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CHAPTER 15

Interurban migration and dynamics of the French urban system : socio-economic components

• Lena SANDERS, Denise PUMAIN, Thérèse SAINT-JULIEN

I. - Introduction

According to a static description, the essential function of a city is to valorize a situation in a network, at a geographical scale which is always beyond that of the site where it is localized (Reymond, 1981). A fundamental property of large sets of cities is the interdependency of their elements, which appears in their hierarchical and spatial organization and in their evolution. The evolution of a set of cities exhibits phenomena of synergy and coherence which recall characteristic processes of the dynamics of self-organized systems : production of stable structures at a macro-scale from extremely fluctuating interaction processes at the micro-level, long-range correlations in the evolution of individual cities, transformation of macro-structures by the amplification of small fluctuations (Pumain, Saint-Julien and Sanders, 1989).

Beyond such an inductive analogy, which stems from empirical results, it is to be hoped that mathematical models will help to improve the formalized description of urban dynamics. The weakest point of urban theory is indeed the prognosis of urban population growth. Several economic theories have tried to derive models from the knowledge of the industrial mix of one single city. But forecasts are still difficult, because urban evolutions are always fluctuating.

Our hypothesis is that the relative situation of a city in the whole urban system and its evolution has a higher stability and could be better analysed and predicted than the trajectory of one single city. The model which has been proposed by Weidlich and Haag (1988) for the study of interregional migrations is helpful in many respects for the formalization of such an hypothesis. It considers a geographical system as a set of interacting units whose population configuration is modified by migrations. It links the migratory behaviour of individuals at a micro-level and the evolution of the spatial configuration of populations at the macro-

level. The model will then generate a measurement of the relative attractivity of cities (their "utilities") which can be tested in a second step and compared with their socio-economic characteristics.

II. - The data base

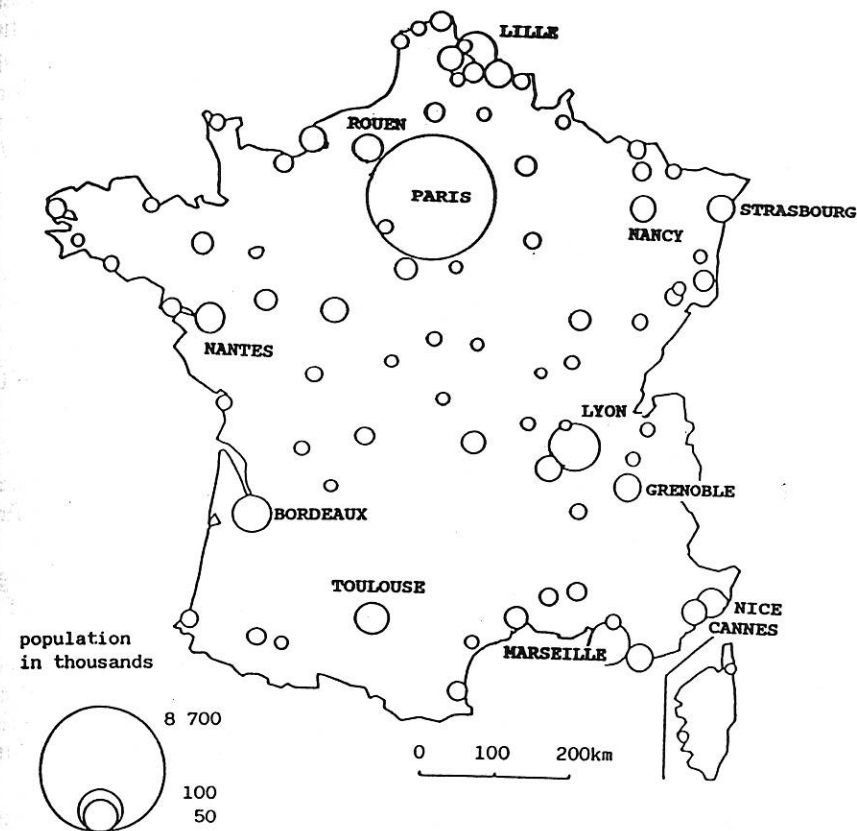
Since France does not have any register of population, information about spatial mobility is available from census data. For the first time in 1962 a question was asked concerning the place of residence at the date of the preceding census in 1954. The same question was asked at the following censuses in 1968, 1975 and 1982. Answers were exploited to produce migration tables, in an exhaustive way for the 1954-62 period, and from samples for the others (with various rates: 1/4 in 62-68, 1/5 in 68/75, 1/20 in 75/82), for all urban agglomerations having more than 50,000 inhabitants. All data are computed for urban agglomerations in their geographical delimitation of the last census date, for each period.

As a first approximation, the urban system is described here by the same set of 78 large "urban units" or agglomerations, for which informations about migration were available at each of the four periods. However, a few of them were included later into another agglomeration, like Denain, or Bruay-en-Artois, and only those aggregated agglomerations have been considered. The cities which reached the threshold afterwards have not been added to this set (in 1982, 112 french cities have more than 50,000 inhabitants). Further models should of course take into account such "newcomers" in the system.

