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Chapter 12: Towards integrated systems of cities (France, 18th-19th centuries)

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Introduction

If the city-systems emerge at the same time as the invention of the city in the Neolithic era (see chapter 7), they are profoundly transformed with the advent of contemporary civilisation. The appearance of complex and numerous networks of information, no longer dependent on networks of circulation of people or goods, allowed the emergence of ‘integrated urban systems’ (*systèmes urbains intégrés*¹) whose characteristics have been described by many geographers for long-industrialised countries with unplanned economies: (1) these systems are ‘self-organised’ (bottom-up processes, stemming from numerous and repeated interactions between the agents – notably economic since the Industrial Revolution – participate in their evolution on the same basis as the decisions taken at the national level by political managers); (2) their structure is extremely stable, both on the hierarchical level (regularity of spatial distribution or statistics of city populations) and on the functional level (regularity of the relation between sizes of cities, level of centrality and level of economic complexity); (3) this stability is especially assured by a co-evolution with the networks of communication, in other words a positive retroactive feedback loop between level of accessibility and level of urban centrality: the innovations in the rapid networks are diffused in a hierarchical way and permit an increase in the range of interactions for the largest cities, thus favouring their enrichment and the improvement in their accessibility, while the smaller ones are short-circuited and undergo a relative or absolute decline². These effects of geographical selection³, added to the economies of agglomeration, make it possible to shed light on the process of hierarchisation of the sizes of cities, as identifiable, for instance, in France from the 1830s.

The exact moment and modalities of this emergence of integrated urban systems are, however, relatively little known. For France, one can describe fairly well the evolution of the city-systems from the Industrial Revolution, thanks to population censuses, economic and railway statistics. These studies show that the urban systems are already fully integrated at this period. Their hierarchical structure is very stable, the interdependencies between the cities are strong, such that the exceptional urban growth recorded from the 1830s does not substantially modify this structure. One historian has nevertheless focused on the moment of the emergence of such systems in France and developed the hypothesis that it dates from the century preceding the Industrial Revolution: Bernard Lepetit⁴ cites the emergence of relations of a new kind, qualitatively different from those preceding, between the cities in the northern half of the country at the turn of the 18th and 19th centuries.

We propose to study the emergence of integrated urban systems in France in a combined study of the evolution of the cities (as deduced from their populations) and networks of communication (as gathered from horse-postal routes). Our hypothesis is that the ‘complex networks of information’ (*réseaux d’information complexes*) evoked by Claude Raffestin for contemporary civilisation are introduced in France beginning in the second half of the eighteenth century; we will proceed by

¹ Raffestin Claude, *Pour une géographie du pouvoir*, Paris, Litec, 1980, 250 pages.

² Pumain Denise, ‘Pour une théorie évolutive des villes’, *L’Espace Géographique*, n° 2, 1997, pp. 119-134.

³ Mackinder Halford, *Britain and the British Seas*, London, William Heinemann, 1902.

⁴ Lepetit Bernard, *Les villes dans la France moderne (1740-1840)*, Paris, Albin Michel, 1988.

studying the routes of the horse-carried post, which underwent a considerable transformation at this time. Indeed, the length of the routes more than doubled in a half-century, and, especially, the network changed quantitatively with the extension of coverage, that is, multiple roads permitting the emergence of a certain self-organisation of the principal hubs, which were the cities. The transition which we have studied here permitted the passage of primate urban networks of limited range, scattered across the territory in an irregular manner, as described by Lepetit for the beginning of the eighteenth century, to integrated urban systems, characterised by a regular hierarchical structure closely tied to the road hierarchy (measured by different criteria deriving from the theory of graphs) and spatially organised according to regularly nested patterns. These regional urban systems originate in the northern half of France during the period that concerns us, before being diffused through the rest of the country.

For the years 1700 and 1750, we make use of the data on the urban populations assembled by Paul Bairoch and his collaborators⁵ and completed for 1750 and 1780 par Lepetit.⁶ For the year 1793, we refer to the census of the so-called 'year II', which furnishes the population of the municipalities newly established. The population of the cities is henceforth accessible for the years 1809⁷, 1831 and 1851 (*Bulletins des Lois*). The second data base used relates to the locations of postal relays. The relays figure in the *Livres de Poste*, which have been digitalised for different dates (1708, 1733, 1758, 1783, 1810 and 1833).⁸ The methods used to analyse the evolution of cities and routes are primarily derived from the theory of graphs and the analysis of data. In our first section, we sketch out a summary table of the cities and routes in France before the beginning of the transition at the beginning of the 18th century. We then bring to light the remarkable transformation of the space of intercity postal relations between 1730 and 1830, which chiefly affects the northern half of France. Finally, we analyse two processes of territorial integration through systems of cities: the first is the 'scale up'⁹ rendered possible by the growth in road network and speed of postal service, permitting medium and large cities to function from then on as pivots in a system of national exchanges; the second is the progressive construction, in the northern half of France, of regional city systems whose hierarchical structure, regular and having several levels, resembles in many ways that of central places such as described in 1933 par Walter Christaller.

Cities and exchanges at the opening of the 18th century: an organisation in lines and stars

An urban infrastructure dominated by regional capitales

The urban infrastructure of France at the beginning of the 18th century was composed of an assemblage of regional networks centred on a great metropolis, which often corresponded to a former regional capital annexed to the kingdom¹⁰. These regional networks followed a model of ecclesiastical primacy, formed by a powerful capital with small centres and market towns. The towns then drew their wealth essentially from the soil: the economy 'repose moins sur la division du travail et sur la circulation que sur la répartition hiérarchique du revenu des terres'¹¹ (*depended less on the division of labour and on exchange than on the hierarchical division of revenue from the land*). The economy of exchange, for its part, merely formed an accessory circuit nurtured by excessive harvests. Maritime and industrial development remained marginal and, from the time of Louis XIV and Colbert, subject

⁵ Bairoch Paul, Batou Jean, Chèvre Pierre, *La population des villes européennes. Banque de données et analyse sommaire des résultats: 800-1850*, Centre d'Histoire Economique International de l'Université de Genève, 1988, 339 pages.

⁶ Lepetit B., *Les villes ...*, op. cit.

⁷ Le Mée René, « Population agglomérée, population éparse au début du XIXe siècle », *Annales de démographie historique*, 1971, p. 454-510.

⁸ Bretagnolle Anne, Giraud Timothée, Verdier Nicolas, « Modéliser l'efficacité d'un réseau : le cas des routes de poste en France (1632, 1833), *L'Espace Géographique*, n° 2, 2010, p. 117-131.

⁹ Garrisson William, « Networks: Reminiscence and lessons », *Flux*, n°1, 1990, p. 5-12.

¹⁰ Lepetit B., *Les villes ...*, op. cit.

¹¹ Roche Daniel, *La France des Lumières*, Paris, Fayard, 1993.

to administrative initiative and administrative control. In the correspondence of Colbert¹², cities are presented in hierarchical fashion and according to their administrative and commercial functions. The exchanges accorded priority are those that permit access to the capital of the kingdom, the great provincial cities constituting sites of governance, ‘celles dans lesquelles il y a des foires et des marchés considérables’ (*those in which there are fairs and markets of importance*), and the centres of exportation of wine, salt, fish or minerals.

Besides these distant exchanges linked to the administration or to major commerce, the regional urban networks communicated little with each other. The letters of Colbert giving instructions for repairing or constructing paved roads testify to a vision organised around star-shaped conjunctions of routes, each centred on a regional capital. The object of the instructions is thus to repair the ‘chaussées et banlieues’ (*paved and suburban*) sections of the large cities, in other words to open ‘de belles étoiles aux portes de la ville’ (*handsome star-shaped entries at the gates of the city*) (texte de l’An XII)¹³. This concept is particularly revealing of a phase prior to the establishment of integrated urban systems, in which the cities are perceived as ‘nodosités’¹⁴: each of them constitutes the centre of a territory permitting it to be supplied, a situation that implies a policy of controlling the system of reserves, including grain-growing surfaces, nearby routes, the urban market and sites of stockage.

Major routes and road policy

The routes traversing France at the beginning of the 18th century follow a logic of transportation and not of network. Certainly, notable advances were achieved under Colbert and Louvois, with the construction of numerous paved roads. Previously, routes corresponded chiefly to dirt tracks with highly variable contours.¹⁵ The grand-route itineraries constructed at the end of the seventeenth century constitute privileged lines, which necessarily intersect but nevertheless do not constitute a network. Moreover, these paved roads had a relatively limited life-span and required regular expensive maintenance. At the end of the reign of Louis IV, the sources testify to an important degradation of the routes constructed under Colbert.¹⁶ Nevertheless, this first transformation is important, for it signals an evolution in the concept of territory: ‘de la labilité des chemins, on passe à la mise en place de lignes reliant des points’¹⁷ (*from the unreliability of the roads, one passes to the establishment of lines connecting points*). For the postal routes, these points correspond clearly to the capital cities of the *généralités*¹⁸ and the major ports (figure 1).

