cornerstone for assessing the usefulness of theories, we have to look at first for simpler but verifiable dynamic models.

Of particular interest are the models which derive a skewed distribution of sizes from the **growth process of the population of cities**. Several models of the distribution of growth among cities have been designed in order to demonstrate how they could lead to a Pareto distribution (Steindl, 1965 ; Simon, 1955) or to a lognormal distribution (Gibrat, 1931) of the sizes of cities. Most of them were stochastic models. Their specifications could be different but they were all based on the same kind of main hypothesis. Gibrat demonstrates that any distribution of city sizes will become a lognormal distribution if the following growth process is observed:

- cities are growing at each small time interval of an amount of inhabitants which is proportional to their size (it is equivalent to say that the growth rates of cities are independent of their sizes) ;
- the distribution of growth rates among cities is independent from one time interval to another.

In other words, the "law of proportional effect" assumes that the causes of urban growth are diverse and numerous, that the effect of one of them is small when compared to the total effect of all causes, and that this global effect is multiplicative, and proportional to the size of cities.

It is this model that we have experimented here. The model looks at first as a simple statistical interpretation of the distribution of city size in an urban system. This model is probably too simple for a dynamic description of an urban system. The results of its testing over real empirical data can nevertheless suggest improvements for the design of more sophisticated models of urban dynamics. Using findings about the French case, we would like to propose a few issues for the formalization and modelling of the evolution of sets of cities in the framework of the theory of self-organizing systems.

4 QUASI-STOCHASTIC DYNAMIC PROPERTIES OF URBAN SYSTEMS

The experimentation of this model has required the construction of a large data base about the evolution of the French urban system (Pumain, 1982, INED, 1984). The first reliable data concerning the population of cities are to be found in the 1831 census. Censuses occurred afterwards every five years but with breaks in 1916 and 1941 due to the wars and with a different periodicity from 1946 up to now : 1954, 1962, 1968, 1975 and 1982. Population figures are given in the censuses only for administrative units, the communes, which are rather small (15 square kilometers in average). Communes are considered as urban when they group more than 2 000 inhabitants. We wanted however the concept of "city" to remain consistent over this large period of time. That is why towns and cities have been defined as "agglomerations" or urban areas. The urban agglomerations were thereafter reconstituted in the data base on a contiguity criteria, including all neighbouring urban communes. The data base comprises from 617 urban agglomerations in 1831 to 1782 in 1982.

From 1831 to 1982, the French urban population increased from 6.5 to 39.6 millions (a multiplication by 6.1), the number of urban communes from 854 to 4 888 (5.7 times), the number of urban agglomerations from 617 to 1782 (2.9 times) and the mean population size of an agglomeration from 9 500 to 22 300 inhabitants (2.3 times; figure 1). When compared with the urbanization process of other similar countries, the French one appears as rather slow and belated : during all the XIXth century, whereas the mean annual growth rate of urban population was more than 2 % in Great Britain, it was about 1 % in France ; the urbanization rate, which was already much lower in France than in Great Britain at the beginning of the XIXth century (20 % versus 44 % in 1831) passed beyond 50 % as late as in the nineteen thirties. It is only after the second world war that the urbanization process accelerated, with mean growth rates of urban population larger than 2 % per year. Still in comparison with Great Britain and even with Germany, very few new towns were created during this expansionary stage of the urban system, even during the first Industrial Revolution.

4.1 Structural stability

Despite of the dramatic growth of the urban population and of the number and size of cities, the urban system has remained remarkably stable in its geographical and dimensional configurations. The maps (figure 2) show that the sites and the relative sizes of cities do not exhibit large visible change all over the territory between the beginning and the end of this almost two centuries long period. The correlation between the ranks of cities in the urban hierarchy is surprisingly high: 0.71 from 1831 to 1982 and 0.83 from 1911 to 1982.

This inertia in the relative positions of cities in the urban hierarchy is characteristic of the urban systems which have a long history. Two thousand years afterwards, the ordering of cities of the Roman Empire is still largely observable today: at that time, according to R. Etienne (in Dupâquier, 1988, p. 90) "the modern urban network is already designed, the hierarchy of cities is confirmed". Among the 107 heads of "pagi" located in the actual framework of France, 85 are still larger than 5 000 inhabitants. 37 of the 55 largest urban agglomerations of today were Gallo-Roman cities.

In countries whose settlement system is younger, as for instance in the United States, the correlation between the current rank of cities and the one they had in the last century is highly negative (Moore, 1958). In France, among the 43 towns with more than 20 000 inhabitants in 1831, 37 are still today at the 43 first places. The remaining six which have lost a part of their relative importance still appear before the 79th rank. All the cities which have now more than 100 000 inhabitants were already larger than 10 000 in 1831.

The general translation of the whole urban hierarchy towards higher sizes is well illustrated by a transition matrix of cities from one population size class to another between 1831 and 1982 (table 1). Most of cities have either remained in the same size group (this is the most frequent case for towns smaller than 10 000 inhabitants) or have increased their size by one level (especially when they were larger than 10 000 inhabitants in 1831) but very few have changed their size by more than one hierarchical level and almost none by three or four. Robson (1973) has found very similar transition matrices for England and Wales during the XIXth century.