The 78 cities are very different by their size, from 50,000 inhabitants to 8.7 millions in 1982 (see map 1).

In France, as in many other countries, migrations from rural areas into cities were mainly responsible for the fast urbanization process and for the high urban population growth rates during the thirty years period following World War II. As rural population surpluses decreased, urbanization entered in its phase of saturation.

Meanwhile, migration is no longer the main source of urban growth but it keeps a significant role in the dynamics of cities, since its effects are more and more discriminant: the statistical dispersion of migration rates is higher than that of natural growth rates; moreover, net migration rates are becoming more and more unequal, whereas on the contrary natural growth rates tend to equalize their values among cities. Finally, there is also a growing tendency towards a persistancy of low or high net migration rates in the same cities: the correlation between their values measured on successive census intervals has increased from about .3 to .7 during the last thirty years. It seems then that migration could be more revealing than before as far as selective changes in the urban system are concerned. Therefore, a model specifically based on the interurban migrations seems interesting to describe the past evolution and to improve the forecast of the French urban system's future.



Map 1. - The 78 largest cities.

III. - The model

The dynamic model of a system of cities used for this study has been developed at the University of Stuttgart. It is a stochastic model, the formulation of which is based on master equations; the above paper by G. Haag shows the general framework of the model and we will simply recall here the basic principles of the simplified form that we are going to apply.

The aim of the model is to study the dynamics of the distribution of the total urban population N between the L cities of the system. This distribution can be represented by a configuration vector $n = (n_1, n_2, \dots, n_L)$ where n_i stands for the number of inhabitants of city i . The change of this distribution in time results

from the conjunction of birth, death and migration processes at the individual level. In a first step we suppose that birth and death processes are regularly distributed inside the system and we concentrate only on the effects of interurban migration.

A change in the distribution of the urban population from a configuration $n = (n_1, n_2, \dots, n_L)$ to a configuration $n' = (n'_1, n'_2, \dots, n'_L)$ at a macro-level depends directly on the accumulation of changes at a micro-level. The model is then based on the expression of an individual transition rate p_{ji} for moving from a city i to a city j :

$$p_{ji} = v_0(t) f_{ji} \exp(u_j - u_i)$$

with

$v_0(t)$ = general index of mobility,

$f_{ji} = f_{ij}$ = a measure of "proximity" between i and j ,

u_j, u_i = utilities of cities j and i .

This formulation supposes a decomposition of the probability to migrate into 3 effects :

- a global index of mobility of people which can vary over time,
- a symmetrical effect measuring the general proximity between each couple of cities: this measure depends of course on the geographical distance but reflects also more generally all social or economic distances between two cities,
- an asymmetrical effect measuring the advantage that the inhabitants living in city i will find in moving to city j , through the differences of utilities of the two cities. These utilities depend on the socio-economic characteristics of the cities. The expression "utility" is partly ambiguous. In economic theory, it usually refers to an evaluation of the benefit that an individual gets from a specific set of goods. It is here related to an aggregate property of an arbitrarily defined subdivision of the territory. It is then also a measure of the differential attractiveness which is given by those utilities.

The link between the micro-level and the macro-level is established through the master equation. If the individual probabilities are supposed independent, the probability of change from one population configuration to another one is a function of the addition of all the individual probabilities of moving from one city to another.

If $P(n, t)$ is the probability to find a certain configuration n at time t , the master equation $dP(n, t)/dt$ describes the dynamics of this probability which depends in a complete and complex way of the individual transition rates. The complexity of this equation and specially the lack of empirical data makes it impossible to solve it. So, practically, a deterministic model is actually derived from the master equation which is based on the mean value equations corresponding to the most probable configuration. The latter are defined by a set of differential equations of the following form :

$$dn_j/dt = \sum_{i=1, L} n_i v_0(t) f_{ji} \exp(u_j - u_i) - \sum_{i=1, L} n_j v_0(t) f_{ij} \exp(u_i - u_j)$$

for $j = 1, \dots, L$

where n_j designs the mean number of inhabitants of the city j .

The confrontation with the empirical matrices of migration and the use of this system of equations enable to estimate the parameters and to realize some prognoses.