¹² *Lettres, instructions et mémoires de Colbert*, publiés par Pierre Clément, Paris, Imprimerie impériale, 1861-1873 (tome 4).

¹³ Lepetit B., *Les villes ...*, op. cit.

¹⁴ Raffestin C., *Pour une géographie ...*, op. cit.

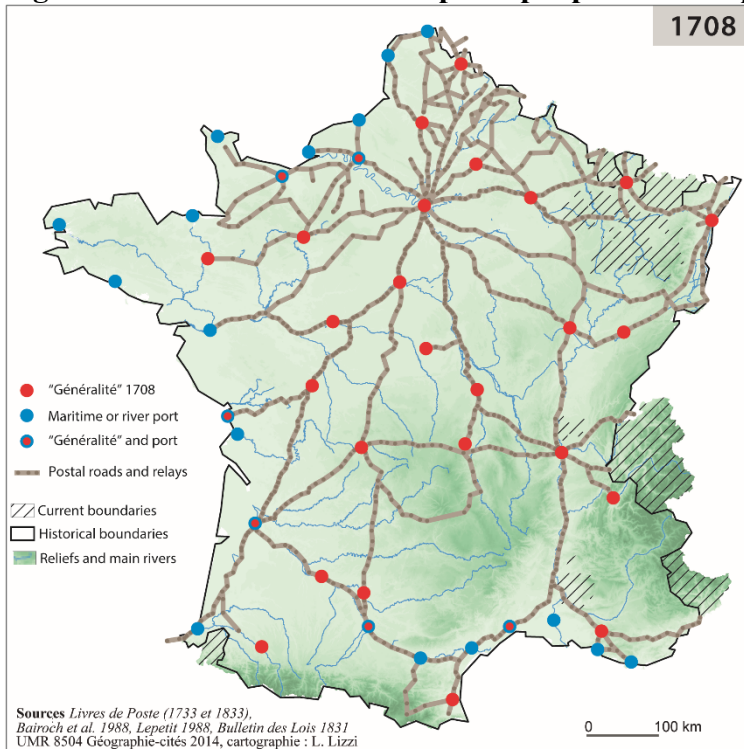
¹⁵ Imberdis Franck, *Le réseau routier de l’Auvergne au XVIIIe siècle, ses origines et son évolution*, Paris, Presses Universitaires de France, 1967.

¹⁶ Sée Henri, *L’évolution commerciale et industrielle de la France sous l’Ancien Régime*, Paris, 1925 (réédition Genève 1980, Slatkine Reprints), 402 pages.

¹⁷ Verdier Nicolas, « Le réseau technique est-il un impensé du 18e siècle : le cas de la poste aux chevaux », *Flux*, n°68, avril-juin 2007, p. 7-21.

¹⁸ *Généralités* were fiscal and administrative regions established by the monarchy beginning in the sixteenth century.

Figure 1: Postal routes in 1708: principal ports and capital cities of *généralités*.



A new step in the evolution of the roads is marked by the *Mémoire instructif sur la réparation des chemins*, which constitutes the ‘texte fondateur de la politique routière du XVIIIe siècle’¹⁹ (*the foundational text for road policy in the eighteenth century*). Prepared in 1738 by the Contrôleur Général Orry, its purpose was to schedule road maintenance by establishing the priority of work to be accomplished. Not only are the roads presented as fixed routes, made of stones or paving blocks, but the text particularly establishes a clear hierarchy among the axes. The ‘grandes routes’ lead from Paris to the great provincial sea-ports and to the frontiers; the ‘routes’ lead from Paris to the other provincial capitals; les ‘grands chemins’ connect the provincial capitals with each other; the ‘chemins royaux’ link the non-capital cities; the ‘chemins de traverse’ lead from city to city, without postal or messenger service. This vision comes closer to resembling that of a network, but it still remains very much local. When the engineers indicate, for their sectors, the sections to be reconstructed, they do not have in mind an overall logic but strictly that of a line to renovated.

The programme of construction of royal roads was at its height all through the eighteenth and from the beginning of the nineteenth centuries. The total length doubled in the space of forty years (table 1). The nomination of Daniel-Charles Trudaine to the direction of Ponts et Chaussées in 1743 gave a vigorous impulse to this programme, which from this point had the backing of a corps of engineers.²⁰ Moreover, notable advances were made with regard to construction and maintenance, thanks to the *Mémoire* presented in 1775 by the chief engineer of the *généralité* of Limoges, Pierre Trésaguet. The horse-post exploited these royal roads to carry the mail at the speed permitted by the use of relay points, located at distances on average from 10 to 15 km. Part of the mail concerned the administration; another part was transported by the postal letter service to the nearest office, to be

¹⁹ Lepetit Bernard, *Chemins de terre et voies d'eau. Réseaux de transport et organisation de l'espace en France, 1740-1840*, Paris, Éditions de l'École des Hautes Études en Sciences Sociales, 1984, 139 pages.

²⁰ Arbellot Guy, « La grande mutation des routes de France au XVIIIe siècle », *Annales E.S.C.*, mai-juin, n°3, 1973, p. 765-791.

collected by users.²¹ The relays were managed by post-masters (“Maîtres de Postes”), generally inn-keepers or substantial farmers, who placed a certain number of horses at the disposition of the system in return for remuneration. Post-horse riders brought the rented horses as far as the next relay, then led them back. The postal route played an essential role in the diffusion of information: for the merchants or bankers established in cities, it allowed for the transmission of commercial instructions, means of payment, account documents, information on the level of prices or credit, on the size of expected harvests or arrivals of merchandises.²² In regions poorly served by the royal roads, such as the south-east of France, systems of private couriers were employed and permitted, for instance, to satisfy the needs of the merchants and ship-fitters in Marseille.²³ In addition, coastal navigation was important in effecting exchanges of information in regions along the shore. The system of postal routes thus assured only a part of these exchanges, but a part of increasing importance throughout the eighteenth century, as measured both by the amount of mail transported and the amount of territory covered.

	Total distance (in km)	Total number of relays
1632	7 350	638
1708	10 668	822
1733	11 805	877
1758	16 361	1091
1783	23 610	1410
1810	20 505	1279
1833	28 213	1504

Table 1: Total length of the network of postal routes and total number of relays.

Transformation of the space of inter-urban exchanges

Modelling the historical distances

Even if we possess abundant information concerning the placement of postal relays, this is far from sufficient to allow reconstruction of road-distances as they were experienced and practised by contemporaries. We know little, in particular, about the routes followed between two relays (in the Geographical Information System they are modelled by the distance as the crow flies) and about the rapidity of conveyance. To improve the estimate of these historical distances, an exercise of formal adaptation and modelling of data has been undertaken.

The first step in the treatment consisted in importing the data to construct graphs. A graph, built as a set of nodes or vertices and a set of edges, has been constructed for each year. The nodes are the postal relays, and two relays are connected by an edge if a route exists leading from one to the other in a single step. Since the words ‘relays’ and ‘stage’ are ambiguous (each may designate a place or a journey), we use the term ‘relays’ in this text rather than ‘change of horses’, and take ‘stage’ to mean

²¹ Belloc Alexis, *Les postes françaises, recherches historiques sur leur origine, leur développement, leur législation*, Paris, Firmin-Didot, 1886.

²² Cauvin Colette, Lepetit Bernard, Reymond Henry, « Cartes postales : un espace de relation dans la France pré-industrielle », *Histoire et Mesure*, n° 3-4, vol. 2, 1987, p. 89-113.

²³ Lepetit B., *Les villes ...*, op. cit.

the journey undertaken between two successive relays in the course of an itinerary. We add weights on the edges of the graph (the distance of the stage in kilometres), and value to the points (the population of the locality in which the relay is situated). Finally, the weighted adjacency matrix was constructed. If there are n relays, it is a square $n \times n$ matrix having as elements $(i, j) = 0$, if i and j are not successive relays (extremities of a single stage), or, otherwise, the length of the stage. This matrix, as well as the populations, serves as the essential basis of the calculations subsequently presented.

Since the graph is connected, there exists a path (a succession of contiguous edges) to link each pair of relays. This allows calculation of a distance between each pair of relays, consecutive or not. For each pair of relays, there exist one or more routes connecting them. All of them are taken into account (while avoiding the loops²⁴, hence going in circles). One can calculate the length of a route by adding the lengths of the stages that compose it. Among all the road distances, there exists one which is the smallest. It is taken to be the distance between the two relays. One may readily check that this defines a distance in the mathematical sense of the term.