The shape of the distribution of city sizes has also remained very stable (figure 3). The high level of primacy, which is a well-known specificity of the French urban system

(the population of Paris agglomeration is six to seven times the one of Lyon at the second rank) has kept about the same intensity at least since the beginning of the XIXth century, and very likely since long before.

The French settlement system has then maintained its main structural properties and its specificity through two centuries (or more), through two or three industrial revolutions, rural depopulation, during the stagnation in the interval between the two wars as well as during the demographic and economic boom and the rapid urbanization period of the last forty years. To the strong constraints resulting from industrial revolution, railways construction, diffusion of automobile transportation or the final stage of rural depopulation, the urban system reacted without changing radically its configuration.

4-2 Fluctuations in growth of individual cities

Such a stability is all the more surprising, as urbanization is in itself a very fluctuating process. It fluctuates in time : the mean annual growth rates of urban population oscillated between 0.5 % and 2.8 % during the 26 census intervals (when negative rates of the war periods and exceptionnaly low and high rates of the periods 1836-41 and 1841-46 due to a systematic bias in the census data for 1841 are excluded). The values exhibit cyclical fluctuations of twenty to fifty years periods; they are roughly followed by the fluctuations in the growth rate of the number of cities (that is, in the number of settlements whose population passes over or below the threshold of 2000 inhabitants, figure 4). At each time period, there are very large variations in the intensity of growth among cities : the statistical distributions of the growth rates are almost normal but their standard deviation values are usually about three times the mean value. For each town, there are large fluctuations of growth from one census interval to another.

4.3 Is urban growth a purely random process ?

The test of Gibrat's model over French data leads to convergent results, as to its main hypothesis, with the ones of Madden (1955) and Robson (1973):

- a proper description of the urban growth process is actually given by the "law of proportional effect". On the one hand, on average, the variations in the number of inhabitants of a city are roughly proportional to its size, or, in other words, in the whole urban system, urban growth rates are randomly distributed among cities, irrespective of their size. On the other hand, the spatial distributions of the growth rates are rather independent from one period of time to the other. Both rules hold for the largest part of the growth process in any urban system.

- It may be added that, despite non negligible fluctuations of the ratio between the growth rates of urban population and of the number of cities, there is a rather strong parallelism in the evolutions of both rates (figure 4) and then the hypothesis of a not too unstable relationship between those two processes of expansion in urban systems can also be hold for true. Of course, this last observation relies upon the degree of relevance of the geographical definition which is used for the delimitation of urban subsystems. In a simpler way, it can be said that the dynamic of the rural settlements whose population is large enough to let them grow above the threshold of urban size is similar to the one of the cities already belonging to the urban system.

Why does urban growth follow the two fundamental hypothesis of the process described by Gibrat? It is possible to understand why cities grow in average at the same speed: as they are all connected in the same system, they are all submitted to the same general conditions (demographic and economic growth, socio-economic and technical innovations...) which are responsible for the urbanization process. The variety of local conditions and the slight differences in the timing of the diffusion of innovations may explain the quasi random fluctuations in the growth rates of individual cities.

What remains to be explained is why urban growth is proportional to urban size. Urban growth has two components, natural growth and net migration. The natural growth of populations is always multiplicative, proportional to their initial size: when there is no limitations of resources, it is exponential, otherwise it follows a logistic curve. It would require a very peculiar segregation of the age groups among cities, according to their size (for instance all young people in small towns and old ones in the largest cities) before this rule is changed. Net migration is also roughly proportional to city size, as long as the immigration and outmigration flows are also proportional to this size. This is normally the case, as it is described in the analogic models of gravitation which are used most of the time to adjust the observations of migratory flows or to predict them. According to spatial migration theory (Courgeau, 1984), interaction flows between various places are proportional to the probability of contacts of their residents, and this probability is a function of the size of the places.

It is then the multiplicative aspect of the spatial process of the agglomeration of population which has to be explained, in order to find out a proper explanation of the size distribution of cities. The main characteristic of the urban systems is their hierarchic structure, which reveals a principle of ordering in the system at the macro-level; it can be interpreted as resulting from a specific process of interactions between the individuals at the micro-level, which define the spatial variations in their reproductive and migratory behaviour. There is no explicit intention in the behaviour of the individuals regarding the city-size distribution. It is in this sense that urban systems can be described as self-organized systems. If one or both of the behavioral features of urban populations would change from what they have used to be during the centuries of slow and then rapid urbanization, or if they cease to be rather homogeneous over space, the evolution and the structure of the urban systems could become very different.

5 GEOGRAPHICAL DYNAMIC PROPERTIES OF URBAN SYSTEMS

However, we have observed, as well as Robson (1973), systematic deviations from the stochastic process described by Gibrat. This should lead to a reformulation of a dynamic model including hypothesis which would take into account the specific nature of urban systems.