IV. — Distribution of the utilities

From 1954 to 1982, interurban differences in utility level mainly reflect inequalities in population sizes. The comparison of maps 2 and 3 representing the utilities at the first and the last period with map 1 (size of cities) illustrates clearly the relations between city-size and utility level. To take into account these effects, the following model has been used :

$$U_i(t) = K P_i(t) - \sigma P_i^2(t) + \delta_i(t) \quad (1)$$

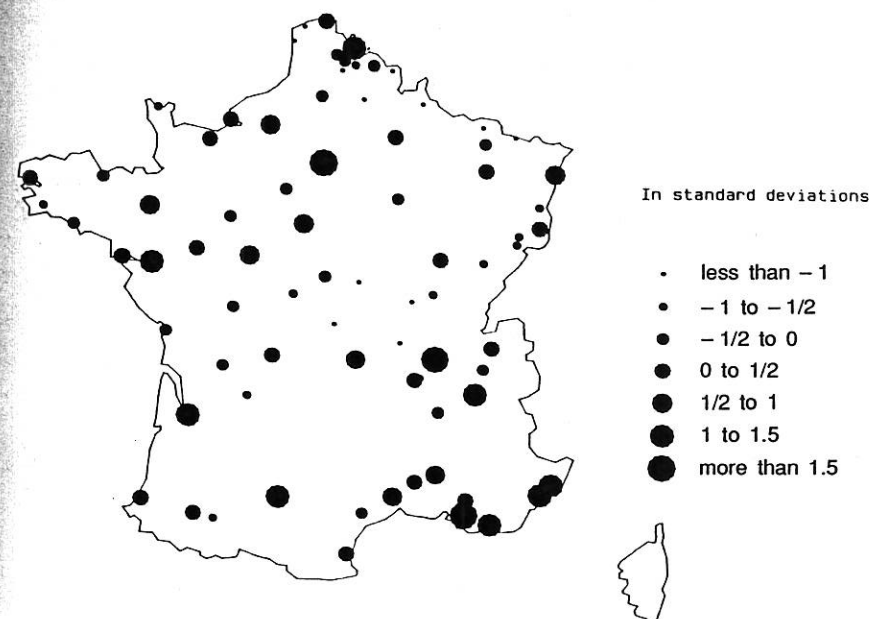
where

$U_i(t)$ represents the utility of city i at time t ,

$P_i(t)$ the population of city i at time t ;

$\delta_i(t)$ is the residual of the regression and is called preference for city i at time t ;

K, σ are parameters to be estimated, measuring respectively the agglomeration and the saturation effects of the city size on the utilities.



Map 2. — Utilities 1954-1962.

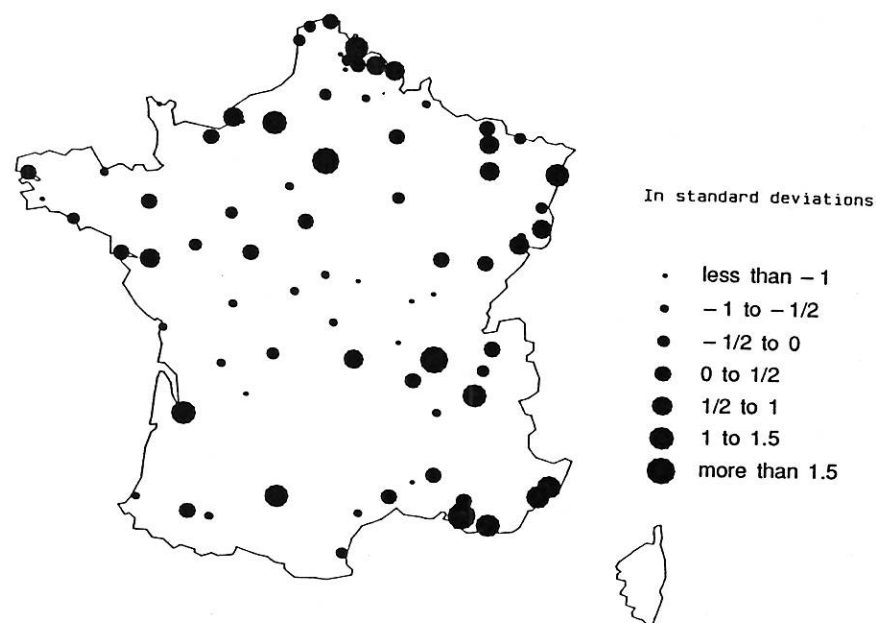
Equation (1) integrates two effects which are summarized in table 1 for the four periods :

- an agglomeration effect; the absolute number of inhabitants is associated to a positive coefficient. This collective effect describes the tendency of the population to agglomerate in large cities. Therefore K is called an agglomeration parameter.
- a saturation effect; the attraction is not infinite and a saturation appears, which is described in equation (1) by the saturation parameter σ negatively associated to the squared number of inhabitants.

TABLE 1. - AGGLOMERATION AND SATURATION COMPONENTS OF THE UTILITIES

	agglomeration K	saturation	R^2
1954-62	3.0×10^{-6}	4.1×10^{-13}	.61
1962-68	2.1×10^{-6}	2.3×10^{-13}	.62
1968-75	2.1×10^{-6}	2.2×10^{-13}	.57
1975-82	1.9×10^{-6}	1.9×10^{-13}	.68

Both effects retain the same significance over the whole period, since both parameters keep the same sign but one can remark that they both tend to decrease very regularly in time.



Map 3. - Utilities 1975-1982.