Analogy with an electric circuit and resistances

Flows of information present a strong analogy with flows of electric current. This analogy was described in 1934 by the American geographer Warren Thornthwaite,²⁵ who proposed using the notion of resistance to evaluate the migratory flow between two localities. Distances thus present certain analogies with the resistance in an electric circuit: they are added along a route, like resistances in series, and they may be considered as a brake to the transmission of information, just as resistance is a brake to the carrying of electric current. An electric circuit formed by contacts linked by resistances may be modelled as a graph, whose nodes are the plots and the edges pairs of plots connected by a resistance. If a difference in potential is applied between any two plots, a resistance can be measured with an ohmmeter, when the graph is connected. This resistance between any two plots can also be calculated from the graph and the set of resistances between two successive plots.²⁶ The rule for calculating is that the resistances are added in series, and the conductances in parallel, the conductance being the inverse of the resistance. According to this analogy, one associates a resistance between any pair of points of a graph with weight on the edges. This means of calculating has been applied to the adjacency matrix of the graph of the postal routes, in order to calculate an equivalence of the resistance between any two relays. This 'resistance' will be proportionately weaker as the routes connecting the two relays are numerous. Thus, if two relays are connected by two different routes of the same length, the resistance is the distance divided by two. The resistance is therefore weaker to the extent that loops exist. This property is extremely useful in the subsequent calculations.

Weighting by elevation

²⁴ A loop in a graph is a path from node to node along edges which comes back to its initial node (without turning back).

²⁵ Thornthwaite Charles Warren, *Internal migration in the United States*, Philadelphia: University of Pennsylvania Press, 1934.

²⁶ Klein Douglas Jay, Randic Milan, « Resistance Distance », *Journal of Mathematical Chemistry*, vol. 12, p. 81-95, 1993.

If distance constitutes a brake on the transmission of information, the increase of speed, important in the eighteenth century, allowed this effect to be diminished. Given the known source of energy (animal), this diminution could not be equivalent whatever the slope. A levelling as pronounced as it is was significant slowed postal vehicles, even to the point where transport by horses could become as slow as travel on foot or by mule. We have therefore corrected the distance according to the slope. Theoretically, one would have to have a Digital Elevation Model and apply a corrective coefficient to each point (pixel) along the route. We should remember, however, that we do not know the length of the journey overland and that this is modelled in the GIS according to distance as the crow flies. On the other hand, we know the elevation of the relays. Thus we have applied to each stage a correction reflecting the difference in elevation between the starting and finishing relays. If d is the distance as the crow flies between two consecutive relays calculated in kilometres; if Δz is the difference in elevation (as an absolute value and in metres), then the corrected distance is $d = d'(1 + k\Delta z)$. We have calibrated k by choosing in the sources²⁷ certain journey times of the postal courier on a flat surface and in the mountains, in the middle of the study's time-frame (the years 1750-1760). A comparison between the speed known on the flats (from 7 to 8 km/h) and in the mountains, when relays presented a difference in level of around 100m over 10km, and where the speed diminished to 3-4 km/h, leads us to choose a coefficient of $k = 5.10^{-3}$. We have applied this correction to each stage, then calculated the distances and resistances between each pair of relays.

Simplification of the graph

We term an intermediate relay a relay of degree 2 (a node belonging to two contiguous edges only) whose population is unknown (the data bases being incomplete for localities of less than 10,000 inhabitants until 1780). Even if the intermediate relays allowed for the loading or discharging of the mail, their existence had an essentially logistic cause, the need to maintain a sustained rhythm over the course of each itinerary. They did not modify the topology of the network, nor the distances between the cities. We have therefore simplified the graph with the aid of a simple algorithm: all the relays are examined one by one, and each intermediate relay is suppressed as a node, as are the two associated edges. A new edge is added between the two relays of which it was intermediate, with, as distance, the sum of the distances of the two edges removed. This procedure has been applied insofar as intermediate relays remain. The graph thus produced has the same topology as the complete graph and the same distances between relays of some population or forming an intersection (a degree equal or superior to 3).

The construction of matrices of shortest distances on the basis of the simplified graph and distances corrected by elevation and/or resistance has been realised for each date of the study. Their comparison over time brings to light three major types of transformation of the space of exchanges.

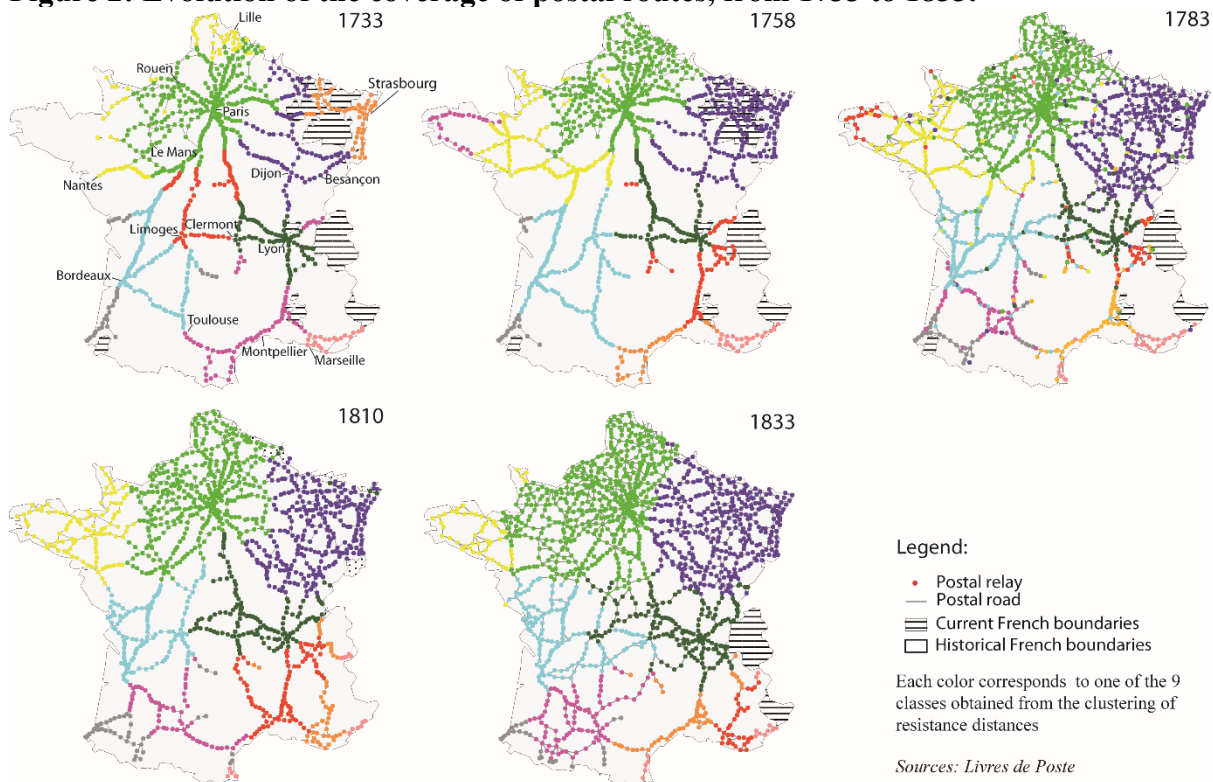
Efficacy of the exchanges: the invention of connectivity

Connectivity (or the development of loops) is an extremely important property of a transportation network. First, it permitted routes to be rendered secured in a context of uncertainty, such as characterised the eighteenth century. Chance events, whether climatic (torrential rains, flooding,

²⁷ Belloc A., *Les postes françaises...*, op. cit. ; Arbellot G., « La grande mutation... », op. cit.

ruptures of bridges or dykes) or natural (landslides), contributed to the difficulties linked with wear-and-tear of pavement as a result of passage of vehicles. But the coverage of the road network also made it possible to pass from the line to the surface, in other words, to optimise the diffusion of information, notably of a commercial nature, by creating ‘surfaces d’échange que l’on peut parcourir en tous sens’ (*surfaces of exchange which one could traverse in every direction*).²⁸ Merchants or ordinary inhabitants of isolated localities understood this well when they demanded the opening of a relay for the postal administration to profit from a movement that created wealth.²⁹ If loops are extremely rare in 1708 (figure 1), they become progressively more pervasive from the 1730s, not as a fortuitous proliferation of itineraries but according to a process of regional diffusion, from the north to the south. This is shown by the Clustering analysis³⁰ concerning the matrices of resistances between pairs of relays. The process identifies the closest profiles of resistance (the vector of values obtained by each relay relative to each of the others). The clusters obtained are then charted and identified by a particular colour, and for each date (figure 2).

Figure 2: Evolution of the coverage of postal routes, from 1733 to 1833.