5-1 Urban systems are geographical systems

A first kind of deviation from Gibrat's model is the existence of a slight positive correlation between growth rates and the size of cities. This correlation is higher with the logarithm of size than with the size itself, the trend for an increasing growth rate with city size is then a non-linear one (figure 5). It is responsible for a larger increase in the slope of the rank-size distribution (absolute value) than it would be expected from the Gibrat's model (figure 6). The largest French cities have then taken a greater advantage of the urbanization process than the smallest. The correlation between city growth and city size was on the contrary negative in a developing urban system like the American one during the XIXth century (Madden, 1955), it has also become negative

during the last fifteen years in the most urbanized countries, leading to a slight decrease in the concentration of city sizes (figure 5 and 6). This trend was interpreted by several scholars as a complete reversal, called "counterurbanization", which would reduce the inequalities in size among the cities. However, this interpretation is at variance with the observations for the eighties and the previsions made for the nineties, at least in Europe, which show again a trend towards an increasing concentration of urban population.

A second type of deviations from a random process is less frequent and seems less continuous in time but may have stronger effects on the geographical structure of urban systems: city growth rates are not always independent from one time interval to the next, or in other words they exhibit a slight temporal autocorrelation (figure 5). In France, this correlation was rather high at the end of the XIXth century, and during the last forty years. Instead of a random distribution, there is then a trend for a geographical selectivity of urban growth. This last process is totally independent of the previous one, since it occurs in all classes of population size. It may have contributed to reinforce the concentration of city sizes in the urban system, but it is also compatible with a de-concentration (as observed during the period 1975-82 in France (cf. figures 5 and 6). It corresponds to the development of innovations whose diffusion has been limited in space, for specific reasons (non substituable resources, location close to mountains or to the sea). Detailed studies of the distribution of growth in such regions which have been momentarily favoured show that they are submitted to the same general stochastic process, with large inequalities in the growth rates of individual cities at any time, only the average level of growth is higher.

Whereas the "law of proportional effect" can be seen as a very general process for the evolution of any hierarchic open system, trivial since just explaining the Paretian structure, the selectivity in the growth process, according to the size or to other properties of the cities, appears now as a specific feature of the evolution of the urban systems. We want to show that this can no longer be considered as a residual in a stochastic theory of the growth of cities, but that it has to be integrated in a dynamic model.

5-2 The interurban competition process

We have recalled that large scale interaction is a specific property of cities, and that the organization of urban systems in hierarchized networks is more a "self-organized" structure than the result of any planning. This structure has progressively emerged from a continuous process of competition between cities. For instance, B. Lepetit (1988), when studying the construction of the national road-system in France during the XVIIIth century, found that at that time, the very concept of a road network did not exist. But there was already at a local scale a very strong competition between neighbouring cities for attracting the infrastructure. Other well-known examples of such interurban competitions for developing were for instance about the choice of the capitals of départements in 1793, or more recently about the location of industrial zones, creation of airports or of technopoles.

As a result of the competitive process, not only the demographic growth is equal in average among cities over long periods of time, but also the same kinds of socio-economic changes are occurring everywhere, at about the same pace. For instance, the tertiarization of the economy, the substitution of new to old types of activities and the modifications in social structure have been very general in French cities during the 1950-1980 period. This process explains why very old differential in the socio-economic profiles of cities, like the ones induced by the industrial revolution of the last century,

have remained almost unchanged since that time (Pumain, Saint-Julien, 1978). Imitation of what has been done elsewhere and anticipation about how to get a better position in the urban hierarchy are permanent and very old concerns for public and private local authorities. Both processes have been quoted by P. Allen (1978) as being responsible for non-linearities in self-organizing social systems. Those processes play an important role in the systems of cities, because information has been circulating in urban networks since a long time, as soon as they were connected.

Illustrating the effects of this interurban competition are the graphs which show the changes in the ranks held by cities in the urban hierarchy at different dates (figure 7). Except for a dozen of largest cities, for which the changes are fewer and of lesser amplitude, the rises and falls in rank are distributed through all the urban hierarchy, on long periods of time as well as for shorter intervals.

5-3 Shrinking space and urban hierarchy

If this was a perfect competition process, it would lead only to random fluctuations and in average the growth rate of cities would be the same. This explains the large relevance of a stochastic process like the one defined by Gibrat. But the process of urban change is not perfectly ubiquitous as one would expect from a simple theory of the diffusion of innovations in space. The hierarchical diffusion process gives an initial advantage to the largest cities. Two effects can explain the advantage of the largest cities. First their large size increases the probability of appearance and use of innovations, and especially of associations of innovations. Second, because of their size, they have more interactions in the urban network and can capture the innovations which come from elsewhere.

This explains the systematic advantage of the largest cities for urban growth, at least at the beginning of the cycles of the diffusion of innovations. The stages during which smaller cities grow faster may be regarded as periods of the end of such a process (Robson, 1973).

There is a third reason for large cities having an advantage. We have classified the curves of the evolution of the population of cities in six types (figure 8). Despite of the general growing trend, two categories at least have a decreasing importance in the urban system in relative terms. Those cities whose share in the total urban population is decreasing are in average smaller than the growing ones. Their geographical distribution is rather regular, dispersed all over the country, in all regions, most of the times in the intervals between largest and more rapidly growing cities. This can be interpreted as an effect of the shrinking of space (Janelle, 1969, Juillard, 1970). With the course of time, the speed of the communications is increasing, the range of the largest cities is extended in such a way that the smaller cities are short-circuited, even for low level functions. As interurban competition is taking place in a shrinking spatio-temporal framework, the urban hierarchy tends to become always more and more contrasted.

