CONTEXTUALIZING THE URBAN HEALTHCARE SYSTEM

Methodology for developing a geodatabase of Delhi's healthcare system

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Abstract: This paper introduces the setting up of a Geographical Information System on Delhi for studies in the Social Sciences. Through an explanation of their methodological procedure and demonstration of thematic applications focusing on the healthcare system's spatial organization, the authors lead us through the inherent difficulties of building a GIS in an emerging country like India. They also attempt to demonstrate that this kind of tool remains, however, a relevant support for research in the Social Sciences as long as it is used with care and knowledge of the dataset frame. From this perspective, Exploratory Data Analysis coupled with the play of scales provide powerful ways to assess socio-spatial dynamics taking place in the Indian capital.

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FOREWORD

Importance of looking at data sets, generated through different systems and using different technologies within an integrated framework, for having a comprehensive view of the complex social reality of today can not be exaggerated. In large countries or those with a federal structure, it would further be necessary to put the data in space and analyse variations across the federating units and administrative boundaries. Understandably, application of Geographical Information System (GIS) in analysing the spatial pattern of distribution of socioeconomic phenomenon and relating it to a number of physical and socio-economic characteristics is gaining ground in many of these countries. Unfortunately, there is sluggishness in its adoption and propagation while the practitioners of GIS have shown high level entrepreneurship in coming up with extremely innovative applications. The sad consequence is that it is the latter that get flashed in seminars and workshops while much of the socio economic research and policy decisions are undertaken without a spatial perspective that could come through application of this tool.

The popular application of GIS in social research has been visual representation of data across spatial units like states, districts, towns and villages, by putting together maps generated in different scales, through digitization. After putting the maps in an identical format and scale, one can view a large number of socio-economic attributes in the maps sequentially. This is of immense value in social analysis in a country like India where most development problems have significant spatial dimension. Even in the context of assessing inequality in the distribution of development or wellbeing indicators within a city or location of transport, telecom networks and other civic amenities in relation to city centre and sub-centres, use of GIS has been strongly recommended.

In viewing thematic characteristics in space, one gets insights into data through GIS that are rarely possible when one looks at the same, in a matrix form. By superimposing one map on another, one can observe co-variation of two characteristics in space. It is indeed true that correlation coefficients between the two indicators can capture such relationship quantitatively. However, for hypothesis formation, looking at two or more patterns on a map is much more revealing and useful than statistical correlations.

Besides representation of a large number of indicators across spatial units in thematic maps, GIS allows superimposition of other maps, showing location of railway lines, river basins etc., on the former. GIS is very helpful in relating the two kinds of information in space, in building hypothesis about their interdependencies and drawing inferences. One can, for example, work out the density of transport routes say within a district and relate it with other socio-economic indicators, available from official sources. GIS could help in calculating water availability for each village based on how its total area falls in different basins as also its distance from different water sources, once they are digitized on the map. It thus helps in generating additional information on the spatial units for which conventional (including administrative) data are published on a regular basis. This renders statistical analysis richer in terms of content.

Depiction of statistical data in space and generation of additional information through combination of maps, as noted above, may, however, be considered elementary and of minor significance by many GIS practitioners. Remaining confined to these two functions and eschewing its potential application for analytical purposes, would be viewed as a gross underutilization of the technology. Indeed, given the rapid developments in this field at global level, one would consider the present applications in India, to be at a nascent stage. There is thus an urgent need (a) to increase the dissemination of this technology in social analysis and policy making as also (b) to go for innovations and a higher level of sophistication in designing the tool itself. I am extremely happy to note that the present study by Pierre Chapelet and

Bertrand Lefebvre has made an attempt to achieve both the objectives as it builds up a Geodatabase on Healthcare System in Urban Delhi. The authors display the analytical potential of GIS, by incorporating in it and building upon various multivariate statistical tools, like techniques of classification and clustering, regression and principal component analysis (PCA). More importantly, they demonstrate that even simple applications of GIS brings in a spatial perspective that help in looking at health care system in Delhi in the 'context' of a number of socio-economic parameters. This is of immense value in understanding intra-urban and intra regional inequality and can become a useful input in redesigning a delivery system with greater equity.

The scholars demonstrate how one can get rich insights into provisioning and availability of health care facilities in a city through spatial representation of different types of facilities, including the number of health personnel and community based workers. These are useful in identifying the areas with "no facility" and analysing the economic and social characteristics of the population living there. These insights can then be carried into an exercise of formulating a strategy for more balanced provision of health services to match the needs of the population. The study would also go a long way in motivating other researchers in contexualizing health services in relation to several other socio-economic dimensions, not covered in the study. Hopefully, it would be a forerunner of many other studies that would look at spatial distribution of other basic amenities in Delhi or other large cities and their hinterland.

A few simple exercises carried out in the study are worth mentioning as illustrations. The scholars have presented univariate as well as bi-variate data across space, villages, census towns, census charges etc. in a number of maps. Two-fold information on the spatial units has been presented by assigning distinct colours to values (intervals) of one indicator and showing the other by the size of a circle. One can bring in additional variables by giving shades within the circle/bar or other schema but undoubtedly these are subjects of traditional cartography.

The relevance of such exercises can hardly be over emphasized since one misses out on aspects of spatial relationship, when visual images are not prepared. Indeed, very many hypotheses about spatial interrelations would strike a reader immediately as soon as he/she looks at the distribution of various indicators in the maps, presented in the book.

For discretisation of the village/ town/ charge level data and building up of categories, the scholars, however, depart from the traditional quartiling or equal interval methods. The categories are identified through a statistical tool that takes into consideration the nature of the distribution of the indicators. For six fold classification, the method adopted puts extreme values at the two ends in two categories and identifies the frequencies in the remaining categories, based on the nature of the distribution. This obviates the need to exercise judgments with regard to class intervals in an ad-hoc or mechanical fashion. It is through such, and possibly even more, extensive discussions of the value judgments upholding these methods that one can increase the acceptability of GIS in social research and policy making.

Another interesting map is one which shows deviations of each spatial unit from the line of best fit of two variables viz. fertility and women literacy. Further, the scholars combine two or more characteristics by giving appropriate weightages through PCA and generate new maps to get multivariate picture. While the interpretation of various principal components in terms of their constituent indicators would always remain subjective, mapping of the positive and negative values gives insights into the development dynamics in and around Delhi.

It may nonetheless be worthwhile to reiterate that much of the analyses undertaken through application of GIS could have been done through conventional statistical methods and of mapping. However, such exercises would be so energy and time consuming that one would hardly undertake the task.

A strong point of the study is the analysis of socio-spatial differentiation by combining thematic maps with those generated through remote sensing (RS) technique. The authors argue that it is possible to generate a continuous surface from a thematic map by assigning the discrete values (say density) of each areal unit, say village or town, to its geographic centre and then using interpolation. An alternate but more accurate method of generating this trend surface would be assigning values to the barycentre in each built up area, identified through remote sensing image, and then using interpolation. The additional insight that one gets into the variation within a spatial unit through this trend surface is impossible to get otherwise.

