AIR AND RAIL ACCESSIBILITIES AND ATTRACTIVITIES OF EUROPEAN METROPOLIS

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Opening, integration, unification of the European space, many expressions which are becoming familiar today. In a Europe in restructuration, the questions relating to its space have reached a central position. We wonder what will be the effect of the opening of the borders, what will be the evolution of the strong and the weak points of this space, and how will take place the transformation of its centres, its peripheries.

To define the poles around which the European space takes shape leads to characterize the position of each large city within the European urban network. The position of a city within a network can be defined on one hand by its centrality i.e. its aptitude to be the centre of a given space and on the other hand by its attractivity i.e. its effective capacity to attract to her, to polarize. The city's accessibility is an indicator of its centrality. Thus it defines its relative position within a transportation network and further in an urban network. The traffic concentrated by a city is a measure of its attractivity. The attractivity is an indicator of the economical power, of the city influence. Our purpose is to clearly dissociate the accessibility from the attractivity notions. To characterize the nodes of an urban network, we choose to distinguish, in a communication network which links the cities, what deals with the infrastructure, i.e. with the whole possibilities or material potentialities, what we call thus accessibility from what deals with the interaction, i.e. the communications really exchanged, what we call attractivity. We consider that the fact that certain cities occupied a privileged position in the network because of their centrality can be independent of their capacity to polarize high densities of flows, thus to be attractive.

A strong dialectic relation exists between these two notions and some authors combine them. When talking about the railway connections, E. Auphan (1989) define the city centrality by its proximity to the other cities and by the frequency of rail connections which serve the city, he mixes up these two notions and makes dependant the accessibility on the centrality, i.e. on the city capacity to polarize important flows. This author introduces two other notions, the one of the nodality which is the number of trains stopping or passing in the city and the "desserte", which is an indicator giving an idea of how a city is served and measured by an index which integrates the centrality, the accessibility and the nodality. A. Suarez (1991), closer to our choice to define the city's accessibility, increases however the number of ways to measure the centrality by using many indexes forms. These indexes are not so differenciated and the improvement introduces from one to another are small. The latest index used by this author combines the time-distances and the kilometer-distances. This index was developped by B. Marchand and somehow measures the displacement spreed (Dupuy, 1985). We think those combinaisons make the appreciations of city positions more confused rather than clarify them.

Based on the sampling of cities taken into account, i.e. the 90 cities with over than 200 000 inhabitants and with an important airport, we will define the poles of the air and rail relations around which the European space is taking place.

1. THE CENTRALITY IN THE NETWORK OF EUROPEAN LARGE CITIES

1.1. The measures of accessibility

The accessibility measures owe very much to the proposals made by Shimbel (1953), forty years ago. This author defines the accessibility as a function of the distance. If dij is a measure of the necessary distance to join the city i to the city j in a network including n cities, the accessibility of the city i, (ACi) is equal to the sum of the distances from the city i to all the others (row sum of the distances matrix):

$$ACi = \sum_{j=1}^{n} dij$$

To give an immediat ranking of the cities for different criteria and to eliminate the effect of the measure unit, the accessibility measures can be express relatively to the maximal accessibility. Thus, it is in terms of relative accessibility that we characterize the positions of the European large cities within the network. These relative indexes that vary from 0 to 1 take the following form:

$$ACRi = \sum_{j=1}^{n} dij \, / \, \sum_{j=1}^{n} maxdij$$

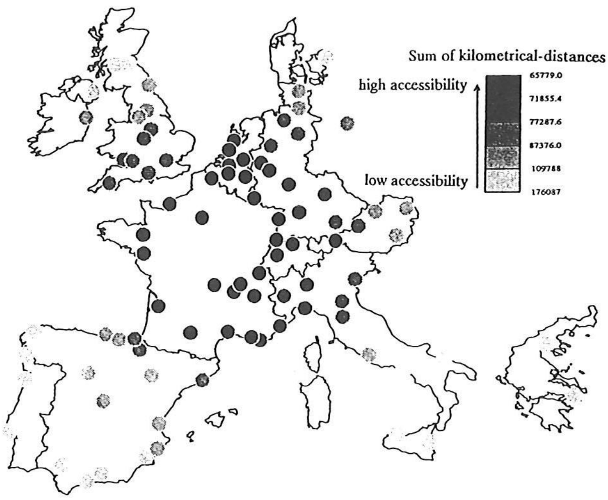
Two types of accessibilities can be distinguished: the physical accessibility and the functional one. The kilometer-distance will define the first one while the time-distance will be an indicator of the second.