CONCLUSION: MODELLING THE INERTIA OF URBAN SYSTEM

The "normal" evolution of an urban system tends to preserve its structure, that is, the hierarchic organization, the position of cities in the hierarchy of sizes, and also the main socio-economic differences. This evolution is produced by two processes which are highly fluctuant on the short term but rather regular on the long run: the rule of the population growth proportional to the size of cities, and the very quick diffusion in every town of qualitative changes and innovations.

Each time when an innovation cycle is concentrated in space like the one of the first industrial revolution, or today of the "sun-belts" developments, it may change the relative positions or the weights of sub-systems of cities, and then change the geographical structure of the urban system, without necessarily changing much its hierarchical structure. This happens when the initial advantages or the expected benefits of concentration are stronger than the spontaneous trends to the regulation in the urban system, which are usually occurring by imitation and competition between cities.

If a dynamic model of city sizes in urban systems is to be conceived in the framework of self-organizing systems theory, it will derive the macro-level hierarchic structure of the system from a micro-level process of interactions between the individuals. Even if this interactive process is reduced to hypothesis concerning the natural growth and the migratory behaviour of the individuals, this process cannot be defined independently of the previous state of the system: the behaviour of individuals is influenced by the size of the settlements and by the relative location of cities. The advantage which is given to the largest cities is not only a matter of size but also of the shrinking trend in the spatial organization of the system.

This may give to the urban system a larger inertia, which is also a characteristic of their dynamics and can be explained by the fact that a city is not only a grouping of inhabitants, but also has a material, built-up structure. This "concrete" inscription of the past processes of accumulation of wealth and values, slow down the momentaneous trends which would tend to change the ordering of cities in the urban hierarchy. Few major bifurcations may be expected in the historic trajectory of urban systems. It may be that any modelling using only a conceptualization of cities in terms of aggregation of people will prove irrelevant.

This kind of formalization could however provide measures of the degree of freedom of local and national governments when they pretend to intervene in the distribution of population over a territory. We should answer such questions as: is an hierarchical organization of city sizes the only possible state for an urban system? Is the trend towards a higher concentration of urban population unavoidable? Dynamic modelling of urban systems would help us to explore and to measure the "costs" of other possible solutions. Experiments with computer simulations are (almost) painless for the inhabitants!

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Table 1 - GENERAL STABILITY OF URBAN HIERARCHY

Transition matrix by hierarchical levels 1831-1982

1831 \ 1982	0	1	2	3	4	5	6	7	8
0	.05	.60	.23	.09	.02	.01			
1	.13	.50	.27	.07	.02	.01			
2		.14	.45	.31	.08	.01			
3			.06	.27	.50	.13	.04		
4					.22	.44	.33		
5						.28	.43	.28	
6							.25	.50	.25
7									1.0

(Proportion of cities belonging to a size class in 1831 in each size class at 1982).

Hierarchical levels (size classes) :

0	< 2.500	5	40.000 - 80.000
1	2.500 - 5.000	6	80.000 - 160.000
2	5.000 - 10.000	7	160.000 - 320.000
3	10.000 - 20.000	8	> 320.000
4	20.000 - 40.000		