This experimental exercise of integrating thematic and RS maps enables a researcher to take into consideration the variance in the values “not only across spatial units but within the unit” and thus decipher spatial discontinuities of much smaller order. It demonstrates how the data, obtained through RS methods can be combined with those generated through traditional statistical system and how discreet and continuous data can be put in the same scale for gaining better understanding of a multivariate phenomenon. This indeed is a step forward since, until recently, statistical analyses for obtaining locational solutions have been carried out independently and the physiographic viability of the solutions are examined using RS maps in the next stage, almost as an afterthought or a window-dressing.

The applications of RS maps in policy making over the past couple of decades have been rather elementary, as noted above. Researchers have often obtained solutions to their complex location problems through quantitative models, involving extensive use of statistical data. They would then superimpose a RS map, on the solution set. This undoubtedly makes it possible to check if there are physical/geographical factors, not incorporated in the statistical analysis that could impede implementation of the solution. Also, RS maps have been useful in determining the exact location of a facility within the spatial unit, the latter identified through statistical analysis. Such usages of RS technology, for validation or detailing out the results at the final stage, would mean utilizing less than full potential of GIS.

The present study illustrates how GIS allows integration of different data sets to arrive at holistic or aggregative solutions. It shows how the technique can help in generating additional indicators (of discrete and continuous nature) from RS maps and incorporate these into the core of the analysis. Indeed, the level of desegregation at which the analysis has been undertaken in the present study is not possible through conventional methods.

An interesting exercise that could have been attempted is generation of a map of accessibility to medi-care system, based on the distance of village/charge from all the facilities. The study, nonetheless, makes it amply clear that this can easily be done. An aggregative thematic map or trend surface can be generated at charge level, once the location of facilities is incorporated into a map, showing the charges. One can then undertake statistical analysis by combining this new data set with the others generated by Census or local level agencies at ward level.

The basic message that comes out of the exercises undertaken in the study is that GIS software always has a mathematical model built into it. Although it is generally difficult to de-link the two, the scholars have shown how GIS can be used for simple mapping of the results obtained through application of PCA and other statistical tools. Taking a clue from this, one may argue that the only way to demystify GIS is to make the underlying mathematical model and its implications explicit to the users. Indeed, the scholars have not undertaken statistical analysis separately and then use GIS merely for visual representation of the results but it is certainly possible to do that. This possibly would allow the researcher to attempt a rigorous examination of the assumptions of the statistical model. Even when a GIS model does not permit such clear separation, it would make sense to enquire into the validity of the implicit mathematical model before applying it in a given social context.

Chapelet and Lefebvre must be complimented for presenting us with a treatment of GIS, refreshingly different from most other practitioners wherein the statistical tools get so deeply buried into the tool that these become matters of least concern. Since the underlying mathematical formulations are not stated explicitly in GIS software, not many bother to dig these out of the standard packages. Even when explicit, these are presented as axiomatic or reflecting universally accepted principles so that an unsuspecting or indolent user is not ‘unduly perturbed’ by them. One even tends to forget that a complex set of judgments has gone into the emergence of neat spatial maps. Understandably, it is convenient to resort to this practice since it spares the researcher the responsibility of understanding the underlying model, examine its relevance and apply the tests to check their level of significance empirically. In many such studies, one does not know when computer cartography ends and statistical model begins and vice versa.

Application of GIS must grow so that it does not remain a fancy tool in the hands of a few. It should be so common that its application ceases to be news and it stops figuring in the title of a study. A scholar who uses computer for data processing or runs software packages these days no longer writes in the title or even the text that solutions are computer based. The important thing would be to ensure that its use is justified in terms of getting additional insights into development dynamics. It is for this, as also for probing into the assumptions of the inbuilt statistical models that the practitioners would have to do a lot more work. The study has made an excellent beginning in bridging the gap between frontier methods in GIS and its applications in current policy. I hope the challenge of bridging it further would be taken up by them and many others working in the area.

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INTRODUCTION

A Geographical Information System of the Census Data and the Delhi Health System. For Whom and Why?

"Understanding territories built by mankind, appraising their use, diagnosing their intrinsic contradictions and tensions, appraising their dynamics is part of Geography's ambitions. Such ambitions are not satisfied with discourses only but need rigorous tools and methodologies"[1]. This quotation of the well-known French geographer R. Brunet could well illustrate the research posture of the following work.

This Occasional Paper presents the setting-up of a Geographical Information System (GIS) of the Delhi agglomeration first developed in the context of a research project on access to pharmaceuticals in Delhi. Initially developed for the purpose of selecting representative samples of urban areas and health infrastructure for fieldwork investigations and to better assess the socio-spatial dynamics taking place in the Indian capital, it soon became evident that this tool could be very useful to any researcher working on Delhi, particularly in the field of social sciences, urban development, and health studies. Moreover, the imperfections of datasets already existing in this tool as well as the additional value obtained by merging as many datasets as possible within the same framework rapidly led us to design it in order to ensure that it could be re-used and, above all, easily updated with fresh datasets coming from other research projects.

That is how this Occasional Paper was written. Its aim is to present this tool; the way it is developed and how it works, allowing other researchers to use it with the necessary knowledge. In order to help researchers in discovering the spatial database underlying the following discourse, we decided to publish this Occasional Paper on a digital support (CDROM). This has especially allowed us to incorporate interactive mapping tools[2]. We hope this will enable the reader to see and explore by himself basic cartographic representations of several datasets available in this GIS as one goes through the text.

The paper is organised in the following way:

In the first part, we shall briefly contextualise our work to see what the actual use of GIS in social sciences and health studies is, the pros and cons in the use of such technology, quickly focusing on what is being done in India.

This will lead us in the second part to present our research posture and the way we had to design the GIS in order to provide a useful tool for our research and for other researchers. We will then focus on the methodological aspects of our work in order to achieve our objectives in an urban context such as the Delhi agglomeration. Examining data and cartographic sources used in the system, we will conclude with a more descriptive part presenting each perception level.

The third and last part shows by means of an Atlas aimed at contextualising the Delhi Health system, the kind of output we can generate with such a tool and how we can actually use it in the field of health geography.

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[1] Roger Brunet: Foreword in Joël Charre's book on statistics and territories (CHARRE 1995)

[2] The interactive maps presented in this CDROM are in Flash format. In order to view and use them properly, please install a Flash player on your computer (available at http://www.macromedia.com). Some of these maps have been generated from our GIS using Geoclip software (see http://www.geoclip.net).

We hope that the reading of this Occasional Paper will convince both researchers and policy makers that the GIS can be a useful input in the formulation of research hypothesis and strategies for setting-up health services.