1.2.The physical accessibility

For the two transportation modes, air and rail, the physical accessibilities of the large European cities are calculated according to the kilometer-distance matrix. Smaller is this index lesser kilometers we must travel to reach all other cities of the network and better is the city's position. Even if the earth curve is minimal at the European scale, the distances are calculated according to the orthodromy formula.

The image obtained is without surprise as it gives back the geometrical centrality of the cities (figure 1). The Swiss cities, some French ones Lyon, Saint-Etienne and Paris, and Luxembourg are thus best located. The decreasing of the accessibility is made according to concentric cercles around this nucleus. The cities of the peripherical space, Lisbon, Porto, Athens, Thessalonic, Dubin and Belfast show the lowest accessibility.

FIGURE 1: PHYSICAL ACCESSIBILITY (KILOMETRICAL DISTANCE)



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1.3. The functionnal accessibility

The functional accessibility of the cities is calculated on the time-distance matrixes. The air accessibilities, by direct links, are measured by the travel time which includes not only the flight time but also the time needed to join the city centre to the airport. The rail accessibilities are calculated by the travel time from rail-station to rail-station.

The method preferred here to evaluate the cities' accessibilities in term of time-distance is given by the time calculation of the direct and indirect connexions from a time-distance matrix of direct connexions. Shortest path matrixes, for the travel time, have been thus constructed for each transportation modes.

To determine the shortest path matrix, Shimbel (1953) made the sum not of the total number of pathes between two nodes but of the length of the shortest path between these two nodes. In this research about the European cities accessibilities, the travel time calculation for the direct and indirect connexions has been automate using the shortest path algorithm (program H. Mathian, 1991) recommended by the graph theory. The calculated distances give the time-distances which are theoretically the shortest between two cities: it is impossible to know if, in practice, the connections, by plane or by train, necessary to warrant these indirect connexions, thus to minimize the travel time and find the theoretical shortest time-distance exist or not. Except for Barcelona, Madrid and Nice, the highest air accessibilities, evaluated by the shortest time-distance, caracterize the Northern cities of Europe (figure 2). The rail accessibilities benefit to continental cities of Northern Europe, London is penalized by its insular position (figure 3).