The results show that similar profiles, in terms of connectivity, have a tendency to group themselves within the same spaces, thereby outlining a regionalised map of the degree of coverage of the road network. In 1733, three groups presented higher connectivity: the north, the north-east and the centre-west of France. In the first two cases, we are dealing with regions characterised by a dense distribution of cities involved in the textile industry and dynamic commercial relations, notably with the

²⁸ Lepetit B., *Les villes ...*, op. cit.

²⁹ Goger Jean-Marcel, « Une ambition révolutionnaire : rendre la route accessible aux ruraux. Equipement routier et querelle du luxe en France (1776-1815) », *Domitia*, n°3, Décembre, 2002, p. 173-184 ; Marchand Patrick, *Le maître de poste et le messager. Les transports publics en France au temps des chevaux*, Paris, Belin, 2006, 365 pages.

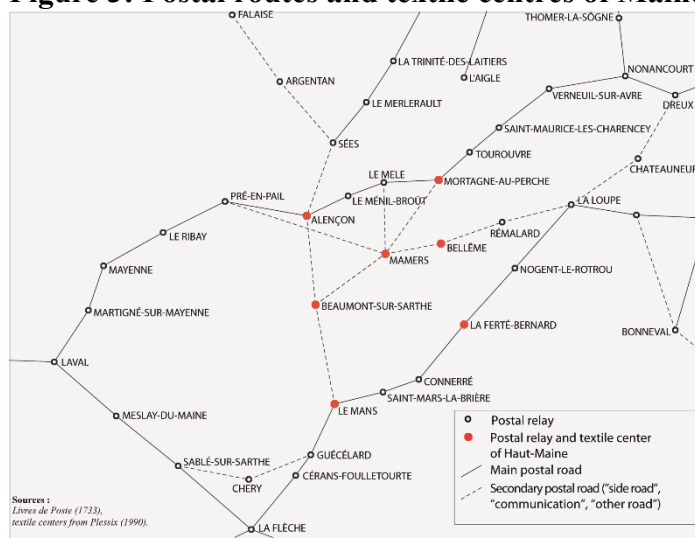
³⁰ this HAC has been built with Ward method for aggregation of clusters.

neighbouring countries of the north, the north-east and the east. One observes already in the correspondence of Colbert sustained attention to the construction of dense routes to serve the great textile centres, such as Lille, Saint-Valéry, Amiens, Beauvais, Saint-Quentin and Bray. The development of road coverage also responds to military preoccupations: information must be communicated at whatever cost, even if it means changing the route if the road is cut. The northern and north-eastern zones were accustomed to frequent troop movements, as a result of an active military history and numerous changes of frontiers: Lille became French in 1667, while Lorraine, annexed in 1766, came under the French postal jurisdiction (“Ferme des Postes”) beginning in 1703.

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The situation was very different in the case of the centre-west. Here the increased density of roads was recent, and the coverage did not concern a heavily militarised zone or a region of urban industry. On the contrary, the zone is rural, but extremely dynamic commercially.³² It is dotted with small centres of textile production, of wool or hemp, as described by René Plessix and Henri Sée.³³ In the lower-Maine, the city of Mamers did not have more than 6000 inhabitants in 1793 and Beaumont-sur-Sarthe 2300 inhabitants. Nevertheless, entrepreneurs or merchants had dealings with Spain, Italy, Germany and even the Antilles by means of the Atlantic ports, notably Nantes and La Rochelle. The road coverage that appeared in 1733 in this region was clearly tied to the existence of these textile centres (figure 3). Moreover, the classifications given to these routes in the *Livre de Poste* are distinctive: ‘autre route’ (*other route*), ‘communication’, ‘traverse’ (*connecting road*). In 1758, another heavily covered zone appeared to the south of Rouen, around Lisieux, Evreux, Orbec and Pont-Audemer, also known for their textile activity linked with the proximity of ports. The postal route, which to this point had assured administrative exchanges and commercial initiatives of the monarchy, thus seems to have evolved, at least in certain regions, to serve also the needs of entrepreneurs and local merchants.

Figure 3: Postal routes and textile centres of Maine in 1733.



³¹ Vaillé Eugène, *Histoire générale des Postes françaises, vol. 5 La Ferme générale et le groupe Pajot-Rouillé*, Paris, P. U. F., 1951.

³² Sée Henri, *L'évolution commerciale...*, op. cit.

³³ Plessix René, « Les tisserands du Haut-Maine à la fin du XVIIIe siècle », *Annales de Bretagne et des Pays de l'Ouest*, n°3, tome 97, 1990, p. 193-205 ; Sée Henri, *L'évolution commerciale...*, op. cit.

Increase in speed : the progressive avoidance of high and low points

The search for speed is a constant preoccupation during the period that concerns us. It is, however, clearly identified as a royal privilege: in 1775, the French monarchy refused to create a service of despatch-riders capable of covering a hundred kilometres per day, for ‘ces facilités doivent être réservées au gouvernement’ (*these capacities should be reserved for the government*).³⁴ But little by little speed becomes widespread within the postal service and so comes also to involve others who do not necessarily depend on the royal administration. The timetables of the stage-coaches serving the principal cities of France show³⁵ that the average speed was doubled between the middle of the 1760s and the end of the 1780s. This increase can be explained not only by technical progress (road paving, lessening the weight of the coaches) but also by the selection of horse-breeds adapted to the requirements of the post or by shortening the pauses at relays.

The rapidity of the post could not, however, be improved in mountainous regions. The figures proposed by Patrick Marchand³⁶ speak for themselves: 2.2 km/h between Aurillac and Clermont-Ferrand, 2.95 km/h between Clermont-Ferrand and Ambert. The post-horses advanced at a walk, with a third mount even being added to deal with the most difficult sections.³⁷ The installation of loops in the road was not adapted to mountains; the gap in the level of accessibility with flat areas increased steadily. One way of realising this is to construct an anamorphosis of the territory, on the basis of distances weighted by resistance and by elevation. The method used for this is termed *Multidimensional Scaling* and involves effecting a Principal Components Analysis on a table of distances, with a slight pre-treatment³⁸ (see Izenman³⁹ for a detailed presentation).

The results (figure 4) bring to light a massive transformation of the space of inter-urban exchanges thanks to the network of postal routes, with a marked contraction of the northern half and an equal expansion of the southern half, notably in the Massif Central (whose cities have been indicated in red to facilitate their location). The circular ring which takes shape progressively in the second half of the eighteenth century shows that this Massif henceforth constituted an obstacle to the circulation of the horse-drawn postal service, as it was not in the Middle Ages,⁴⁰ or even in 1632 (for this year the relays have been numbered according to the map of Nicolas Sanson).⁴¹ The mountain routes become not merely less dense but also of inferior quality: in 1820, they are characterised by numerous sections still in dirt-form, while those paved-covered are greatly in need of renovation.⁴² Complaints concerning the progressive isolation of mountain localities constitute, indeed, a recurrent theme in lists of grievances. Thus the inhabitants of Vénézobre, south of Alès, affirm that their village ‘n’est

³⁴ Marchand Patrick, *Le maître... », op. cit.*

³⁵ Arbellot G., « La grande mutation... », op. cit.

³⁶ Marchand Patrick, *Le maître de poste et le messenger. Les transports publics en France au temps des chevaux*, Paris, Belin, 2006, 365 pages.

³⁷ Belloc A., *Les postes françaises...*, op. cit.

³⁸ Pour une présentation détaillée, voir Izenman Alan Julian, *Modern Multivariate Statistical Techniques*, Springer, 2008.

³⁹ Izenman Alan Julian, *Modern Multivariate Statistical Techniques*, Springer, 2008.