Figure 1

EVOLUTION OF THE SIZE OF THE URBAN SYSTEM

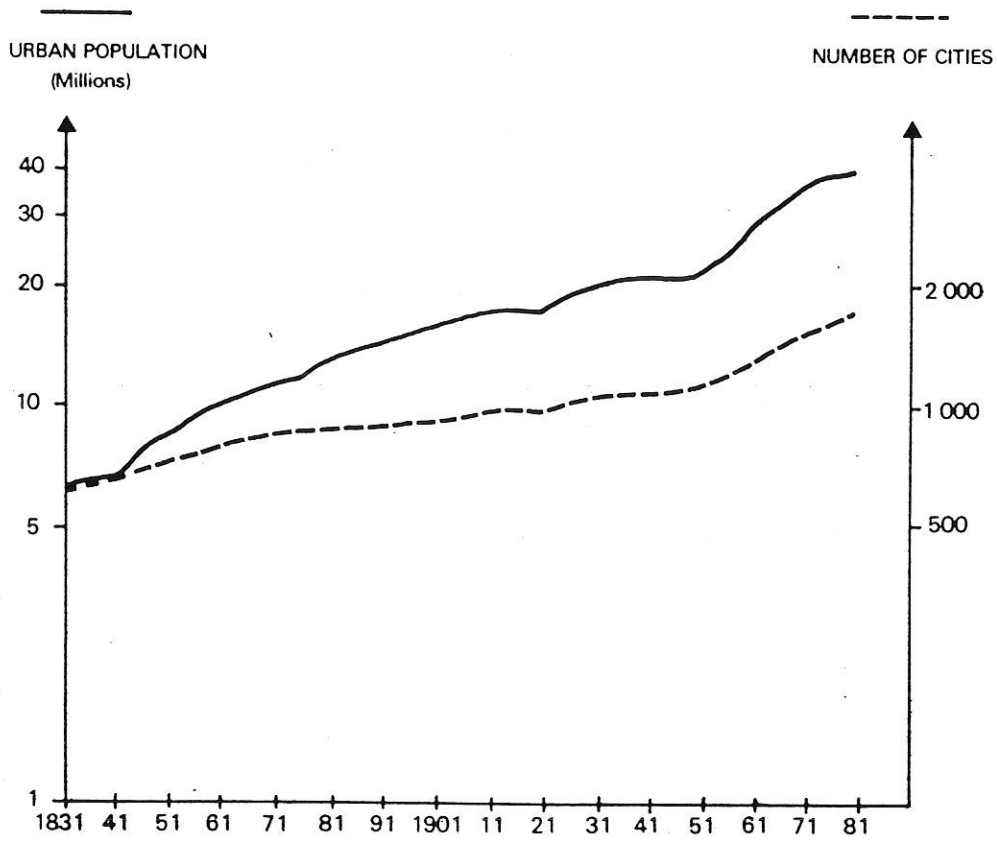
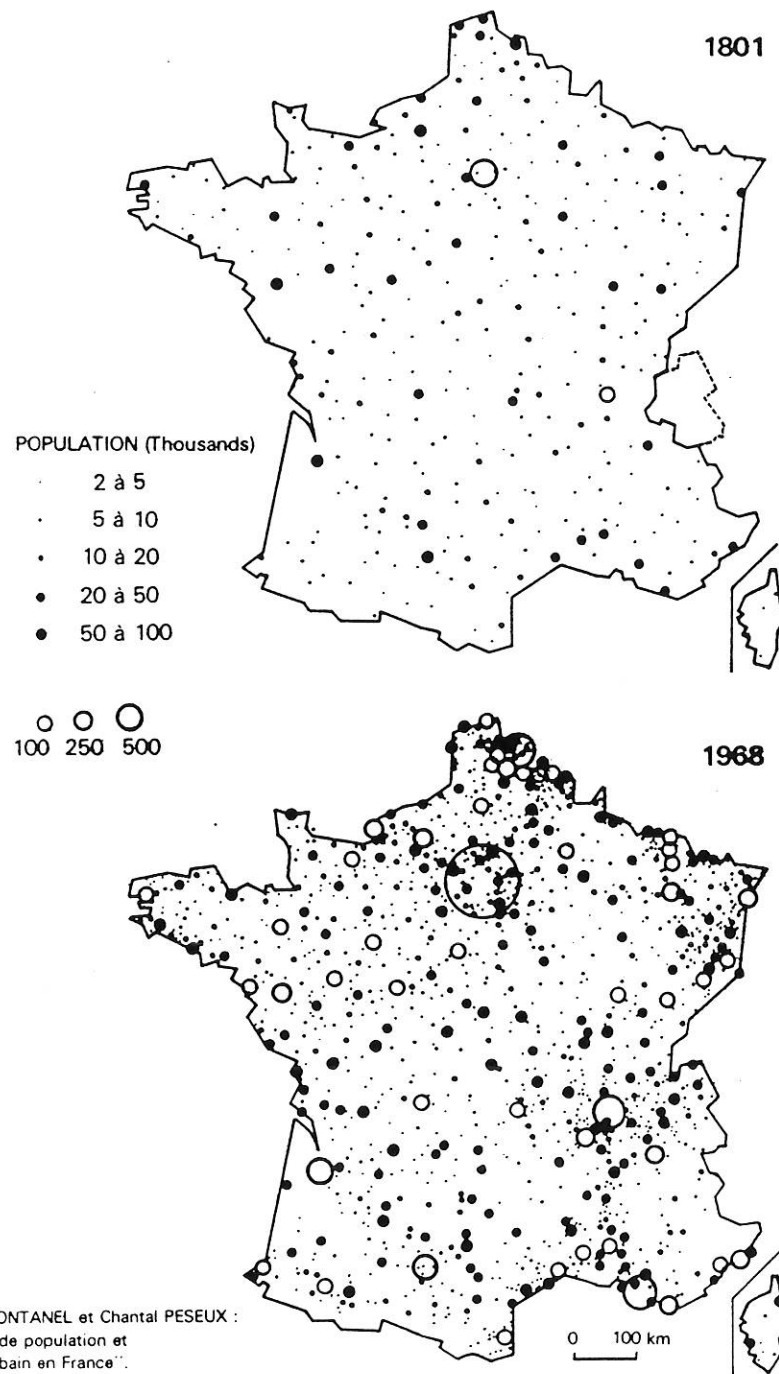


Figure 2
PERSISTENCY OF THE SPATIAL STRUCTURE
OF THE URBAN SYSTEM



after :
Colette FONTANEL et Chantal PESEUX :
"Potentiel de population et
réseau urbain en France".
L'Espace Géographique, 1976, n° 4.