FIGURE 2: AIR ACCESSIBILITY MEASURED BY THE SHORTEST TIME

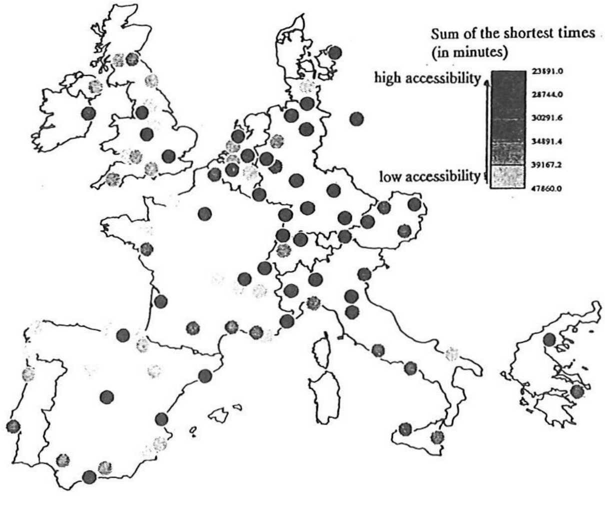

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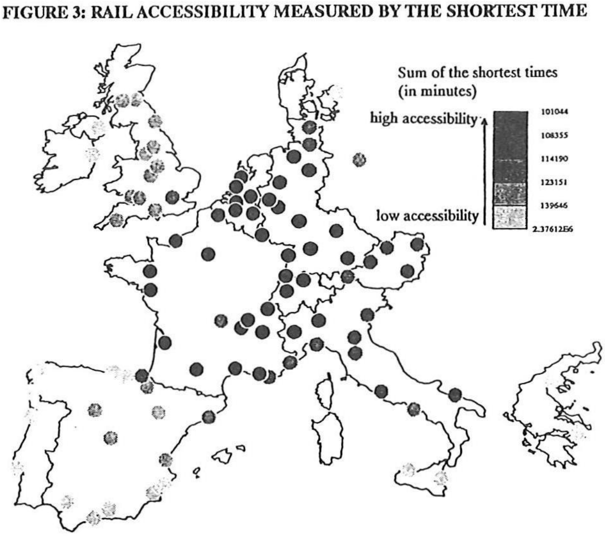
FIGURE 3: RAIL ACCESSIBILITY MEASURED BY THE SHORTEST TIME



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For the air traffic, the cities weakly accessible are cities like Grenoble, Toulon, Cardiff, La Rochelle, San Sebastian and Kiel. For the rail traffic, the cities with a low accessibility are situated at the periphery of Europe (Porto, Lisboa, Malaga, Sevilla, Murcia, Copenhagen) and all of those which are penalized either by their insular position (the British cities, Dublin, Palerm, Catania) or by the territorial discontinuity that exists between them and the others of the network (Athens, Thessalonic).

2. THE ATTRACTIVITY OF THE EUROPEAN LARGE CITIES

The measures of the city attractivity can be considered as indexes of its power and of its influence. The traffic which underlies the attractivity can proceed from relations that take place from the only direct connexions. But it can also include connections following indirect pathes. We take however in account the direct interurban connexions only. Indeed, the direct links are sufficient to translate the relative quality of "desserte". As it is precised by E. Auphan (1989), in a rail relationships study, to be convinced of the negative effect of the indirect connection, it is sufficient to listen to the rail user comments concerning this point and mainly to observe the frequency and the increasing importance of the traveller which prefers to go by car to a rail station further away but served by a direct train rather than taking a train at the rail station from which they depend, which will force them to make one or several connections".

The interurban traffic created by the cities can be evaluated in planes, trains and passengers numbers.

The relations between the European large cities can be subdivided into relationships between cities from the same State on one hand, and on relationships between cities from different States on the other hand. We analyse in a first step city attractivities for the whole traffic, including therefore its national traffic and its international traffic, then we isolate, the international traffic. This distinction is essential in our approach which intends to detect the different levels of organization of the European urban network. It should permit, about attractivities, to glimpse which large cities stay confined in national range functions thus for which the role could be widely explained by the dynamic of the national urban system. But this distinction permits also a first identificationn of the cities which actively participate to the pattern setting of the national urban systems thus to the formation of an European network of large cities.

2.1. The measures of attractivity

With the same approach than the one used in the measures of accessibility, we can define the city attractivity ATi, with the measure of its total traffic (number of planes, trains, passengers) with the whole other cities.

2.2. Traffic and polarization in the network of European large cities

We look here at the entire traffic for each transportation mode. The urban polarizations brought out by the total rail traffic illustrate important regional contrasts (figure 4). We note, in a first step, the isolation of the South-West cities of Europe. The Spanish and Potuguese cities appear particularly disadvantaged and the Greek cities are so much penalized by the territorial discontinuïty between