THE USE OF GIS IN SOCIAL SCIENCES AND HEALTH STUDIES

This chapter presents an overview of GIS technology capabilities and limitations in the field of social sciences, especially in health studies, in order to develop a pertinent methodology for the setting up of our GIS. After briefly defining and describing the components of a GIS, we will focus on current GIS implementation in these fields. The next part will present the principal limitations that appear when resorting to such tools. We will then focus on the actual use of GIS in India in the field of Health Studies. This contextualisation associated with previous technical explanations will allow us to set up an appropriate methodology in the next section.

1. Geographical Information Systems and spatial analysis

Since two decades, Geographical Information Systems (GIS) have become a common and central tool for researchers in various domains. Therefore the abbreviation “GIS” is more and more commonly used, not always with respect to its real meaning. Hence, before introducing our work, it seems appropriate to briefly question what is exactly behind this emerging technology.

Broadly speaking, a Geographical Information System is a set of analytical software tools for making and using spatially organized data (such as census data; soil-type samples; biological-population distributions; zip-code files, etc…). It helps at modelling spatialised phenomena by structuring spatial data.

More precisely, it can be described as an organized set of computer hardware, software, geographical datasets and people able to input/collect, store, update, manage, analyse/transform and show/retrieve/output every spatially referenced geographical information (DENEGRE 1996). Geographical Information (**figure 1**) is officially defined by geographers as the information/data on places on earth. More concretely, it aims at recording spatial phenomena through an agreed standard[3], to provide a model of the distribution of natural or anthropogenic phenomena[4]. Hence, it can be defined by three components: spatial, thematic and temporal, informing us on “what is where and when”. Geographical Information is a central concept in geography especially for spatial analysis.

[3] The first agreed standard to choose when using a GIS is a georeferencing system. It is indeed essential that all spatial data are located with respect to a common frame of reference. It is provided by one of a limited geodetic coordinate system, often plane, orthogonal Cartesian coordinates, oriented north-south and east-west. This system of coordinates is in fact an approximation of reality, given that the earth is not a plane, not even a sphere. Geodesists have thus devised several Ellipsoids for mapping the actual curved surface of the earth on to a plane. The transformation which projects locations from an ellipsoid to a plane is called the Projection System.

[4] The idea of Geographical Information was first developed by Mercator in the 17th century along with the concepts of mathematical projection system and accurate set of coordinates. See (HODGKISS 1981)

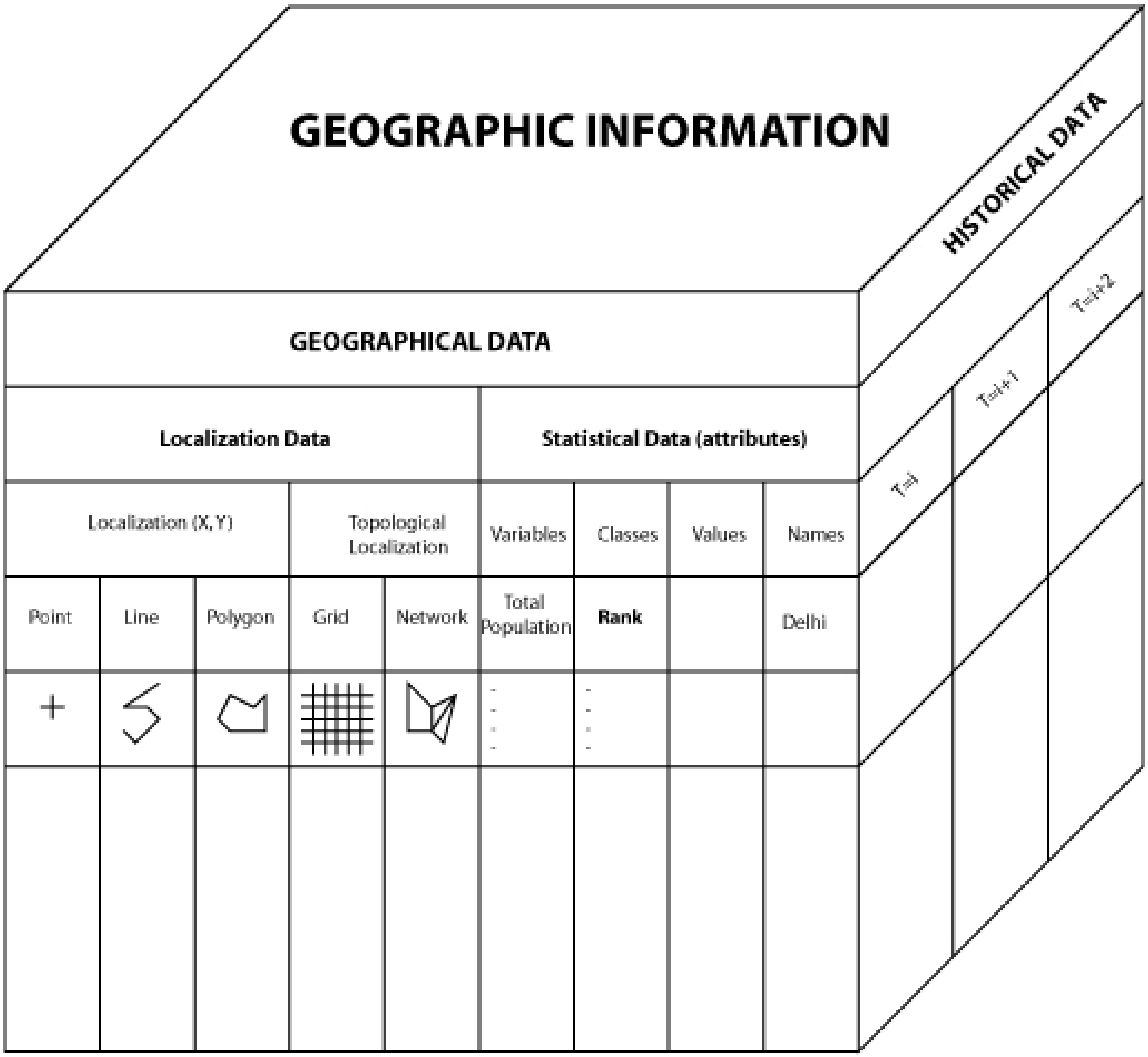

Figure 1 - Components of the Geographical Information concept

Source: (DANGERMOND, 1990)

The tool-based definition[5] of GIS proposed by Denegre (DENEGRE 1996) has the advantage of exposing its various functionalities (BURROUGH and MCDONNELL 1998) which are as follows (**figure 2**):

- **Data input and verification:** covers all aspects of capturing spatial data from existing maps, field observations and sensors and converting them into a standardised digital format; Two kinds of data can be identified: vector and raster. Raster data refers to data stored as square cells (pixels) as in an image. Vector data refers to information stored as geometrical objects. In the vector data model, space is represented as a series of discrete entity-defined point, line, and polygon units. Depending on the work scale, a physical entity such as a city could then be defined as a point entity (for example when working on a continental scale), or as a set of polygons (when working on intra-urban phenomena). This question of choice of representation is crucial when conceptualizing data structure, as it will affect the range of available analysis.
- **Data storage and database management:** the way in which spatial data is structured and organised. Hence, in a GIS geographical information is integrated in a geographical