Figure 3
RANK-SIZE DISTRIBUTION OF FRENCH URBAN
AGGLOMERATIONS

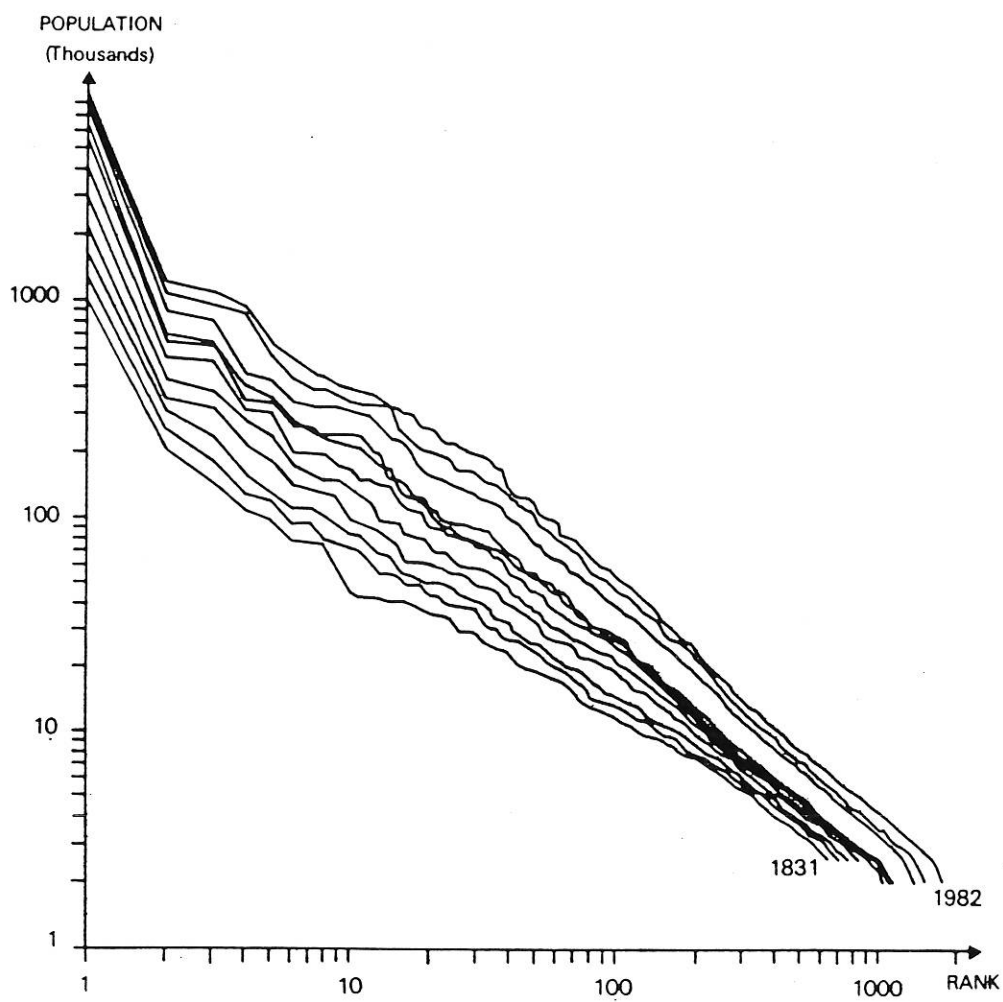


Figure 4