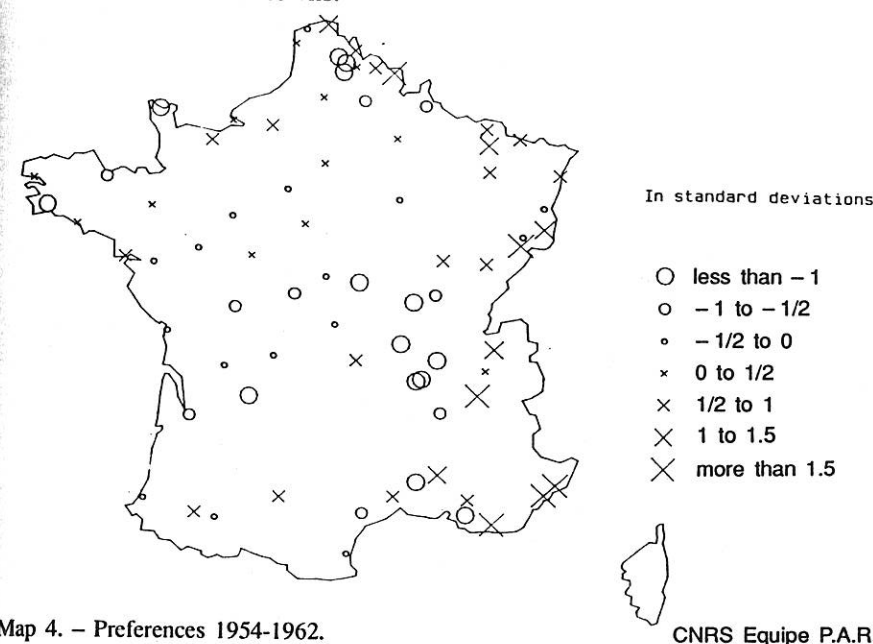
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V. - Preferences

The residuals of the regression of utilities against the size and the square of size are called "preferences": $\delta_i(t)$, $i = 1, \dots, L$. They refer to the differentials in geographical attractivity.

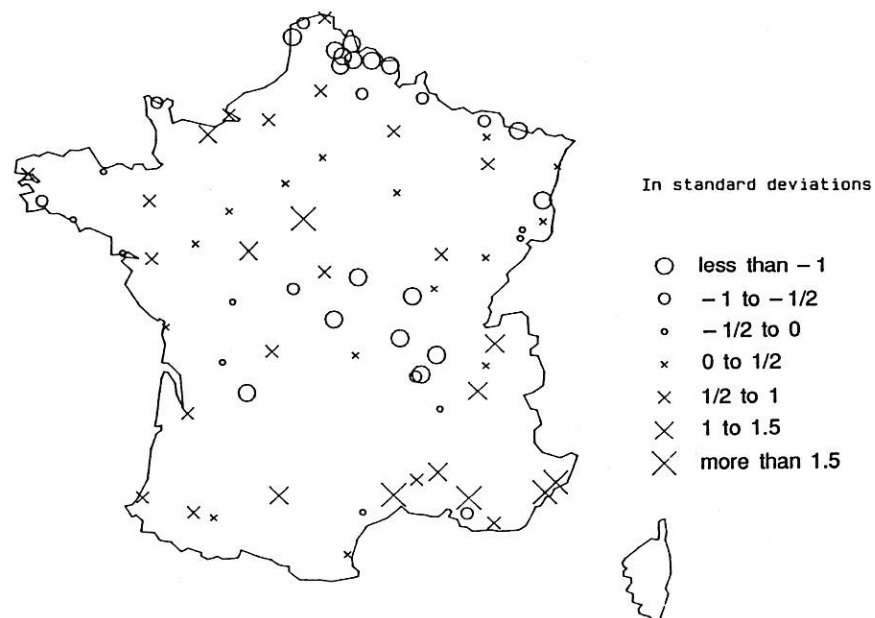
The maps of preferences (maps 4 to 7) have characteristics in common with those of net migration rates (correlations between .6 and .7 for the four periods) but these preferences appear to be a quite specific measure when compared to the classical demographic indices of urban dynamics. The first period (1954-62) exhibits a pattern which is quite different from those of the three following ones : the correlation coefficient is only .36 between the preferences of the first and the last period, .55 between the first and the second, and .89 and .84 between the second and the third and the third and the fourth respectively.

On map 8 are shown the relative differences between the preferences of the last and the first period. These differences come mainly from the declining preferences for cities of the northern and northeastern regions (Nord and Lorraine), which were rather high just after World War II with the development of the steel industry until the beginning of the sixties. The 1962-68 period is a period of transition during which the preferences for cities of the mediterranean coast and the Alpine region, already high, spread also towards cities of the Southwest, whereas the cities of the western part of the Paris basin are also very attractive. The last two periods show a generalization of high preferences to the southern half of France, with the exception of both metropolitan areas of Lyon and Marseille, as well as a few smaller towns.