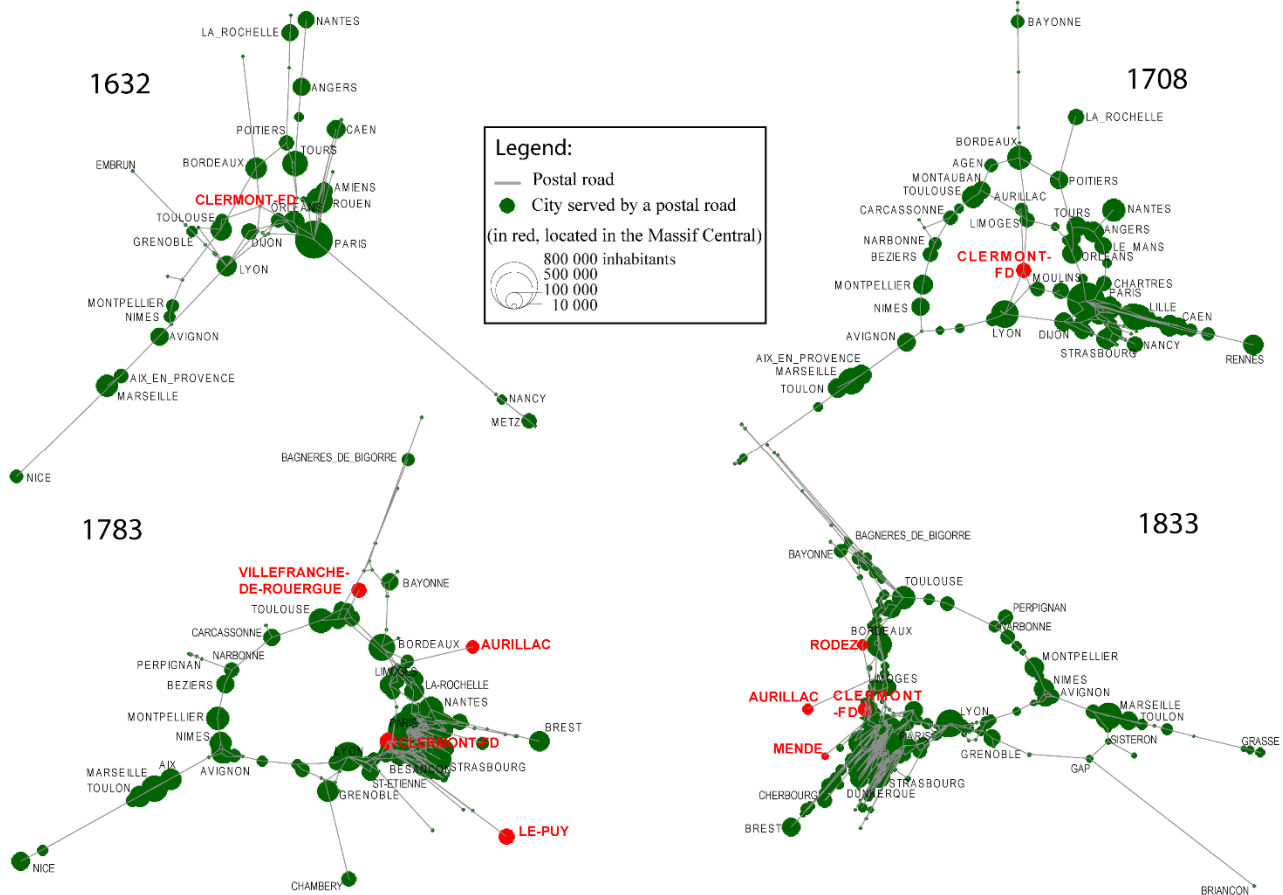
⁴⁰ Imberdis F., *Le réseau routier...* op. cit.

⁴¹ Bretagnolle A., Giraud T., Verdier N., « Modéliser l’efficacité... », op. cit.

⁴² Lepetit B., *Chemins de terre...*, op. cit.

pas accessible à un cavalier monté’ (is not accessible to a horse and rider).⁴³ One passes progressively, between 1730 and 1830, from the era of the pedestrian to that of the cart and riders who avoid the heights because of their mounts.

Figure 4 : Anamorphoses of the space of interurban postal relations



Rationalisation of routes: reciprocal adaptation of road and urban networks

Cities and roads constitute two geographical objects whose logics and temporalities do not necessarily resonate together. The disjunction is, indeed, flagrant in the first half of the eighteenth century: on the one hand, a young network of hard-surfaced roads that reorganise the space of exchanges; on the other, an historical urban network developed over a number of centuries.⁴⁴ In the seventeenth century it is not rare to find relatively large cities poorly served by the postal system, such as Rennes, Dieppe, Avignon or Montauban. On the other hand, one still finds in 1783 simple, indeed rudimentary villages, endowed with impressive road intersections. These discrepancies will disappear little by little, with the installation of a strong relation between the hierarchy of road centres and that of the cities. The road then enters into the service of the city, just as the railway will a century later.

To evoke the hierarchy of road centres supposes that this notion has been defined. To this point, we have shown that the assemblage of postal routes formed a network with more and more coverage.

⁴³ Goger J.-M., « Une ambition... », op. cit.

⁴⁴ Lepetit B., *Les villes ...*, op. cit.

This network could also become increasingly hierarchised, not in the sense that it increasingly resembled a tree but in that the contrast between the degrees of the central points would be more and more pronounced. The hierarchical character thus carries with it a quality of the network, that of the degrees of the centres. Barabási and Albert⁴⁵ have shown that many graphs, termed 'scale-free networks', are characterised by a distribution of the degrees extremely hierarchised, adjusted by a power law, whose slope, as an absolute value, reflects the inequality of the distribution: a diminution of this slope indicates a reinforcement of the contrasts between the degrees. Our analyses show that the distribution of the degrees of postal routes is sufficiently regular to be adjusted by a power law or an exponential law.⁴⁶ The extremely weak value of the number of centres of degree 1 is an artefact to be explained by the failure to account, in our database, for stops between ports and postal connections with cities situated outside the frontiers of the kingdom. These relays of degree 1 have thus been removed from the subsequent analysis.

The results of the adjustments (table 2) show a process of regular hierarchisation throughout the eighteenth and at the beginning of the nineteenth centuries, with the exception of the period marked by the Revolution and the wars of empire, during which many routes were closed for lack of means (the network then lost 10% of its total length). Analysis of the relations between the process of hierarchisation of centres and the evolution of the urban hierarchy reveals two important phenomena. First, between 1758 and 1783, a period of intensive road creation, the major intersections suppressed correspond, for the most part, to large cities, those that have declined to small ones. Certain regional metropolises which experienced an important deficit in road accessibility make up the difference in a hurry, such as Toulouse, Orléans and Clermont-Ferrand (table 3). The subsequent era, between 1783 and 1810, shows another type of reciprocal adaptation, this time in a downward direction. A thorough analysis of the intersections most affected by the road closures, notably in the northern half of France, reveals the preponderance of villages and small cities: of the 73 localities which lost 3 links or more between 1783 and 1810, 70 have fewer than 10,000 inhabitants. Reinforcement of the intersections of the largest cities, as well as reworking of the rural intersections, constituted the slow work of reciprocal adaptation of the road and urban hierarchy. From this point, the level of accessibility matched the size of the population centres.

⁴⁵ Barabási Albert-László et Bonabeau Eric, « Scale-free networks », *Scientific American*, may 2003, p. 60-69.

⁴⁶ Nous montrons les résultats avec une loi exponentielle car rien ne permet de donner la préférence entre l'un ou l'autre ajustement. Les résultats vont dans le même sens, quelle que soit l'équation choisie.

	Coefficient k (slope of the regression line, as an absolute value)	Coefficient of determination R ²
1708	1.32	0.90
1733	1.13	0.86
1758	0.92	0.97
1783	0.89	0.97
1810	1.11	0.99
1833	0.90	0.98

Table 2 : Modelling of the distribution of degrees by an exponential function

	< 10, 000 inhabitants in 1793	10,000 – 30,000 inhabitants. in 1793	> 30, 000 habitants 1793
Decreases in degree (degree in 1758-degree in 1783)	Montdidier (7-5) Avesnes-sur-H. (6-5) St-Pol (6-4) Laon (6-4) Ham (6-3)	St-Quentin (6-5) Cambrai (6-5)	
Stable degrees		Arras (7-7) Nancy (7-7) Metz (6-6)	
Increases in degree	Dreux (5-6) St-Avoid (4-6) Melun (3-6) Dol-de-B. (2-6) Gisors (2-6) Dôle (2-6)	Chartres (4-7) Abbeville (4-7) Beauvais (1-7) Verdun (5-6) Le Mans (4-6) Chalons-sur-M. (4-6) Saumur (2-6) Tarbes (0-6) Tours (4-7) Dijon (4-6) Besançon (3-6) Troyes (2-6)	Paris (9-10) Lyon (6-7) Rouen (7-9) Lille (6-7) Toulouse (2-6) Orléans (3-6) Strasbourg (6-7) Amiens (7-8) Caen (5-6) Rennes (5-8) Clermont-Fd (4-6)

Table 3: Correlation between accessibility and population for the most important road intersections (5 and more) in 1783. Reading of the table: Montdidier (7-5) signifies that 7 postal routes converge towards this locality in 1758 and 5 in 1783.