FLUCTUATIONS OF GROWTH OVER TIME
IN THE URBAN SYSTEM

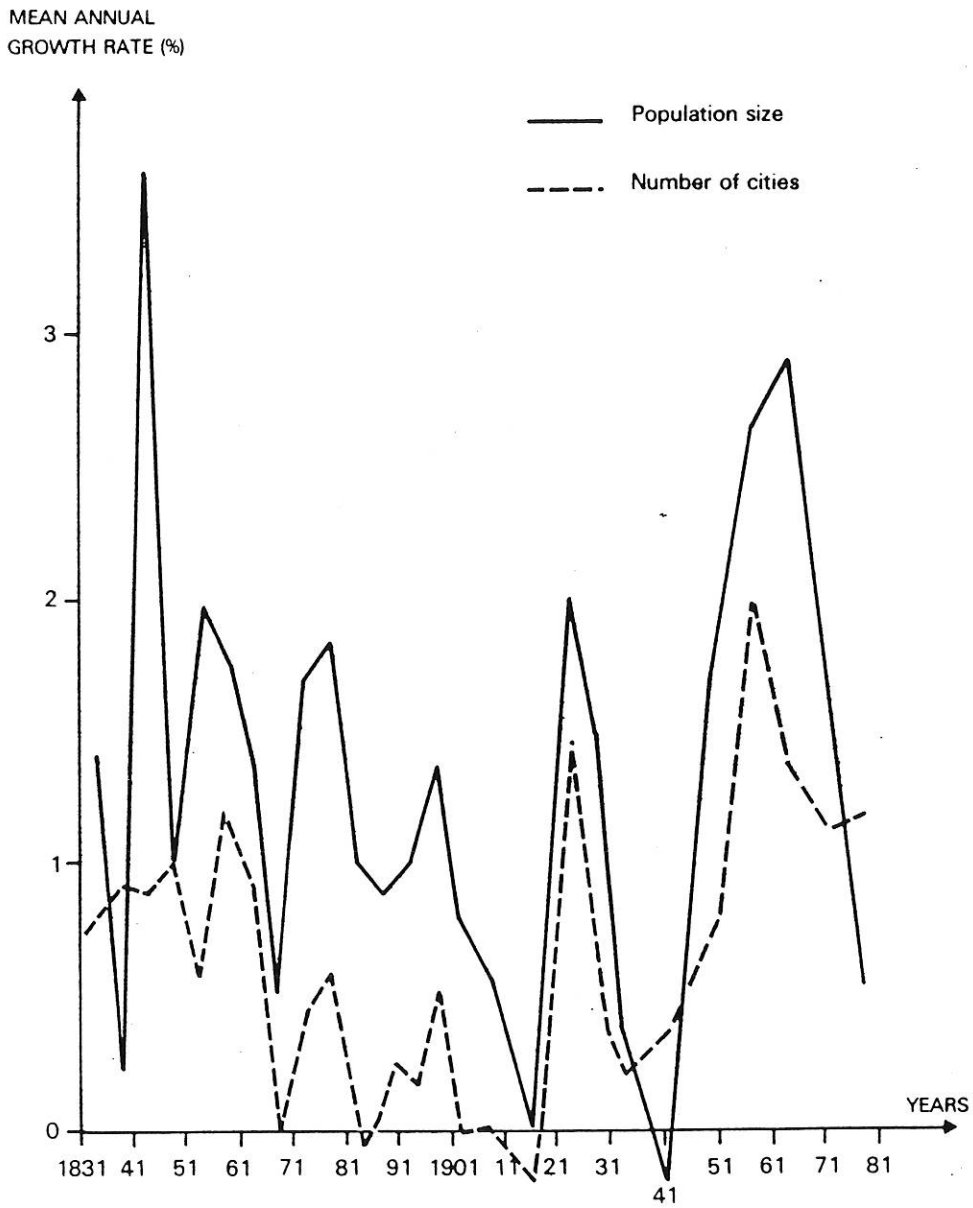
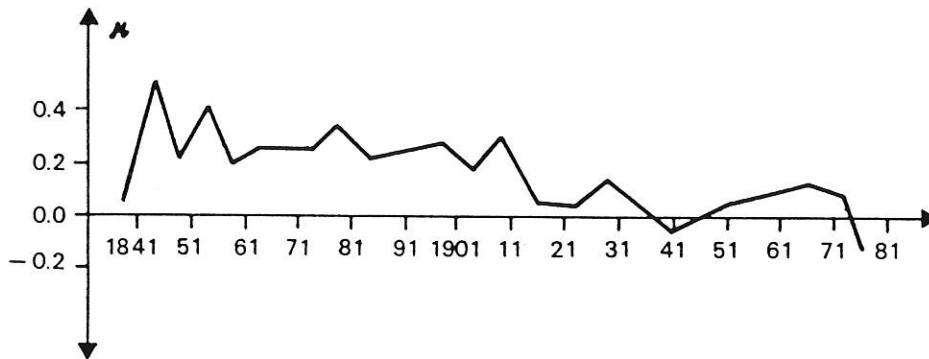