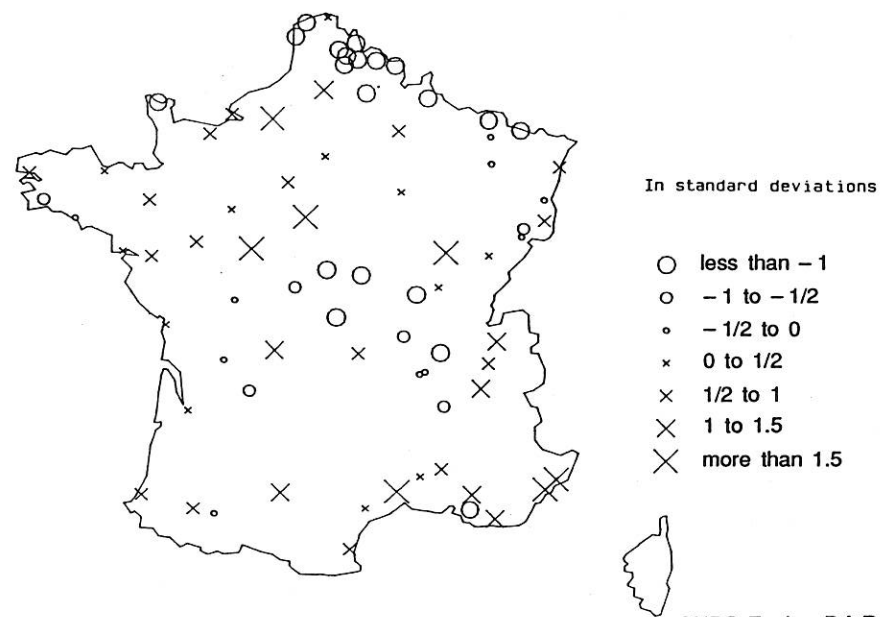
Map 4. - Preferences 1954-1962.

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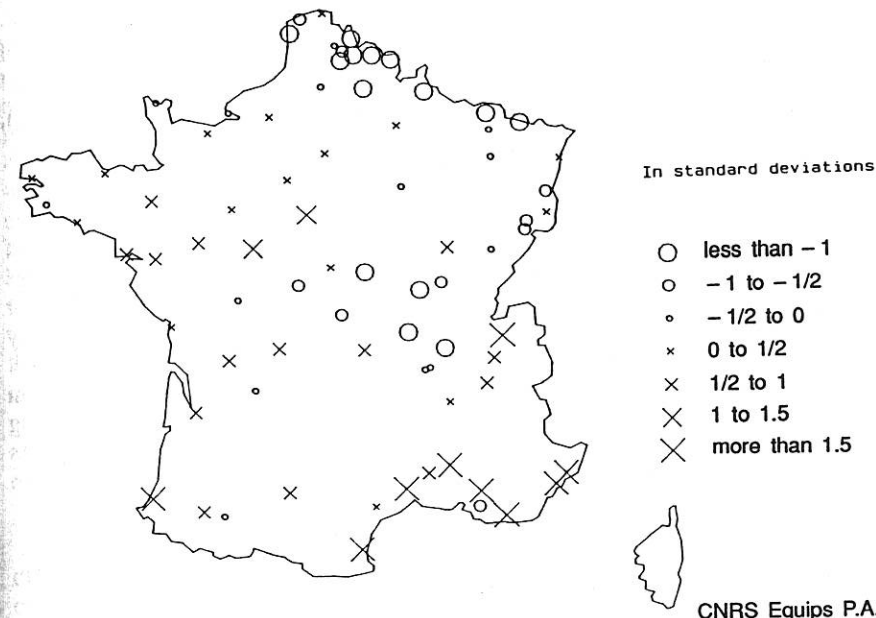
Map 5. - Preferences 1962-1968.

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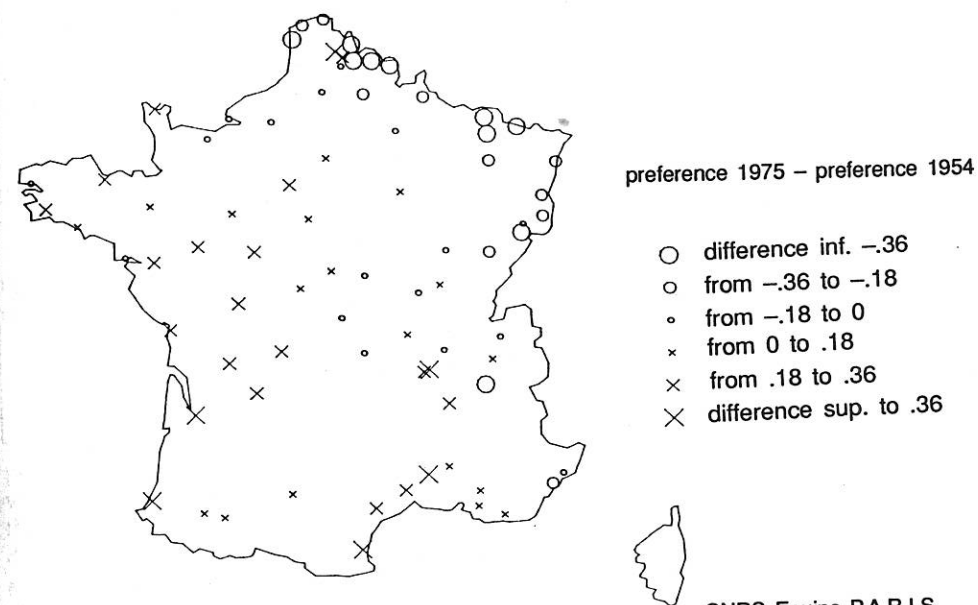
Map 6. - Preferences 1968-1975.