FIGURE 4: ATTRACTIVITY FOR THE WHOLE RAIL TRAFFIC
Trains number

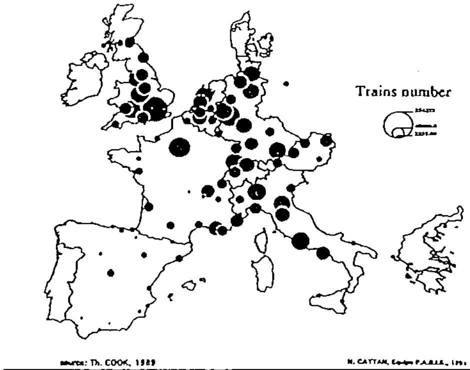


FIGURE 5: ATTRACTIVITY FOR THE WHOLE AIR TRAFFIC
Planes number

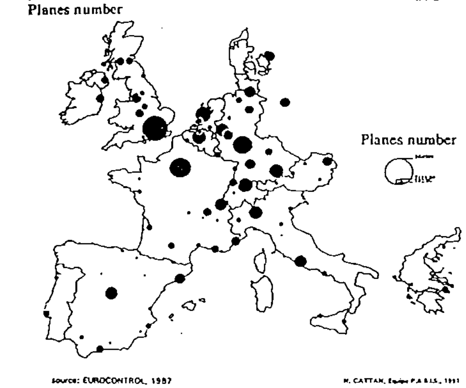
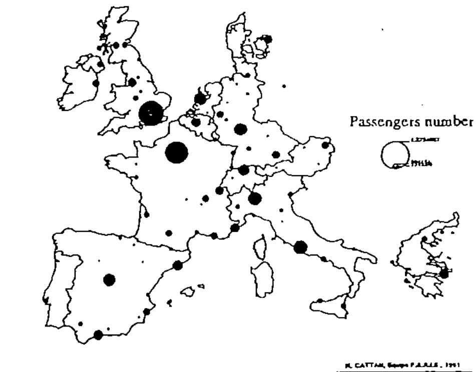


FIGURE 6: ATTRACTIVITY FOR THE WHOLE AIR-PASSENGERS TRAFFIC

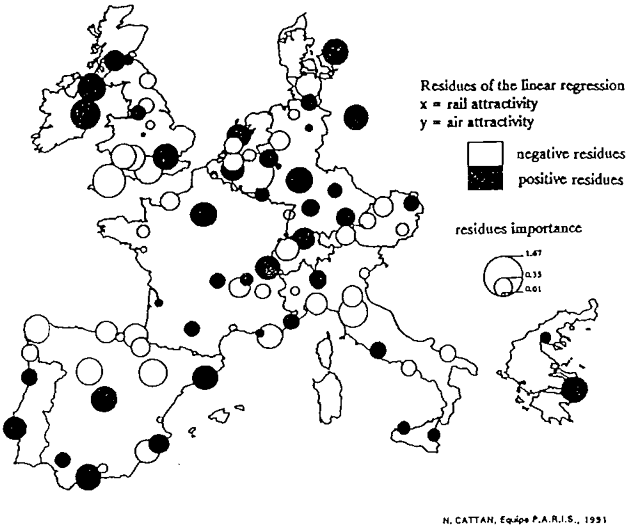


Greece and the other EEC countries; the rail traffic of Athens and Thessalonic with the other cities is nearly non existing. The cities of the Rhein axis, with some extension to East, to the Austrian cities, and to the North, to Hamburg and Copenhagen, are the centres through which most of the rail traffic has to go. Paris and the Mediterranean littoral French cities show also important level of rail traffic. The air traffic allows a better linkage of the peripheral cities to the other European ones. Indeed, the air links, with a longer range than the rail traffic, are less dependent upon the physical discontinuïties. However, the most important poles of these peripherical spaces are mainly the capital cities (Madrid, Athens, Lisboa) and secondarily the principal regional cities like Barcelone (figure 5). In the entire European space, the States capitals or the economic metropolis are best located. The Renish axis still constitute the backbone where the most important poles are concentrated, but a Mediterranean arc, from Madrid to Athens, including Barcelona, Nice and Rome, is taking shape. London, penalized for the rail traffic by its insular position, find itself at the first rank for the air traffic. Paris takes the second place.

When the air attractivity of the cities is defined by the passengers number (figure 6) and not only by the planes number, we find again the same urban hierachy than this brought out by the planes number. The correlation coefficient between the air attractivity defined by the planes number on one hand and by the passengers number on the other is equal to 0.9.