Two processes for territorial integration by the systems of cities

Modelling the emergence of a system of national exchange

According to See,⁴⁷ the increase of road speed and the ‘*révolution commerciale*’ (*commercial revolution*) of the eighteenth century entailed a change of scale in the range of interactions between the cities. The development of the great maritime and colonial commerce took the form of the importation of sugar, spices, tobacco, coffee, cotton, indigo, cacao, etc., and the exportation of textiles (woolen cheese-cloth, linen and hemp), hardware, edible products, wines and spirits. The regions

⁴⁷ Sée Henri, *L'évolution commerciale...*, op. cit.

emerged progressively from their isolation and sought outlets for their industrial production by the intermediary of merchants and financiers. The cities played a key role in this economic development and seem to have freed themselves progressively from the tutelage of the monarchy. This is evident, for example, from the Livres de Poste, whose presentation changes radically with the years 1770. Up to this point, the classification of routes is centred on Paris and the axes are described one by one in clockwise fashion (Paris-Lyon-Marseille, Paris-Toulouse-Narbonne, Paris-Bordeaux-Bayonne, etc.). Beginning in 1774, the routes are classed in alphabetical order by the names of the large cities, those around Paris and Versailles still figuring first, then, after 1810, being presented in their logical order.⁴⁸ Likewise, one finds in 1781, in the work of the engineer Isnard, a theoretical construction of an optimal road network which would connect the level of accessibility and the size of the cities: the routes would form triangles whose points are formed by the large cities, and the sides provide service to the small towns and villages if the detours required are not too great. Finally, the debates of the Constituent Assembly and the National Convention mention on several occasions the notions of ‘combinations’ of journeys and ‘branch lines’ of the road network.⁴⁹ In this new configuration, the capital is no longer the central pivot; it is connected by the totality of the medium and large cities, serving as a sort of switch permitting connection from one end of France to the other.

This double hypothesis of an integration of exchanges on the French national scale and of the particular role played by the cities of medium and large size (other than the former regional metropolises), can be further developed through the theory of graphs. To do this, we propose a modelling of the theoretical flows of information, using the index of ‘betweenness centrality’. The latter is calculated on the basis of a matrix of the shortest route, and therefore a construction by which each city exchanges with any other city located in France according to the shortest route. The index adds, for each city i , the number of journeys undertaken to connect any two cities and which pass through this city i . Barabási and Bonabeau⁵⁰ have shown that an optimal way of organising the flows within a network (minimising the costs of transport as a whole) is to have a hierarchical structure in hubs. These hubs correspond, by definition, to the points presenting the highest degrees but also to the points featuring the strongest intermediate centrality.

The index has been calculated on a simplified graph and according to distances weighted by elevation. A map (figure 5) represents the values obtained for the cities of medium and large size. In the first half of the eighteenth century, Paris is virtually the only significant intersection, a fact that must be interpreted with prudence, given the partiality of the coverage of the postal network, which then extended mainly within the northern half. By contrast, in the second half of the eighteenth century, a number of important intersections emerge, for instance along the route from Paris to Bordeaux (Orléans, Tours, Poitiers), allowing connection of the Atlantic ports with the rest of France. In 1791, moreover, a member of the Constituent Assembly stressed the interest of the great cross-routes relative to the star centred on Paris, pointing out that a ‘route de Lyon à Bordeaux, sollicitée depuis longtemps déjà, favoriserait le commerce avec les villes maritimes de l’océan’ (*route from Lyon to Bordeaux, long in request, would favour trade with the maritime cities of the ocean*).⁵¹ A second major axis is that linking Paris with the ports of the Mediterranean, with intersections such as Lyon

⁴⁸ Verdier Nicolas, « Le réseau... », op. cit..

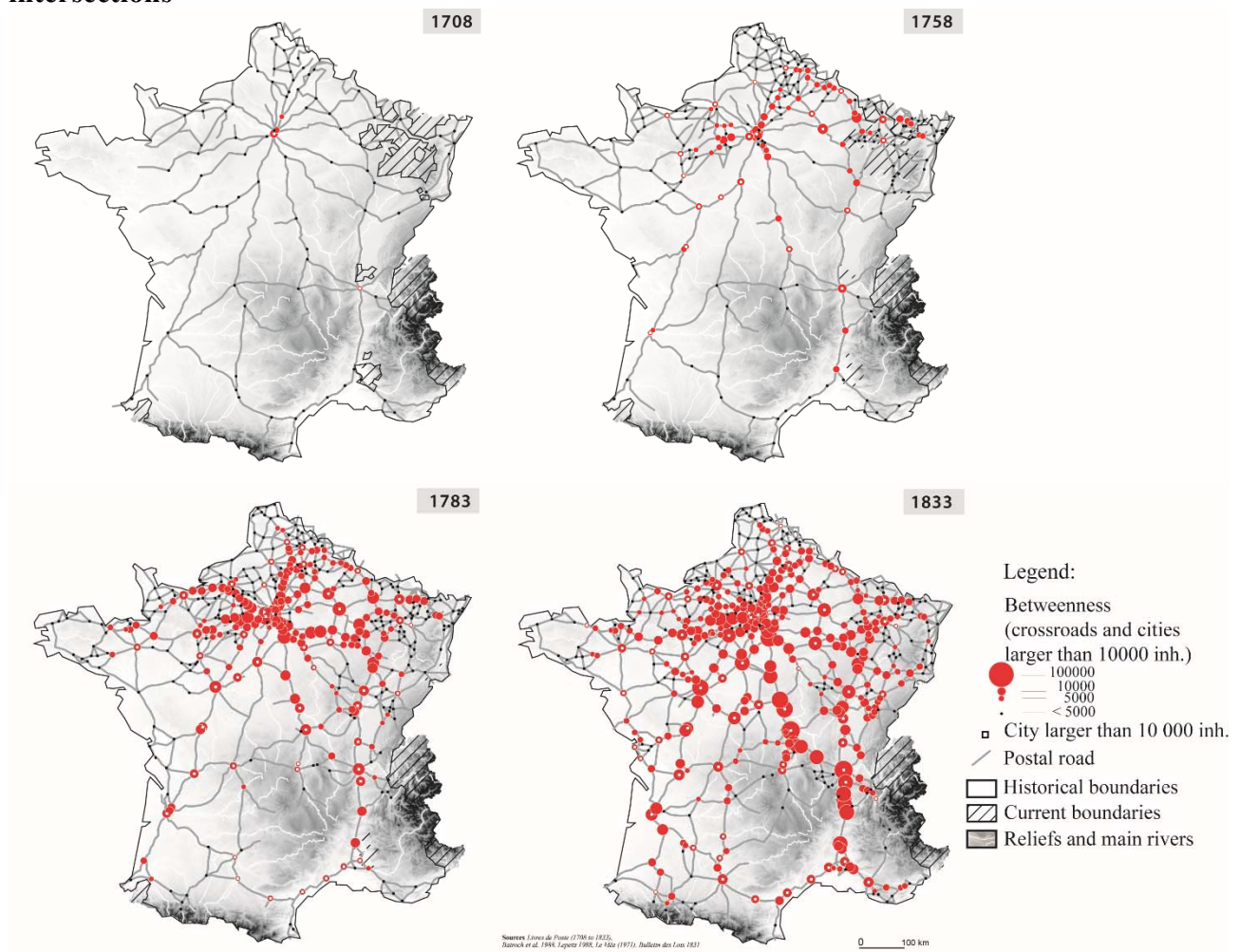
⁴⁹ Belloc A., *Les postes françaises...*, op. cit.

⁵⁰ Barabási A.-L., Bonabeau E., « Scale-free networks », op. cit.

⁵¹ Belloc A., *Les postes françaises...*, op. cit.

and Valence. To the north of Lyon, two itineraries are in direct competition, that passing through Nevers and that passing through Dijon. These two routes are each mentioned as a ‘route de Paris à Lyon’ in the Livres de Poste, and this from the outset of the eighteenth century. According to our analyses, the route that progressively gains favour is that passing through Nevers, while the Livres de Poste privilege that passing through Dijon beginning in the second half of the eighteenth century. This difference is explicable by the fact that our distances are weighted by attitude, thereby favouring the route passing through Nevers. Then, the route through Dijon presents another advantage not accounted for in our database, namely the use of barges on the Saône between Lyon and Chalon, which makes it possible to shorten the journey considerably.⁵² Moreover, from the second half of the eighteenth century another attractive feature, this one also extremely strong, accrues to the north-east of France, traversed by north-south exchanges connecting the valley of the Rhône and the Rhine, Flanders and Germany.