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Map 7. - Preferences 1975-1982.

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Map 8. - Differences between preferences 1954 and 1975.

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To test the relationship between the preference for a city and its socio-economic profile, we have used regression models. The socio-economic structure of a city can be measured by the repartition of the labour force between :

- socio-professional groups : 10 categories (workers, managers, entrepreneurs...),
- economic sectors : 17 categories (metallurgy, public services, banks...).

Although these two structures are strongly interrelated, they refer to two descriptions of a different nature. It is then more interesting to make two separate regression models, one using the 10 variables which describe the proportion of the labour force in each socio-professional group, the second with the 17 variables of the economic structure. Table 2 summarizes the results of these analyses for the four periods of time. The socio-economic structure of the cities seems to play a greater role in explaining differences in preferences for the later periods of time. Especially during the first period, the economic profile of a city did not explain the importance of the preference for this city. All the other analyses show a strong relation between the preferences and the socio-economic structure of the cities. As there are a lot of interrelations between these variables, a few number of them are enough to explain almost half of the variance.

TABLE 2. – PREFERENCES AND SOCIO-ECONOMIC VARIABLES: SIGNIFICANT VARIABLES IN REGRESSION ANALYSIS

	Economic activities	R ²	Socio-prof. groups	R ²
1954-62	hotel trade +	.25	personal services +	.40
	metallurgy +		blue collars +	
1962-68	services to households +	.41	entrepreneurs -	.45
	mining -		personal services +	
	hotel trade +		blue collars -	
1968-75	services to households +	.39	entrepreneurs -	.38
	mining -		personal services +	
1975-82	services to enterprises +	.47	managerial staff +	.45
	public services +		blue collars -	
	hotel trade +		entrepreneurs +	

1) Preferences and economic activities

The relation between the preferences and hotel trade appears to be quite a constant during the whole period. It shows the specific attractivity of touristic towns, especially those of the mediterranean coast.

Otherwise, there is an evolution in the type of the economic structure which makes a city attractive or not. During the period 1954-62, metallurgy is still expanding and so do the cities developing this activity. The two following periods are on the contrary characterized by the decline of mining which explains the low preferences of all the towns of the North and the Northeast and the positive relation between preferences and the services to households (all kinds of services to individuals, laundry, mechanic, medical doctor...) which appears to be overrepresented in all central places, tertiary cities with regional functions. At the last period, the category "services to the households" is replaced in the regression analysis by "services to enterprises" and "public services". Indeed, one can note that the recent urban growth is related to the development of these two economic categories which tend to concentrate in the most tertiary cities. In return, during this last period, the services to households are not anymore directly correlated with the dynamism of these cities.

2) Preferences and socio-professional groups

The regressions using the socio-professional groups give both redundant and complementary information about the distribution of the preferences and, here also, one can note an interesting evolution through time.

The change of sign of the group "workers" is significant : during the first period, some industrial cities were still developing quickly, whereas this category appears to be only repulsive in the following periods.

The opposite signs of the categories "personal services" and "entrepreneurs" in the regressions of the three first periods are particularly interesting. The first one has a positive relationship to the preferences and marks again the attractivity of the touristic towns (a majority of personal services refers to hotels and restaurant staff), especially those of the mediterranean coast. The second one, negative, shows the low preferences for the agglomerations with a more traditional social composition (a lot of small firms and entrepreneurs) which characterizes the whole southern half of France. In the last period, the positive sign of this category shows the expansion of the whole South and no longer the cities of the mediterranean coast only.

Thus, these analyses clearly show the shift, during this period, from north to south, from the expansion due to industry to the one due to the tertiary sector.

These socio-economic variables are representative of some of what G. Haag calls the "material variables" in his general presentation of the model (see the preceding paper). These variables have been used here as exogeneous explanatory variables, but our final aim is to find out what their dynamics are and to integrate them into the model. The dynamics of the main socio-economic variables which describe the urban system are however difficult to observe. Both the global socio-economic state of the system of cities and the variables which are responsible for urban growth do change over time. The idea would be to create a kind of basket with some representative variables of the dynamics of cities, but its constitution

presents of course a lot of difficulties : how are they to be chosen ? How can their general dynamics be studied?