How do the hierarchies of the network nodes restituted by the rail traffic on one hand and by the air traffic on the other hand combine? In a simply way, the question can be the following one: are the most attractive cities for the rail traffic the same as those for the air traffic and vice versa? A very significative linear relation exists between the air attractivities and the rail attractivities of the large European cities (r = + 0.71). The correlation coefficient shows that many cities combine comparable positions in the two cases. If the spatial and hierarchical configurations of the urban poles described by their attractivity for each of the two traffics are in general linked, a more detailed comparative analysis of the two distributions permits to precise where are the most important differencies. If we summarize, by a linear regression, the relation between the cities rail attractivities (x) and their air attractivities (y) we note that all the cities State capitals and all the cities economic capitals show more important air relationships than expected by their rail relationships (figure 7). We can see here the sign of the very important weight acquired by the air traffic in the interurban competitions. Otherwise, the cities of the North-West peripheries on one hand, like Dublin, Belfast, Glasgow and Edimburg, of the South-West as Lisboa, Porto, Malaga and Alicante, and of the South-East peripheries like Catania, Palermo, Athens and Thessalonic on the other hand, register significant gains in the air traffic hierarchy compared to the one of the rail traffic. With regard to their rail attractivity, these peripheral cities show higher air attractivities. We can explain the differences between the two transportation modes by the cities insular or peninsular positions that reduce or prevent the rail connexions, but also by the importance that some airports of the South acquire in terms of touristic flows. Inversely, cities as Bristol, Basle, Dusseldorf, Bologna, Hannover, Florence have fewer air relations than expected by their rail traffic. The principal reason is that these cities are located not only in the areas of very high population density but are also main crossroads in the earth transportation network.

FIGURE 7: RELATION BETWEEN THE RAIL ATTRACTIVITY AND THE AIR ATTRACTIVITY OF THE CITIES



2.3. The international polarizations of European large cities

The polarizations brought out by the whole traffic study give a good image of the economic strength of the different cities in Europe but they inform us very indirectly and in an incomplete way on the direct contribution of these forces to the structuration of an international urban network in Europe. By isolating, from the whole traffic (national and European) the international (European) we must be able to outline, in a better way, the principal characteristics of the relative international positions of the cities.

For the two transportation modes, the most internationl cities, i.e. cities with most important international traffics, are concentrated at the East of a London-Nice axis (figure 8 and 9). For the rail traffic, the nodality of the whole Renish axis cities and of Austrian cities is important. For the air traffic, a selection takes place between the cities of this axis, and only London, Paris, Francfurt, Amsterdam, Zurich and Brussels concentate thus the most important international traffics. The Mediterranean border cities, Malaga, Alicante, Barcelona, Nice, Rome and Athens show also high concentrations of international traffic when this one is measured by the planes number or the air-passengers number (figure 10). These concentrations are without any doubt induced -excluding for Rome- by the touristic traffic volume. The cities which are without any international direct rail connection are the British ones (except London), the majority of the Spanish cities (Saragossa, Bilbao, Alicante, Sevilla, Grenada, Valencia, Valladolid, Santander, Malaga, La

FIGURE 8: ATTRACTIVITY FOR THE INTERNATIONAL RAIL TRAFFIC MEASURED BY THE TRAINS NUMBER

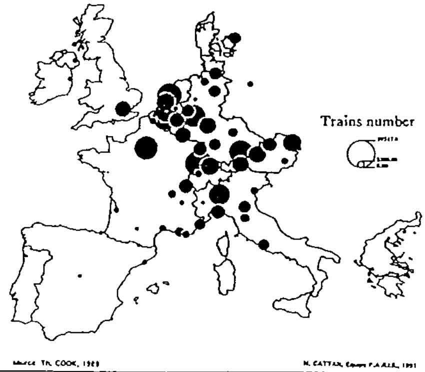


FIGURE 9: ATTRACTIVITY FOR THE INTERNATIONAL AIR TRAFFIC MEASURED BY THE PLANES NUMBER

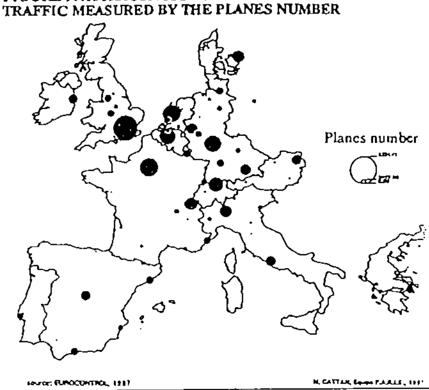
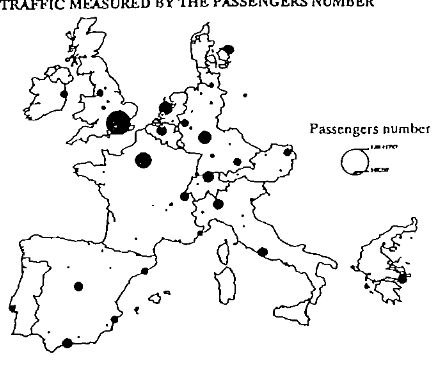