Figure 5: Evolution of the betweenness centrality of cities of more than 10,000 and of the intersections

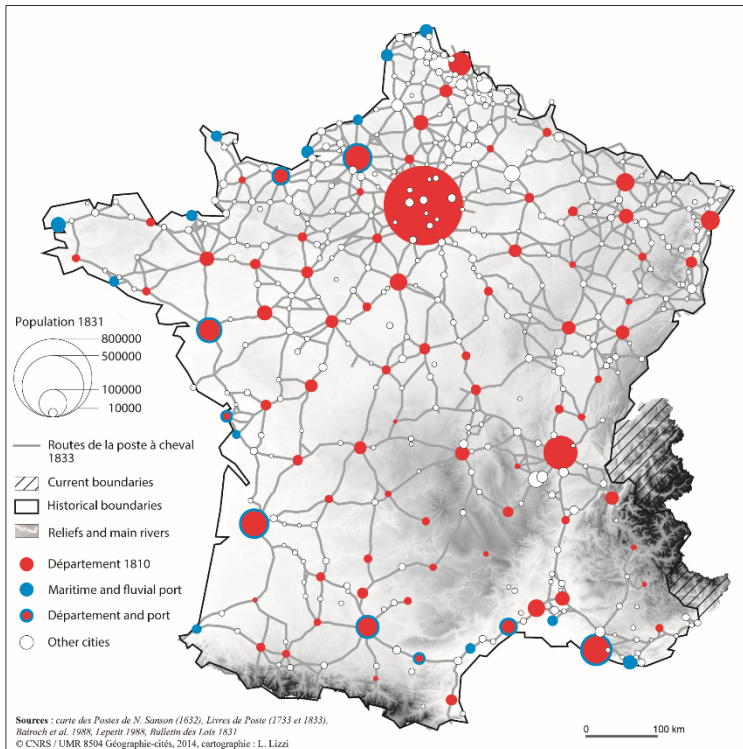


A second process of territorial integration at the national level involves, this time, the administrative functions of the cities. Paving of the territory, beginning with a hundred or so principal locales in a department, chosen for their optimal location with respect to the department’s population (at the most

⁵² Belloc A., *Les postes françaises...*, op. cit.

one day's return journey on horseback), was accompanied by a partial re-organisation of the postal routes (figure 6). Furthermore, by a decree issued by the Constituent Assembly in 1791, 26 routes were appointed to serve these chief centres and assure easy connections with neighbouring departments.⁵³ Two-thirds of these new central administrative locations correspond to cities of more than 10,000 inhabitants.

Figure 6: Postal routes and chief departmental centres at the beginning of the nineteenth century

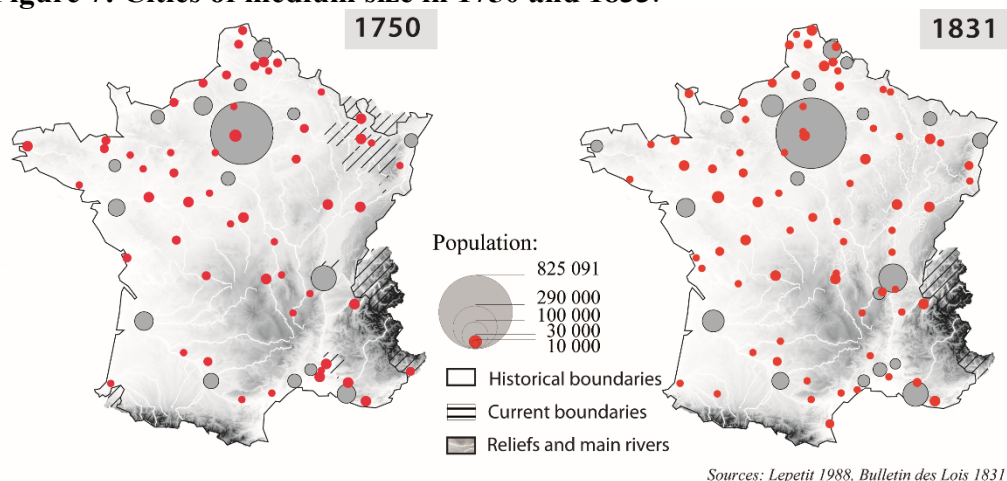


This reinforcement of the middle and large-sized cities, both as intersections in a system of exchange, henceforth national, and as principal centres of departments in the new administrative dispensation, issued in a significant evolution in the urban hierarchy. From this point of view, the cities of medium size, counting from 10,000 to 30,000 inhabitants, seem to have been particularly strengthened.⁵⁴ They cover the territory in a regular fashion in 1780, as was not the case in 1750 (figure 7). The inflation of the distribution of city sizes in this middle zone makes it possible to explain the diminution of hierarchical contrast between the cities which took place between 1750 and 1809 (table 4). The remarkable effort in road creation between 1758 and 1783 also seems in part oriented towards this category of cities: the close connection between the new routes and this class of city is especially visible along an axis joining the Atlantic and Lyon, but also certain regions such as Burgundy, Artois, Normandy and Brittany.

⁵³ Belloc A., *Les postes françaises...*, op. cit.

⁵⁴ Lepetit B., *Les villes ...*, op. cit.

Figure 7: Cities of medium size in 1750 and 1833.



	Degree of inequalities (slope of the regression line as an absolute value)	Coefficient of determination R^2
1750	0,75	0.96
1780	0,74	0.98
1793	0,73	0.97
1809	0,73	0.97
1831	0,76	0.97
1851	0,81	0.98

Tableau 4 : Evolution of the degree of inequalities in the size of cities (1750-1851).

Modelling regional hierarchies

The emergence of city systems integrated at the national level (and even, supra-national for more contemporary periods) did not suppress the regional relations established by the cities. These continue to serve the local and surrounding population in goods and services of all kinds. We posit the hypothesis that the formation of an integrated system on the national scale depended not only on the emergence of national economic circuits (see supra) but also on the progressive transformation of regional systems, which come to constitute little by little a regular arrangement. We have seen that at the outset of the eighteenth century, the regional networks were primatial in structure, formed by a regional metropolis and the small cities or villages which surrounded it, and were relatively isolated. Lepetit⁵⁵ sees the reinforcement of mid-sized cities in the second half of the eighteenth century as the sign of a profound transformation of regional hierarchies. He even suggests the motive role of road rapidity and of the new systems of road loops in the northern France, which favoured the increase in the range of exchanges for the medium cities and the short-circuiting of the small centres. We have wished to test this hypothesis by modelling the regional urban hierarchies before and after the great movement of road transport. The incomplete data concerning the small cities before 1793 have not

⁵⁵ Lepetit B., *Les villes ...*, op. cit.

permitted us to go further back than this date, so we have compared the situation in 1793 (including the road network of 1783) with that of 1831 (including the road network of 1833).

Modelling the regional hierarchies presupposes defining, to start with, the notion of the system of regional cities. Various definitions are possible. Our approach is very simple and has reference to the work of Etienne Juillard,⁵⁶ and, before him, that of Georges Chabot and Jean Reynaud: the limit of a region is constituted by the localities capable of reaching the regional centre in less than a single day's return journey. This facility of exchange notably permits the diffusion of information between the different cities of the regional system. We have used the model of Reilly⁵⁷ to identify the different regional systems, constructing each as an ensemble formed by a regional capital and cities connected to it because situated within its sphere of influence. To improve the reading of the urban hierarchies, we have added to the maps derived from Reilly's model circles proportional to the population of the localities. This permits notably to focus on the number of hierarchical levels in each regional pattern (two if one refers to a primatial network composed of a regional capital and small villages, three or more if one adds the mid-sized cities surrounding the origin of the network, as in the system of central places constructed by Walter Christaller).

The model of Reilly is based on calculation of an index of attractivity:

$$A_{i \leftarrow j} = \frac{P_j}{[d_{ij}(1 + k\Delta z)]^\beta}$$

where $A_{i \leftarrow j}$ is the influence of one locality j on another i , P_j the population of j , d_{ij} the distance between i and j , $1 + k\Delta z$ the correction due to the difference in elevation, and β a parameter of friction based on the distance. We recall that $k = 5.10^{-3}$ (see section 2.1). The parameter β has been fixed at 2, as in most of the applications of Reilly's model. The maximum range capable of being achieved in a single day's return journey has been estimated according to the observations of Guy Arbellot:⁵⁸ about fifty kilometres at the beginning of the period, a hundred at the end. Finally, the distance between the cities is that of the postal roads corrected by the resistance of elevation. For each city i , one has thus considered all the indices calculated for j which meet the criteria. One then selects the city j for which the index of Reilly is the greatest, and one traces a link between city i and city j . The regional patterns are identifiable by different colours when they add up to 4 or more links, and charted for two dates, 1793 and 1833 (figure 8). When the cities are not equipped with a postal relay, they are simply localised on the map with their populations. We have previously verified that these themselves do not constitute regional capitals by constructing for each of the two dates regional hierarchies according to simple distances as the crow flies, permitting us to include all the cities, including those without a postal relay. These all attach themselves to other capitals equipped with postal relays. To connect them to the regional patterns constructed for the postal routes would have constituted a bias, given the large difference in methods (network distances weighted by elevation and resistance, in one case, distances as the crow flies in the other). We have chosen simply to add

⁵⁶ Juillard Etienne, *La « région ». Contributions à une géographie générale des espaces régionaux*, Strasbourg, Editions Ophrys, 1974, 230 pages.