[5] If this definition is commonly accepted, it is possible however to find several definitions, focusing either on the toolbox, the spatial database or the organizational aspects of GIS. For further information, see (BURROUGH and MCDONNEL 1998)

database in terms of (a) its **location** (position with respect to a known coordinate system: geo-referencing), (b) its **attributes** that are unrelated to position and (c) its **topology** (the spatial interrelations with each other which describe how they are linked together);
- **Data output and presentation:** the different ways data is displayed and how the results of analyses are reported to the users;
- **Data transformation:** embraces two categories of operations, namely (a) transformations needed to eliminate errors from the data or to bring them up to date or to match them with other data sets, and (b) the large array of analytical methods that may be applied to the data in order to answer the questions asked of the GIS. This second point underlines the need for conceptual tools like spatial analysis to analyse geographical information;
- **Interaction with the user**

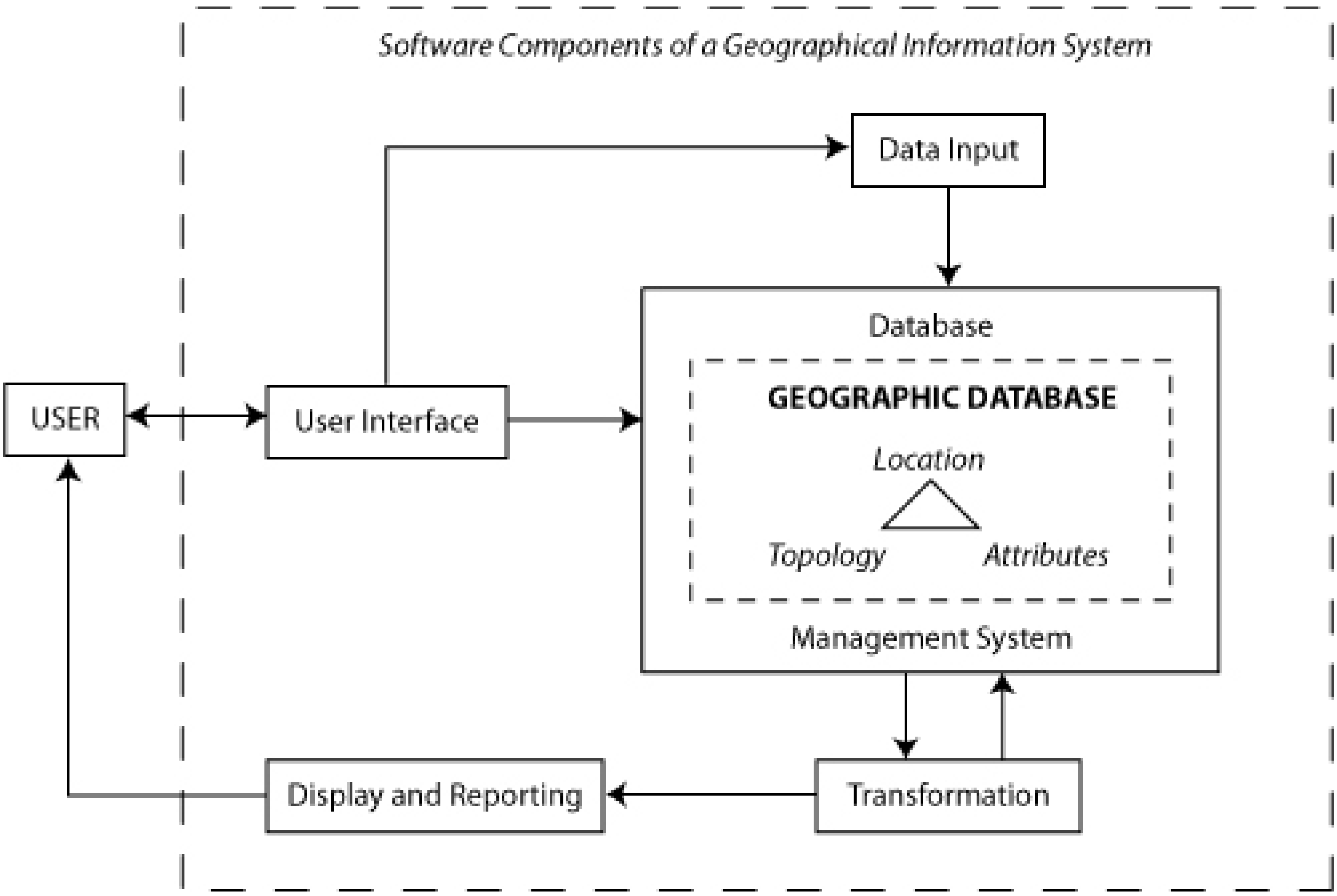

Figure 2 - Main Software Components of a GIS

Source: (BURROUGH and MCDONNELL, 1998)

The principal advantage of the GIS probably resides in its ability to easily geo-reference scattered data series in the same coordinate system through its database management system. Subsequently, it allows users to operate verifications between datasets. Then, with the help of spatial analysis techniques, data transformation functions provide effective ways of interrogating the system and building new data layers to answer a given problematic.

In fact, the setting up of a GIS is really productive when associated with spatial analysis. Linked to the school of applied geography, the objective of this tool is to describe a particular spatial organization, to unveil structure and to explain a particular localization in relation to another. Lastly, it aims at detecting in which way a simple localization can bring out the useful elements for a better understanding of the subjects studied and explain their characteristics in part or totally (PUMAIN and SAINT-JULIEN, 1997). By simultaneously processing topologic (localisation, shape, relations, reliance) and semantic components (meaning, properties, linked

thematic data) of geographical information, space will not only be seen as a support of information but also as an active dimension of the problematic via neighbourhood or proximity between the subjects studied.
Spatial analysis combines data transformations, handling, and every methodology to reveal the underlying structures. Lastly it transforms raw data into usable data and it is therefore an essential component of GIS exploitation. However, as we will see in the following chapters, geographical information systems are often reduced to « cartographical information systems ». This assertion indicates that a GIS is often used only for its cartographic capabilities than for its spatial analytical functions.

2. Increasing use of GIS in Social Sciences

Although it has reached a certain maturity in recent years, Geographical Information System is an ever-evolving technology with many disciplines benefiting from its technology. The GIS user community has grown considerably in recent years both in terms of application fields and countries in which it is used[6]. Recent developments in the handling of digital geographical information have especially created many new opportunities for socio-economic research. Although the principal applications of GIS first took place in the field of Agriculture and Environmental studies, where it is still very relevant, recourse to GIS in the social sciences has become very popular even if this phenomenon is fairly new (90's). Geography, Urban and Regional Planning have been among the first fields of applications but many others have now started to take advantage of these opportunities. One can easily identify subjects adopting GIS methodology in the social sciences including in Business Management, Market Analysis, Archaeology, Criminology, Sociology, Geo-demography, and Public Health[7].