FIGURE 10: ATTRACTIVITY FOR THE INTERNATIONAL AIR TRAFFIC MEASURED BY THE PASSENGERS NUMBER



Coruna), four French cities (Le Havre, Saint-Etienne, Clermont Ferrand, Rennes) and three Italian cities (Bari, Catania and Palerme). The most disadvantaged cities for the air traffic are the Spanish ones (San Sebastian, La Coruna, Valladolid, Vigo, Pampeluna) and some French cities (Rennes, Saint-Etienne, Clermont Ferrand, Toulon, Nantes).

We observe that the major poles around which are organized the exchanges and which contribute to the setting pattern of the European cities at an international scale are either State capitals as London, Paris, Brussels or cities as Francfurt, Amsterdam and Zurich, which, even if they are not State capitals, are the economic capitals of their States, or large cities where the activity is so much specialized in the cultural and touristic functions. This could be a confirmation of the so often formulated hypothesis (Pred 1975, Pumain, Saint-Julien 1979) and according to which the network setting of cities at a superior geographical scale than the one of the national systems is, in a first step, always assumed by the largest cities which are both political and economical capitals of each national urban system.

The urban accessibilities and attractivities permitted to define some aspects of the hierarchy that exists between the cities. We can imagine that the urban polarizations representating the traffic volumes of the two principal transportation modes are dependant on the cities accessibility. Do the urban polarizations reflected by the attractivity indexes calculated for the planes, the trains or the passengers numbers relate to the images restituted by the accessibilities? In other terms we wonder if the most accessible cities are the most attractive ones.

3. RELATION BETWEEN AIR AND RAIL ATTRACTIVITIES AND ACCESSIBILITIES OF THE CITIES

We make the hypothesis that better a city is located in the network, the best is its accessibility, more chances it has to be attractive, and to represent an important pole in the European urban network.

For the total rail traffic, the correlation coefficient between the time accessibility and the attractivity indexes is equal to 0.49. The relation is moderately good. If we define the attractivity as a linear function of the accessibility, the regression line equation is $Y = 5.05X + 22259.2$. The analysis of the residues permits to define the cities with the most atypical positions. London departs from the average. This city shows a most important attractivity than the one expected by its accesibility (figure 11). Bristol, The Midlands (Birmingham) and Manchester, even with a weak deviation from the general model, have also an attractivity much more important than we can expect from their accessibility. Those very positive residuals are essentially dependent on the importance of their national traffic percentage in their total traffic and on their particularly low accessibility. The insular position of these cities is the main explanation for these distorsions. Strongly accessible, Paris, Rome, Milano, Munich, Basle, Frankfurt and Amsterdam have a traffic slightly more important than the one expected and reflect thus a good polarization. Taking in account their accessibility, we could expect, for cities as Vienna, Salzburg, Innsbruck, Genoa, Venice and Barcelona a better attractivity. We can conclude that for the rail traffic, the most accessible cities are, in general, the most attractive ones. The English cities only, with a low accessibility, shows even a better attractivity than expected and some meridional