⁵⁷ Reilly William, *The Law of Retail Gravitation*, New York, Knickerbocker Press, 1931.

⁵⁸ Arbellot G., « La grande mutation... », op. cit.

their population to the map, for the majority are located in the south and their absence may have biased the analysis of differentials between the north and the south of France.

Figure 8 : Postal routes and urban hierarchies in 1783 and 1833

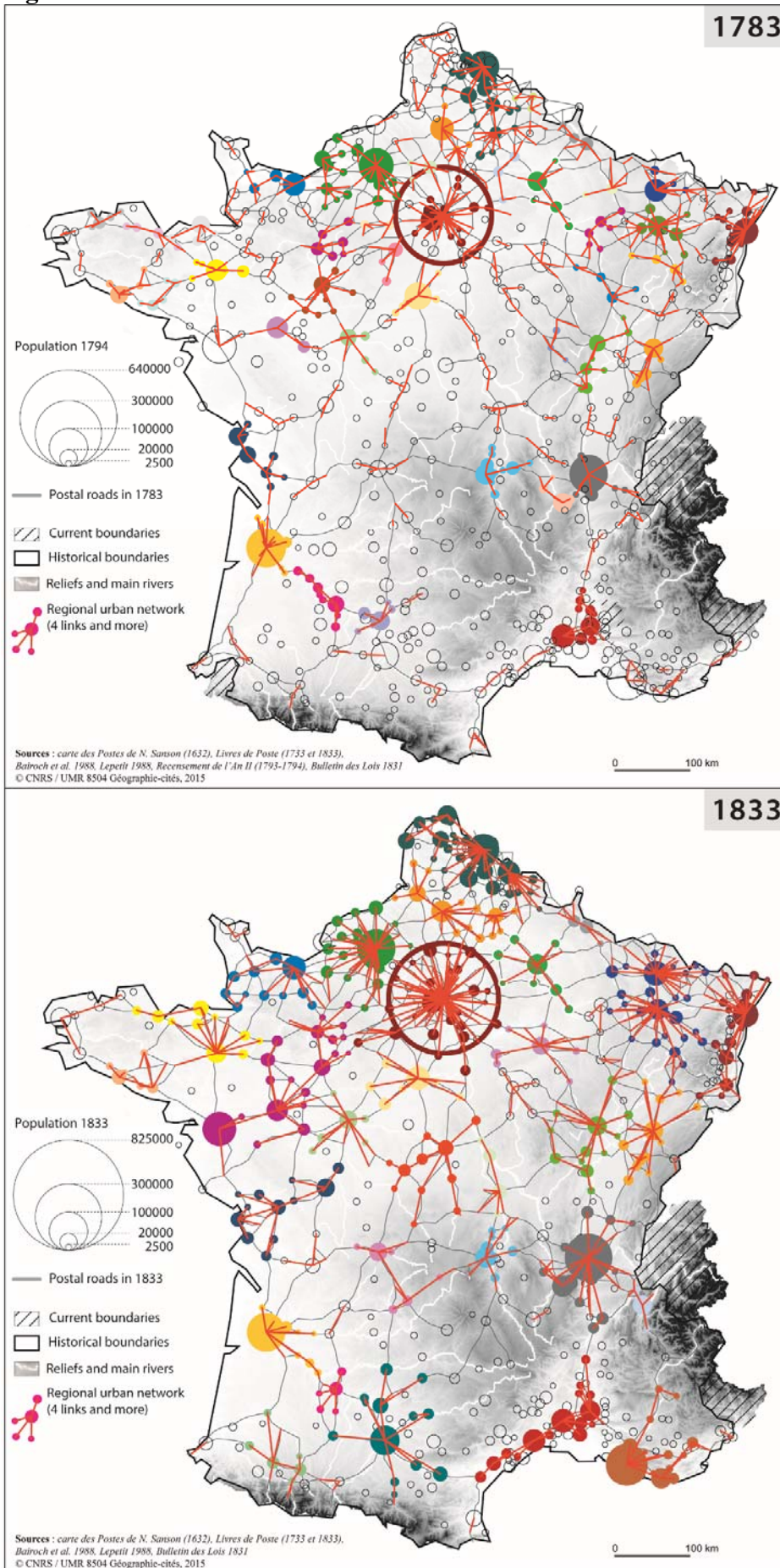


Figure 8 shows that the contrast between the two dates is marked. In 1783, the territory of France was covered by a multitude of small regional networks, corresponding most often to the urban patterns described for the beginning of the eighteenth century, namely a large primatial city surrounded by small ones. It is rare that intermediate levels are apparent: one finds a few for the networks centred on Rouen, Angers, Reims or Paris. In 1833, by contrast, the regional systems are extremely different in the northern half of France. The impression that dominates is of a regular structure comprising similar structures, not only of the different networks but within the interior of each. Three levels or organisation are frequent at this date around the largest cities, such as Paris, Strasbourg, Lille, Nantes and Rouen, and present themselves like the schema of Christaller, with a metropolis surrounded by medium-sized cities, themselves surrounded by small ones. In the south, by contrast, the situation had changed little since 1783. Only Lyon and Toulouse could be considered a relatively dense system of regional relations resembling what is found in the north. If one refers to the analyses of Lepetit, who did not hesitate to speak of 'systèmes de places centrales' (*systems of central places*) in the north of France and the persistence of 'cathédrales dans le désert' (*cathedrals in the desert*) in the south, it would seem that a new economic mode of functioning appeared in the north: a greater presence of markets and shops, homogeneity of grain prices, more rapid diffusion of innovations, such as savings banks. The roads, profoundly different in the north and the south, could be explained in part this difference in evolution.

Discussion and perspectives

In light of the analyses we have conducted, the eighteenth century constituted an important turning point for the cities from several points of view. First of all, the routes linking them were henceforth fixed itineraries, oriented by the search for speed and hence by a new means of displacement, that of the horse and journeys over flat territory. Secondly, those involved in the tracing of itineraries did not seem to be only the monarchs, guided by motives of political and military management, but also those who were involved in substantial commerce (at all levels) and citizens represented by the Constituent Assembly. Finally, the cities found themselves integrated into the networks of durable exchanges, whose form would later be reproduced, as evidenced by the strong resemblance existing between the form of the road network in 1833 and that of the railways.⁵⁹ The destiny of a city from then on depended largely on its capacity to position itself within relational networks, in other words, on its accessibility to the most important transportation networks of the time, that is those that transport expensive goods or information allowing for diffusion of innovations. The function of the city is no longer simply political or religious; it is also economic. And in this economic function, it is not simply the capacity to manage the real-estate income that counts, but also the manufacturing and merchandising capacity.

The interest of the data bases we have used to illustrate these changes consists in the fact that they contain the essential ingredients for this great transformation of the eighteenth century: the size of the city, the speed, the information, long-distance commerce -- and this even if they are sometimes incomplete. Complementary databases (on port-stops, other routes, towns and small cities) would be useful in completing this work.

⁵⁹ Caron François, *Histoire des chemins de fer en France. Tome 1, 1740-1883*, Paris, Fayard, 1997, 700 pages.

Let is note, however, that the hypothetical establishment, from the eighteenth century, of a co-evolution of the dynamic of cities in a system and the network of exchange that connects them cannot be proved in a statistical manner. We have sought to test it with our information, but these tests have rarely permitted us to conclude in one way or another. (This is often the case with refutation of a theory with an experimental or observational database.) The diversity of the individual trajectories of each city, even if, overall, their hierarchy is respected, does not enable one to predict the future of each, even if one is familiar with the network of exchanges. None of the correlations that seem natural, such as between, on the one hand, the degree of a city in the postal network, the profile of resistances or its intermediate centrality and, on the other, its population, is statistically significant. It seems that after three years of research we have not been able to read in our data the narrative of an urban theory connecting cities and exchanges on the basis of statistical models. This does not signify that this hypothesis is false. It seems rather that the narrative of the theory possesses greater substance than the statistical model, which has more limited range. One of the reasons for this limit is that the statistical models on the graphs take into account the calculation of two scales, and two only: that of immediate contiguity (as reflected in our constructing of the graph) and that of the globality of the network (as in the calculations of resistance and of intermediate centrality). Nevertheless, there exist intermediate scales, forms that the eye sees on the maps, and which are presently very difficult to characterise using the indices on a graph. Investigations in these directions, the characterisation and modelling processes on intermediate scales, probably constitute a route to be explored. Supporting evidence for this proposition is the concomitant emergence of mid-sized cities demonstrated by Lepetit, the recognition of these forms, essentially by the eye, on the maps we have produced, and this notion of intermediate scale, between the local and the global, which is presently an active focus for the study of complex systems.

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