Figure 5

**TWO DEVIATIONS FROM GIBRAT'S PROCESS
OF URBAN GROWTH**

**CORRELATION BETWEEN LOG OF POPULATION SIZE
AND GROWTH RATES**



CORRELATION BETWEEN SUCCESSIVE GROWTH RATES

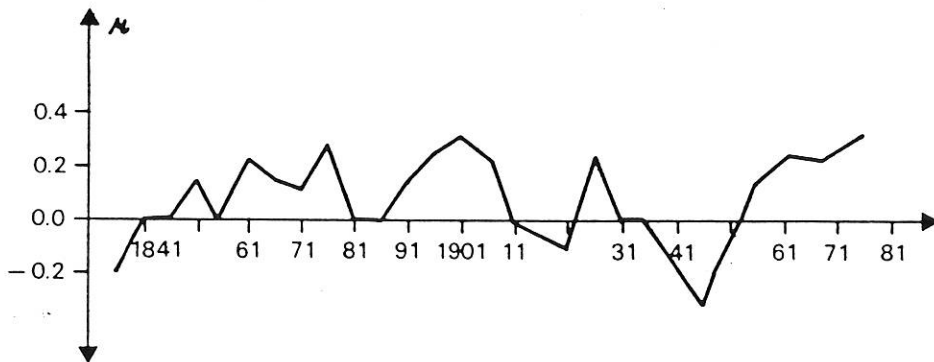


Figure 6

**EVOLUTION OF THE SLOPE OF RANK-SIZE
DISTRIBUTION 1831-1982**

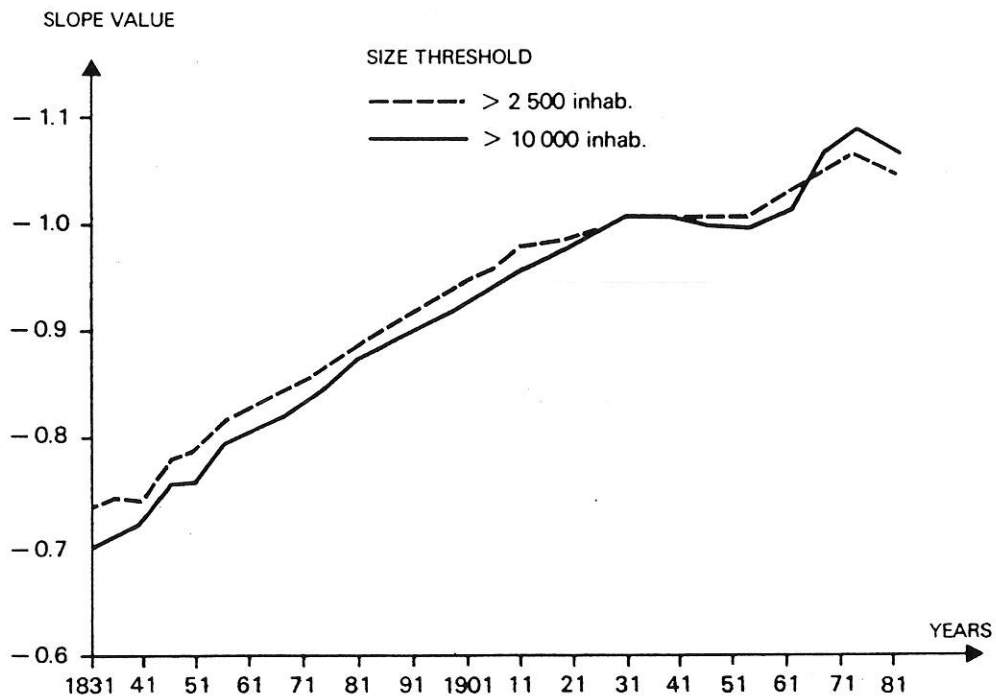
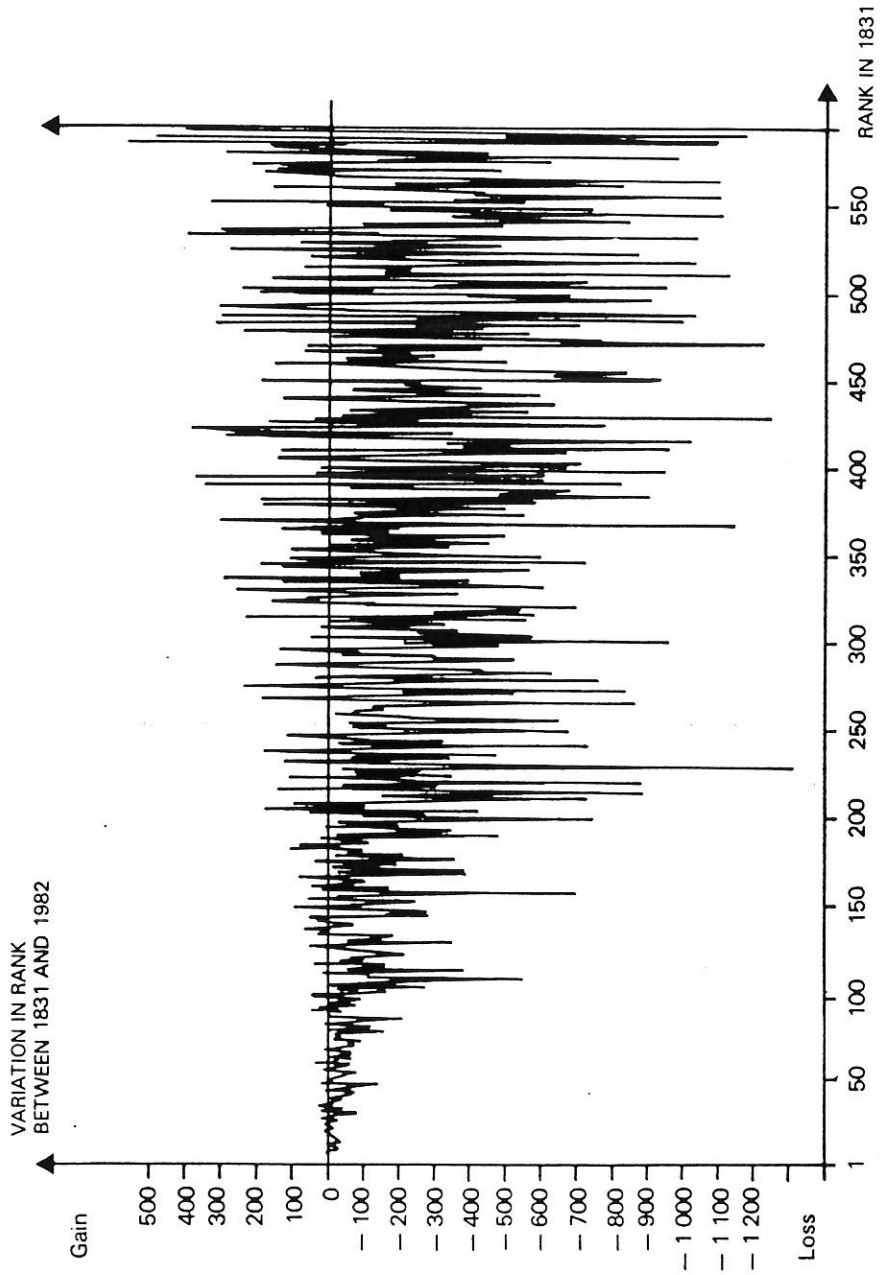


Figure 7

COMPETITION IN URBAN HIERARCHY



after F. GUERIN

Figure 8

TYPES OF URBAN GROWTH 1831-1982