The growing interest in GIS technology in the social sciences can also be observed when looking at major research projects, which are increasingly resorting to GIS technologies. Meanwhile, it seems relevant to note that if we look at these research programs using GIS in social sciences, we soon realise that this instrument is often used as a connecting media for a multidisciplinary approach, more than for its intrinsic capabilities per se. It is indeed an easy way to integrate multiple data sets. We could even say that it is often the underlying argument justifying the use of the term "multidisciplinary" in the titles to research program. However, one can question the efficacy of such use. Of course, the GIS capacity to manage geographical information could be sufficient as such; nevertheless it is the ground zero of GIS use. Proceeding as such, overlaying numerous data layers in a particular place to describe it with the use of a succession of thematic maps, the GIS could be seen as a kind of renewal of old monographs.

The situation at the international level is repeated in the Indian scenario. Indeed, as Karl Harmsen pointed out in a paper assessing the use of Remote Sensing (RS) and GIS in India[8], the sub-continent has an important Information and Communication Technology (ICT) sector, which is probably one of the driving forces of economic development in the country. As a part of the ICT sector, geoinformation technologies are being developed and applied in India even if their use is more recent than in developed countries.

Relevant to any organization or entity dealing with spatial information for monitoring, policy-making, planning or management purposes, geoinformation technology has an enormous application potential in India, from the central government to the local (Panchayats, Municipal

[6] (LONGLEY & Al. 2001) provide an interesting introductory text and (LONGLEY & Al 1999) a comprehensive review of the state of GIS art.
[7] For a good introductory text on socioeconomic applications, one can look at (MARTIN 1996).
[8] Karl Harmsen is the director of the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP), Dehra Dun, India. For more information on the use of GIS and Remote Sensing in India, see (HARMSEN 2004).

Corporations) level, in universities and Research and Development institutions as well as in the private sector or any non-governmental organization. Moreover, the level of skill developed in the country in the ICT sector enables India to develop powerful tools in this domain.

Geoinformation technologies are still strongly backed by a strong space program, which partly explains the profile of studies conducted in this field. Looking at the contents of major national forums and conferences dealing with this subject (**Table 1**), it is indeed not surprising to find that GIS is mainly used in the field of natural resource management (49%), followed by purely technological applications (21.2%). Urban and Infrastructure topics account for only 17% of the papers presented, with only 1.7% for Health related subjects and 5.4% for socio-economic subjects.

SUBJECT AREA	NUMBER OF ENTRIES	% of Total
Natural Resources	380	49
Water	117	15,1
Groundwater	*38*	4,9
Surface Water	*33*	4,3
Watershed	*27*	3,5
Irrigation	*19*	2,5
Agriculture	55	7,1
Geosciences	50	6,5
Soils	48	6,2
Forestry & Ecology	38	4,9
Environment	28	3,6
Marine & Coastal	27	3,5
Natural Resource Management	17	2,2
Technology	164	21,2
Technology (other)	113	14,6
Image Processing & Analysis	24	3,1
Database Management	15	1,9
Communication	12	1,5
Urban and Infrastructure	132	17
Urban Planning & Management	72	9,3
Transportation	42	5,4
Health	11	1,4
Power	7	0,9
Socio-Economics	46	5,9
Disaster Management	42	5,4
Education	11	1,4
TOTAL	**775**	**100**

Source: (HARMSEN 2004)

Table 1 - Subject-Wise Classification of Papers presented in major national Forums and Conferences on Geographical Information Systems and Remote Sensing[9]

3. GIS applications in the field of Health Geography

If we look at GIS applications in health studies at the international level, one can find only a few examples of GIS applications in public health, epidemiology, or health planning from the 1980's. GIS was gradually used by Western public agencies (particularly the federal government of the United States), which were the only ones able to bear equipment costs and possessed the most important databases (census, healthcare system statistics...). GIS consequently found its first "market" in epidemiology and environmental health, especially risk assessment. Indeed, given that environmental management was an early GIS application area, GIS data layers describing

[9] This table, made by Karl Harmsen, uses papers presented at the Map India (1998-2003) and ICORG (1997 and 2001) conferences, the national meeting of the Indian Society of Geomatics (2002) and the national conference of the Geospatial Information & Technology Association (GITA) in 2003. In addition, it uses papers presented by Indian nationals at some international conferences such as the Asian Conferences on Remote Sensing (ACRS) (1989-2002), Map Asia (2002) and the Asian GPS Conference (2001). (HARMSEN 2004)

environmental conditions were available to support these efforts (CROMLEY and MCLAFFERTY 2002). It is therefore not surprising that GIS has been used primarily by epidemiologists from the health sector, and only later by health geographers.

However, GIS can be a valuable tool for health geography. Indeed, a spatialised approach to health events offers an original angle for analysing the geography of a given space and studying the relations between society and territory. In a geographical posture, a health event is a central concept. It can be defined as any factor, in a given place, impacting upon the health condition of its population. A source of pollution, a new healthcare centre, a new medical practice, can be considered as health events. Being localizable in a specific place, health events can be structured as points, lines, areas, and flux on a territory and are therefore interesting subjects for a geographical study through GIS. Through identification and establishment of a hierarchy of risk factors influencing health in a given geographical context, health geography aims at analysing specific spatial combinations of these risk factors, either focusing on disease dynamics or health systems organization/pattern.

As geographers, we look at health events through the spatial dimension of risk factors and health problems. The purpose of a health geography approach is especially to reflect on the influence of place on health or on recourse to care, on the influence of healthcare system distribution on the spatial organization of health events. Lastly, it aims at unveiling the relations existing between spatial disparities of health events and spatial organization of identified risk factors.

When using a GIS, however, the researcher will observe society in relation to space alone. The underlying hypothesis is that geographical space plays a role in occurrence and localization of health events. Thus, concepts of localisation, distance or proximity, and their analysis through GIS can help in understanding disparities in health problems.

Globally, application domains expanded rapidly during the 1990's with growth accelerating in the 21st century. The hardware, software and database developments that took place over the last two decades partly explain this diffusion in the public health sphere.
Finally, GIS is now used in all fields of health geography, from medical geography to healthcare system geography or environmental epidemiology. Nowadays, analysing and mapping of public health based data is becoming increasingly important in the attempt to improve the performance of major public health initiatives and promoting community health.