FIGURE 11: RELATION BETWEEN THE RAIL ACCESSIBILITY AND ATTRACTIVITY OF THE CITIES

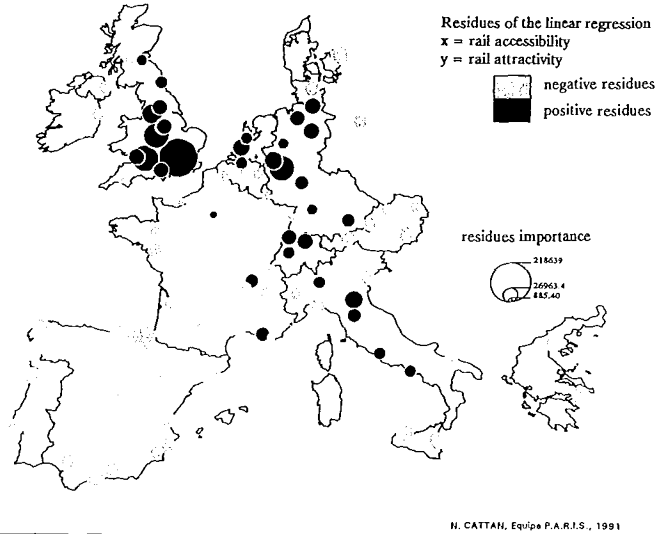
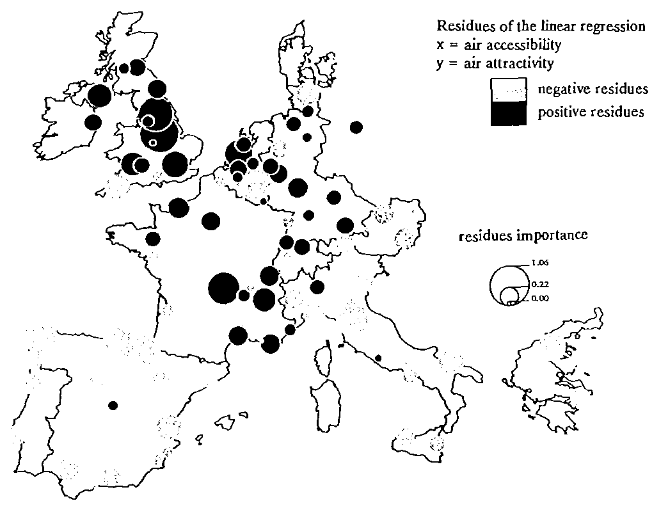


FIGURE 12: RELATION BETWEEN THE AIR ACCESSIBILITY AND ATTRACTIVITY OF THE CITIES



and oriental peripherical cities have a lower attractivity than we could expect according to their accessibility.

For the air traffic, the relation between cities accessibility and attractivity (in planes or passengers numbers) is not linear. A better correlation is obtained by a positive power function with the following form log (y = attractivity) = log (x = accessibility) + b. Among the very accessible cities, London, Paris, Francfurt show attractivities slightly superior to those we could expect, the cities fairly accessible correspond in their majority to the model: their attractivity depend on their accessibility; for the cities weakly accessible, the differences with the model are bigger: based on their accessibility East Midlands (Derby and Nottingham), West Yorkshire (Leeds and Bradford) and Rotterdam seem to be very attractive while Liege, La Coruna, Plymouth have, on the contrary, a low total traffic (figure 12).

REFERENCES

Auphan, E.. Obsolescence ou renaissance des réseaux ferrés pour le transport des voyageurs en Europe occidentale? Université Aix-Marseille 2, thèse, 1989, 1149 p.

Cattan N.. La mise en réseau des grandes villes européennes. Université de Paris I. thèse (directeur de recherche: Th. Saint-Julien), 1992, 379 p.

Cauvin, C., Reymond, H., Schaub, G.. Accessibilité, temps de séjour et hiérarchie urbaine: l'exemple du réseau aérien pour 53 villes d'Europe, Sistemi urbani, n°3, 1989, p. 297-324.

Dupuy G.. Systèmes, réseaux et territoires, Presses de l'E.N.P.C.. Paris. 1985, 168 p.

Pred, A. R.. Systems of cities and information flows. Lund studies in geography, serie B, n°38. 1973, 121 p.

Pumain, D., et Saint-Julien, Th.. Les transformation récentes du système urbain français. L'espace géographique, n°3. 1979, p. 203-211.

Suarez, A.. Accessibilités aérienne et ferroviaire des métropoles européennes. Université de Paris I. Maîtrise de géographie. 1990, 118 p.

Taaffe, E.J., Gauthier, H.L., Geography of transportation, Englewood Cliffs, N.J., 1973.