VI. – The urban hierarchy : stationary distribution and provisional forecastings

As shown on table 3, the French urban system registered simultaneously, between 1954 and 1982, a diminution of the relative weight of Paris and a higher urban concentration in the following largest agglomerations. If we suppose that the parameters of 1982 remain constant, this evolution would be pursued. We have computed the stationary solution, where the distribution of population sizes reaches an equilibrium : migratory flows still exist, but the relative size of cities remains unchanged. This solution shows an equal weight of the population in Paris and of the total population in the next nine largest agglomerations. The relative positions of cities in this upper level of urban hierarchy remains remarkably stable.

TABLE 3. – EVOLUTION OF THE TOP OF THE HIERARCHY

(a) Ranking of the 10 biggest cities

Rank	1954	1962	1982	2002 predicted	Stationary state
1	Paris	Paris	Paris	Paris	Paris
2	Lyon	Lyon	Lyon	Lyon	Marseille
3	Marseille	Marseille	Marseille	Marseille	Lyon
4	Bordeaux	Lille	Lille	Lille	Nice
5	Lille	Bordeaux	Bordeaux	Bordeaux	Cannes
6	Rouen	Toulouse	Toulouse	Toulouse	Bordeaux
7	Nantes	Nantes	Nantes	Nice	Toulon
8	Toulouse	Nice	Nice	Nantes	Toulouse
9	Strasbourg	Lens	Toulon	Toulon	Lille
10	St Etienne	Valence	Grenoble	Grenoble	Nantes

(b) Concentration of the hierarchy

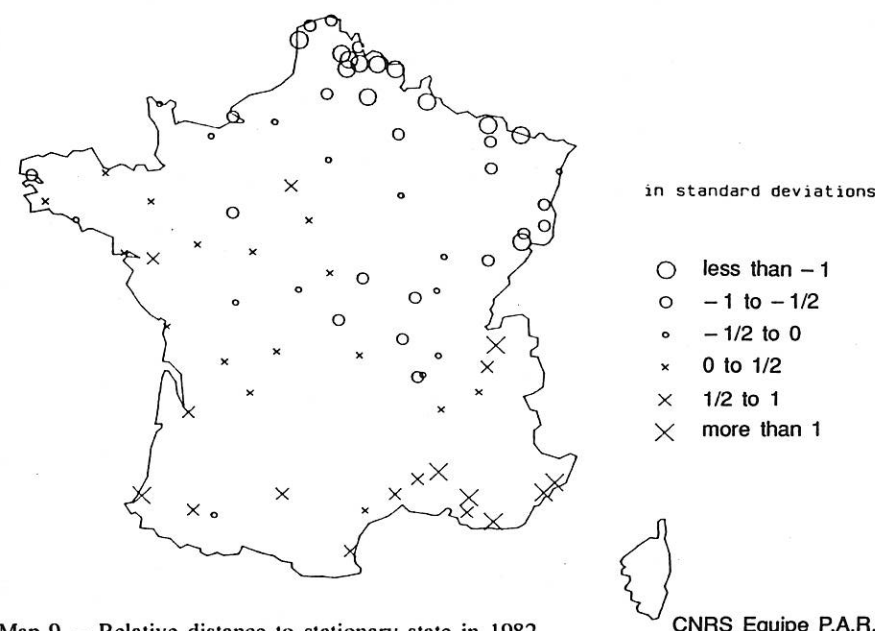
	Paris	The 9 following cities
1954	41,1%	22,9%
1962	36,9%	23,8%
1982	34,3%	24,3%
2002	33,9%	25,1%
Stationary state	32,0%	31,9%

However, a stationary state is very hypothetical since the model reaches it after a duration equivalent to a thousand years !... Its interest is thus purely theoretical, in describing where the nowadays differences in utility would lead the configuration of sizes in the urban system. The obtained configuration could be seen as a kind of limit of the actual evolution. It is meanwhile worth mentioning the few changes which would occur in the urban hierarchy, according to the equilibrium states of each of the four periods : Marseille would outpass Lyon and the agglomerations of the Côte d'Azur, Nice and especially Cannes, would win a few ranks in the hierarchy.

Map 9 represents the relative deviations between the population of the agglomerations in 1982, and the size that they would have at the equilibrium state. The map shows a very contrasted pattern with two concentrations of cities which are far from equilibrium :

- the mediterranean agglomerations have all very high growth potentials, especially Nice and Cannes : they would concentrate 7 % of the total population at the stationary state, against only 2.9 in 1982;
- the agglomerations of the northern and northeastern border, all with marks of the first industrial revolution, would seem condemned to experience a continuous decline.