Hence, GIS application fields can be broadly classified into six categories (CROMLEY and MCLAFFERTY 2002):

- Analysing spatial clustering of health events
- Analysing environmental hazards
- Analysing the risk and spread of infectious diseases
- Exploring the ecology of vector-borne diseases
- Locating health services
- Analysing access to health services

Since our paper focuses on healthcare system, let us go a little further on locating health services and analysing access to them.

i. <u>Locating health services</u>

An expanding field of application of GIS involves issues in health services planning. As the location of health services is a key factor affecting accessibility to care, the way we choose to model the distribution of health services directly influences the identification of poorly served areas. It consequently influences decisions about where additional health facilities should be

located. Location modelling techniques used in GIS take into account size, level of centrality, as well as threshold requirements or capacity constraints of health services to better plan the location of health services in a given space.
Recourse to normative models of facility location or service delivery methods in GIS is an effective way of planning health services location. These models are designed to identify the facility location or flows that maximize or minimize a mathematical function that expresses the objectives of the decision maker.

- Allocation models assume that facility locations are fixed and identify the assignment of patients that maximize or minimize the objective function;
- Location models seek the set of locations from among a set of candidate sites that maximize or minimize the objective function;
- Location-allocation models identify the optimal locations and assignments.

*ii. **Analysing access to health services***

GIS provides effective ways of documenting the geographic variations in access to health services. Access is a multidimensional concept denoting people's ability to use health services when and where they are needed (ADAY, ANDERSON 1981). Thomas & Penchansky identify five dimensions of access: Availability, accessibility, accommodation, affordability, and acceptability (THOMAS & PENCHANSKY 1981). Not surprisingly, GIS especially emphasizes accessibility, the geographical dimension of access. The accessibility concept is, in turn, closely linked to the framework of time geography. Indeed, the user's daily activity patterns in time and space remain key factors explaining recourse to health services.

Another fundamental aspect of health care utilisation patterns is distance decay, or the tendency of interaction with service facilities to decrease with increasing distance. The frictional effect of distance varies among health services. Studies reveal a pronounced decline in utilisation with distance for hospital-based elective. In contrast, acute emergency procedures show little or no distance decay. The role of geographic accessibility in service utilisation also depends on the characteristics of the population (demographic and socioeconomic characteristics). As Cromley & Mc. Lafferty point out in their book, "location and distance have significant effects on people's willingness and ability to use services, but these geographical effects vary in importance and meaning among places, populations, times, and individuals. In emphasizing the spatial aspects of accessibility, GIS can easily hide or ignore its important social dimensions. This means that particular care needs to be taken in structuring GIS-based access studies and interpreting the findings" (CROMLEY and MCLAFFERTY 2002).

A first step in analysing access to health services in a GIS is to map service locations. However, service location information is particularly relevant when analysed along with data on health care needs[10]. Typically, health planners use a combination of demographic, socioeconomic, and health outcome indicators, both quantitative and qualitative, in defining need.
Assessing potential access to health services can be implemented in many different ways in a GIS. One of the simplest ways is to calculate the average distance between the population needing the service and appropriate service providers. A further step could be to examine the frequency distribution of distance to that service provider. Recourse to the widely used "gravity model" and associated models is also often noted as a method for predicting flows of people to health services.

[10] "Need" denotes the prevalence of health conditions that should be addressed by health care services. It can be measured and analyzed in many different ways. Need regroups two dimensions: a quantitative dimension called "effective need" and a "perceived need", its qualitative counterpart. Note that when examining need for particular health care services, characteristics of the service may be important, as services may be targeted at particular population groups or restricted to individuals who meet certain eligibility criteria. See (CROMLEY & MCLAFFERTY, 2002).

The alternate posture taken when analysing access to health services is to focus on revealed accessibility to services, that is, patterns of health services utilization. This implies obtaining datasets on effective use of the services. In a GIS, revealed accessibility can be assessed, identifying service areas (or “catchments areas”) and comparing them with the mandated service areas.

Another step forward from these descriptive approaches is to address the determinants of service utilization pattern through the use of spatial interaction models. These tools describe and explain the movements or interactions between places as a function of distance and others factors. Within these models, we find especially origin-constrained models (FOLLAND 1983) and destination-constrained models, according to the way the health care system is planned[11]. These models remain valuable tools for public health analysis.

4. GIS and Health: The Indian Scenario

Looking at the Indian picture, table 1 has showed that the use of GIS in health sector remains marginal compared to other ones. In fact, the use of GIS in health studies is a recent phenomenon. Consequently, all sectors of health studies are not equally represented and application domains still remain closely linked to epidemiology and environmental health[12]. Many projects are actually mushrooming on these themes[13]. In the case of urban studies, these projects are often linked to the emerging concept of “sustainable/healthy cities”[14].

Not much work has been done on health service location and access analysis.
In the rural context, we can especially mention the work of N. Kumar (KUMAR 2004) who used the location/allocation models to examine the changing geographical access to and locational efficiency of basic public healthcare vis-à-vis private healthcare services in two districts located of Haryana. He further examines the factors that govern their geographic accessibility and locational-efficiency. Using these techniques, he demonstrates that if geographic access to Public Health Centre (PHC) has improved substantially from 1981 to 1996, there is no indication of any improvement in the locational efficiency of PHCs despite a significant increase in their number.
In Delhi, the Directorate of Health Services decided to use a GIS to map all registered health facilities. In view of such an impressive effort, it is therefore surprising to note that the use of this tool takes the form of merely locating health facilities on a map, without any further applications or analysis. Hence, it seems that the GIS is perceived as a marketing tool rather than an analytical tool for public agencies. We hope that this is only a first step towards further applications. In fact, the infrequent use of GIS observed in urban areas going further than the mere mapping of healthcare infrastructure’s locations is partially explained by the fact that many measures to evaluate health events lose their meaning with regard to intra-urban areas. In a recent paper on accessibility to primary care, M.F. Guagliardo highlights how the most popular

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[11] Origin-constrained models have been extensively used in the USA for health care planning. They are based on the assumption that interaction with health care facilities results from decisions in which people compare available facilities and select the one that best fits their need. On the contrary, destination-constrained models assume that the total capacity of each facility is fixed, each one serving a fixed number of customers. These types of models have been widely used in Great Britain where health care is centrally planned and financed and where planning authorities often dictate the capacities of health care facilities.

[12] This statement is largely accepted in the Indian GIS community. For further details, see Map India and Map Asia Conference reports (2003-2004). http://www.gisdevelopment.net

[13] To get an idea of the impressive number of studies conducted in this field, see for example the number of Indian contributors in a conference such as the one recently organized by the International Geographical Union Commission on Health and Environment on “Emerging Issues in Medical Geography”. (August 11th-15th 2004, IRSEE, Germany).
http://ww.geographie.uni-muenchen.de/geomed/pdf/IGU%20Pre-Conference%20Meeting_programme.pdf

[14] See for example projects conducted by Prof. S. Aggarwal (Delhi University) & Dr. T. Kraft (Munich University) on Delhi. A forthcoming project on Chennai is undertaken by IFP and IRD.

measures on spatial accessibility to care (travel impedance to nearest provider and supply level within bordered areas) lose validity in congested urban areas (GUAGLIARDO 2004).
More generally, in the field of public health management, one can hardly find any effective implementation of GIS technology. However, a particularly successful example of such implementation is the Spinfo Healthmap. This project was realized for Karnataka Health Systems Development Project (KHSDP). Its objective was to implement a customized GIS application, which would be an interactive spatial analytical tool enabling Health Officers to reshape, re-locate health jurisdiction for effective utilization of the health infrastructure. Compared to what has been done in Delhi, this system already contains attribute data up to the village level relative to infrastructure, personnel, supply and diseases. Such an integrated state-level health information system is a good example of application for public health management, even though we have not been able to check in the field up to what extent this system was used by the administration.

Apart from these applications focusing on health, and coming back to the broader domain of the social sciences, we should mention the South India Fertility Project (SIFP) project. Indeed, this project totally merges with our approach on GIS use. Coordinated by C.Z. Guilmoto, this titanic project was the first to propose a large-scale database mapping the Census of India datasets down to the village level for the whole of South India. Moreover, its field of application has not been limited to its initial aims (study of fertility) but has been extended to vary thematically through its reutilization by other researchers working in this area[15].

5. Constraints in the use of GIS in Social Sciences and Health Studies

Despite the increasing use of GIS in health studies, many constraints still remain and may appear when designing and using a GIS on health. One can identify two main constraint categories: data constraints and GIS constraints. Note that these constraints are not specific to health geography and may appear in any project using a GIS.

i. Data Constraints

Data constraints are the most challenging constraints to work around when setting up a GIS. As Albert, Gesler and Wittie point out in an article (ALBERT, GESLER & AL 1995) GIS still suffers from what they call the “4-I rule”: Intensive, Inaccurate, Inaccessible and Incomplete. In order to restrict the unavoidable inaccuracy of a system that seeks to simplify reality through modelling, one must intensively feed the system with fresh datasets. Indeed, the processing power of such a system partly comes from data wealth. Now, datasets are often inaccessible, inaccurate or simply incomplete. This is particularly true in the field of health where data confidentiality is rather important[16]. Hence it is almost impossible to get data relating to individual-level health behaviour and consumption patterns in health geography research. We will see below that data mining in India is not an exception to this assumption.

Furthermore, even when accessible, datasets must be available in scale and temporal settings adapted to the project’s problematic and methodology.
Although the GIS manages the question of scale in spatial continuity[17], thematic data is often dependent on administrative divisions, which are on the contrary not spatially continuous. When working on the GIS, this obliges us to choose perception levels adapted to the scale of studied spatial units. (**Figure 3** - Cartographic Scale & Perception Level

[15] To get an idea of the diversity of research projects relying on this tool, see (GUILMOTO, OLIVEAU & AL 2004).
[16] On data constraints and confidentiality, one can refer to J.R. OPPONG’s paper presented at a workshop on “Health Research Methods and Data”, Finland 22 - 25 July, 1999. The document is available on following weblink: http://geog.queensu.ca/h_and_e/healthandenvir/Finland%20Workshop%20Papers/OPPONG.DOC. Another interesting analysis on data constraints in the field of GIS and social science can be found in (O’SULLIVAN 2004)
[17] If we speak about Scales in cartography, we speak about Perception Levels in GIS.

Source: (Roudier-Daval, 2004). For instance, studying intra-urban socio-spatial segregation requires socio-economic datasets dividing the city into spatial units small enough to disclose intra-urban social discontinuities. The wider a spatial unit the bigger is its internal heterogeneity. Statistically speaking, although we can easily compute the variance of a variable for a set of spatial units, we rarely know the variance of observations aggregated in one given spatial unit. Thus, mapping spatially aggregated data such as census administrative divisions can disguise the spatial organisation of the phenomenon studied. However, as we will see below, with the help of some methodological tools, namely the play of scales and data exploratory analysis, it is possible to work around these problems.

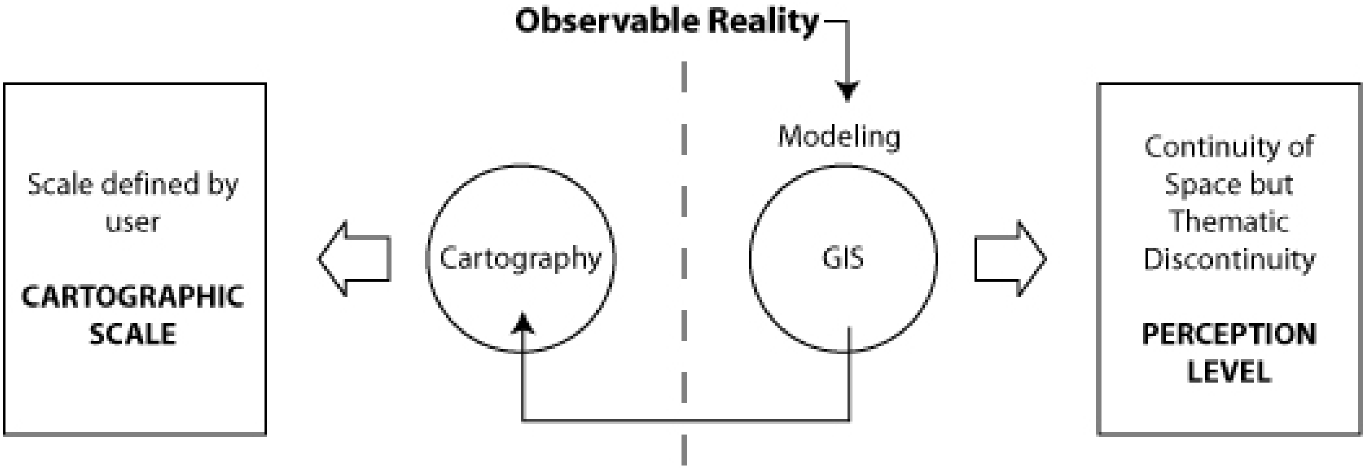

Figure 3 - Cartographic Scale & Perception Level

Source: (Roudier-Daval, 2004)

Moreover, another problem appears when playing with several datasets coming from different sources. Indeed, datasets are rarely available with the same spatial extent and divisions. In that case, combining data layer information is not a straightforward manipulation.

The difficulty to find adapted datasets compels users to resort to specific methods of data processing to ensure data layers compatibility. Then, constraints related to GIS functions may quickly appear.