Between those geographical and structural extremes, most French cities of the central regions of the country are much closer to equilibrium, including Paris. But the geographical pattern is also here quite contrasted : the cities of the Alps excepted, most agglomerations of the eastern half of France have to decline to reach the

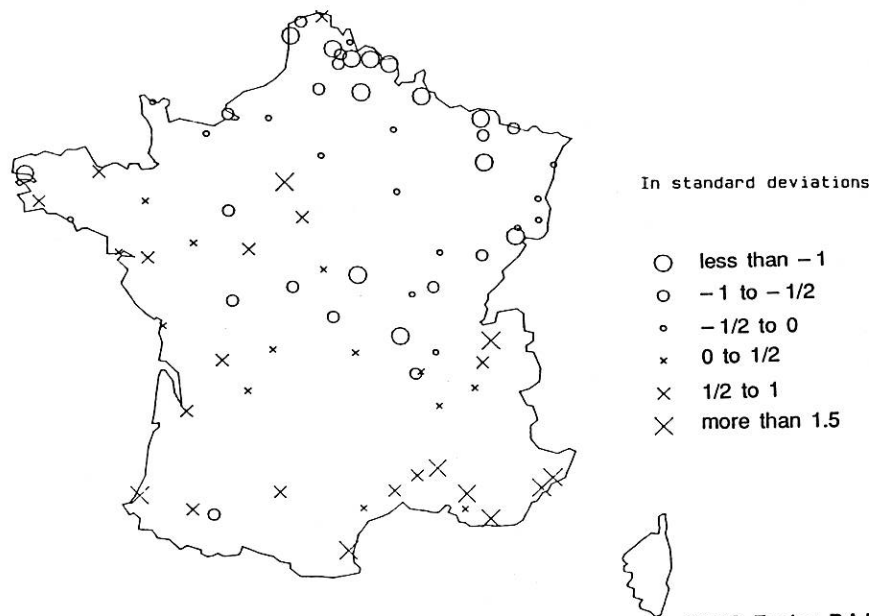


Map 9. – Relative distance to stationary state in 1982.

stationary state, whereas those of the western half have more often some hope for growth.

The model also can be used to generate prognosis at shorter intervals. The 20 years previsions leave the upper level of urban hierarchy unchanged for the ten first agglomerations. This remains true if either the parameters of the 1954-62 or of the 1975-82 period, although rather different, are used.

Maps 10 and 11 representing the relative variation of the population of the 78 cities in our sample for the periods 1982-92 and 1992-2002 show very similar patterns. They are much more contrasted than the maps of utilities or of preferences, but very close to the pattern of the relative distance to the stationary state. Two exceptions, Dunkerque and Saint-Chamond, show the ability of the model to produce an "overturning" of the trend: indeed, the model predicts many years of growth for both towns and then a change in the trend towards a stationary state which implies a net decline.

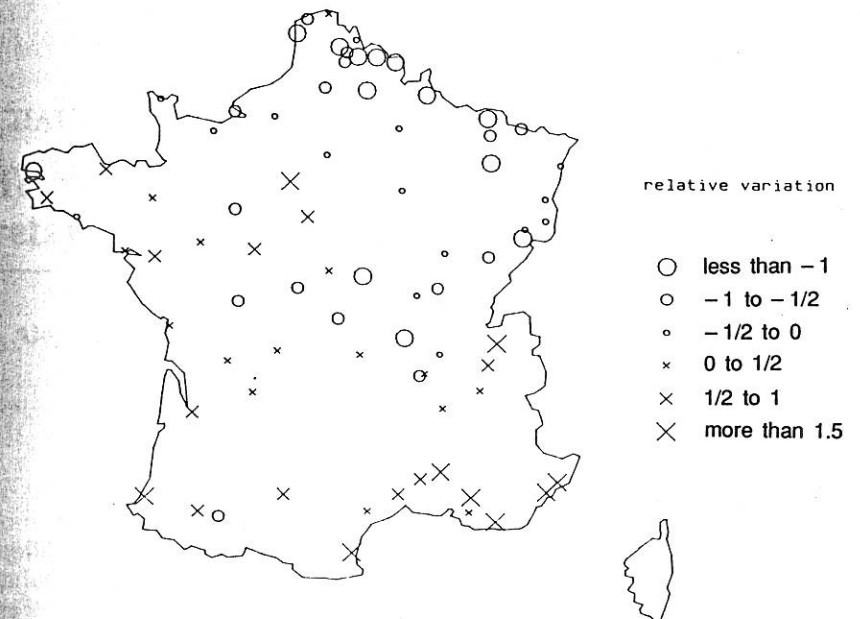


Map 10. - Relative evolution 1982-1992.

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VII. - Conclusion

The model has still to be improved : on the one hand, one has to integrate birth and death processes, as well as migrations to and from smaller cities and rural areas and, on the other hand, to take into account the proper dynamics of the socio-economic variables, including them explicitly in the model. This would allow to derive much more complex scenarios of the evolution of the set of cities and perhaps the model would become a better forecasting tool than it is in its present form.



Map 11. - Predicted variation of the population 1992-2002.

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SUMMARY

Despite decreasing in terms of net contribution to urban population changes, migrations determine more and more inequalities in urban growth. As rural areas are depopulated, the pattern of inter-urban migrations become then a major source of information for predicting the distribution of growth among a set of cities. Weidlich-Haag model is used for analysing migratory flows between 78 largest French agglomerations at four periods from 1954 to 1982. Changes in attractiveness of cities and in their preferences are related to their social and economic characteristics. The model is also used to simulate the future possible changes in the relative size of cities.