This leads us to the second kind of constraints that come from GIS themselves.

ii. GIS Constraints

To start with, the GIS development that took place in recent years being largely explained by demand in terms of service location, GIS has consequently been used primarily for its spatial test abilities rather than for its modelling and analytical potential. This trend has led GIS companies to develop dedicated utilities to the former at the expense of the latter. Thus, GIS still lacks many functions, especially statistical ones. Users often have to resort to external statistical analysis software in order to compensate for this shortage. This can cause problems because these packages rarely take space into account. Now, spatial statistics do not make the same assumptions that classic statistics do. If in statistics the population is a set of individuals, its equivalent in geography is the space being studied, considered as a set of spatial units (or “mapping units”). Now, using statistical analytical models requires studied populations to comply with a few basic properties rarely found when working with spatial units: these populations are supposed to be homogeneous (i.e. any subset must be a representative sample of the whole population); each individual must be independent (i.e. knowledge of a variable’s value is not suppose to inform us about the value of another variable). These assumptions are not met

when working with spatial units because of the underlying spatial structure. Thus, using an external statistical package to select a sample for an in-depth study, for instance, can lead to the selection of a wrong sample, by ignoring constraints emanating from spatially organised data. These constraints are summarised in a concept called "spatial/temporal autocorrelation": for a given variable, there is a link between values of nearby individuals in space and time because of its spatial structure. This means that values are not distributed randomly in space. Geography exists only because spatial autocorrelation exists. This implies measuring the degree of spatial autocorrelation of a phenomenon before using statistical models.
It is unfortunate, however, that basic tools dedicated to spatial statistics, and particularly data exploratory analysis, are still often missing from GIS software.

Secondly, even when these systems are used with full knowledge of their possibilities, the misuse of GIS potential can easily give wrong results and false interpretations. One of the most common mistakes involves the overlaying functions, which often lead to what we call the "ecological fallacy"[18].

Lastly, even when used with care, the results themselves can be misunderstood. GIS provides many tools to easily and quickly draw series of maps. When mapping two variables, for instance, an observed spatial correlation can be interpreted as a causal relation, which is not necessarily true. This simplification, brought about because of insufficient knowledge of spatial statistics, can lead to wrong interpretations and decisions. Generally, the "spatial illiteracy"[19] of users associated with the visual power of a map (convincing power, synthesising power and consecutive clarity illusion brought out by the simplification of a complex reality) remains a major constraint in the use of GIS and maps by non-specialists. Finally, it is the loss of connexion often noticed between the realisation and making of a decision which generates bad interpretations.

The above constraints partly explain actual GIS applications in the social sciences and health studies. GIS still remains a tool often used only for its geographical information management capabilities. It is true also that the lack of documentation and awareness of the scope of GIS has probably led users to underestimate and consequently under-exploit GIS technology.

iii. The Indian Scenario

The constraints exposed above are of course present in India and partly explain the small number of health research projects using GIS.

The Indian situation is in fact quite paradoxical regarding data availability. Indeed, on the one hand India is an important producer of statistics inherited from the colonial period. On the other, these statistics are not easily accessible, especially when looking for detailed data. As soon as statistical information below the district level is needed, it becomes very difficult to procure it.

Let's have a brief look at the main sources of statistical data:

Related to population (demographic, social and economic aspects):

- Census of India: Since the 1991 census, almost all the census datasets are available in digital format down to the village level in rural areas and down to the charge/ward level in urban areas. The range of data is broad, from demography, religion to economics, amenities and education. Even if one has doubts about the quality of the survey, it remains the most exhaustive source of data and the only survey covering the entire

[18] Well known to social scientists, the ecological fallacy refers to the impossibility or extreme difficulty of making inferences about individual behavior from data about aggregates. This problem is a sub-set of a larger issue that is common in spatial analysis: the Modifiable Areal Unit Problem (MAUP). For further details see (WEEKS 2004).
[19] Expression used by Kamel Boulos in (KAMEL BOULOS, ROUDSARI 2001).

country and all the population. We should also highlight a very interesting initiative taken by the Census of India, namely the website "Census GIS India"[20], which allows users to interactively map any census 2001 data at the district level (from Housing, Amenities and Assets Data Tables).

- NFHS data: First National Family Health Survey (NFHS-1) conducted in 1992-1993. NFHS-2 conducted in 1998-1999. NFHS-2 is designed to facilitate implementation and monitoring of population and health programmes in the country. It presents state and national estimates of fertility, the practice of family planning, infant and child mortality, maternal and child health, utilization of health services provided to mothers and children. In addition, the survey provides indicators of the quality of health and family welfare services, women's reproductive health problems, domestic violence, status of women, education and standard of living, measurement of the nutritional status of women[21]. However, data is not available at a sufficiently small level for integration with a GIS, especially when working in an urban agglomeration. In Delhi, despite a sample size of 2763 households, 2477 women and 820 children interviewed between March 1999 and April (carefully selected in the city through stratified sampling in select representative census charges, enumeration Blocks and households), data have been aggregated in two categories only, i.e. rural Delhi and urban Delhi.
- NSS data: With regard to household consumption. Again, no data is available at the intra-urban level. Even, the NSS does not take samples from every Indian district. There are NSS regions, which are intermediate units between districts and states[22].

Related to Healthcare infrastructure:

- Central and State governments maintain lists of public health infrastructures. It is unfortunate however that a description of these infrastructures is often missing or available only for few of them, thus avoiding generalisations. For instance, the Ministry of Health has admitted that there is hardly any upward transmission of information from approximately 24,000 Primary Health Centres (PHCs). The Ministry is dependent entirely on newspaper reports for information and assessment during the outbreak of diseases in many parts of the country. It has been found that it takes nearly a year for information to travel from the PHC to the Ministry. The government has concluded that such disease surveillance is meaningless and its data was only for the consumption of government files[23].
- For private infrastructure, listings can be found in various agencies (public and private). However, listings are often incomplete. For instance, a study conducted in Delhi by the Directorate of Health Services (Government of NCT Delhi) revealed the existence of 1603 illegal nursing homes operating in the city. These nursing homes are not registered with the government and do not have even a licence to operate[24]. The same is true of private practitioners. In the case of medical shops, even if registered by the pharmacy council, the listing is not yet fully computerized.

Many government agencies are finally providing datasets on various subjects, which could be valuable tools for GIS development. However, lack of coordination between agencies often leads to data wastage.

As mentioned by C.Z. Guilmoto and S. Oliveau about statistics in India: "From the census, which provides village-level data every ten years, to the large surveys such as the National

[20] See http://www.censusindiamaps.net
[21] For a full explanation on data availability, sampling methods and results, see International Institute for Population Sciences (IIPS) and ORC Macro. 2002. National Family Health Survey (NFHS-2), India 1998-99: Delhi. Mumbai: IIPS. Note that datasets are available through http://www.nfhsindia.org
[22] For further information about NSS unit sizes and about the ways one can match these data with census data, see (MURTHI, SRIVANASAN & AL 1999).
[23] Information found on "GIS development", Ravi Gupta. (http://www.gisdevelopment.net)
[24] For further details, see Times of India, New Delhi, 14th March 2003.

Family and Health Surveys (dating from 1992 and 1998) or those of the National Council for Applied Economic Research, the statistical data in India cover almost all demographic, social and economic aspects of the society. Notwithstanding this apparent profusion, precise geographical utilization and cartography on a small scale are still rare, or indeed nonexistent." (GUILMOTO, OLIVEAU & AL 2004).

This situation is in part explained by a woeful lack of accessible and accurate map coverage.
The principal source remains the *Survey of India* that provides topographic coverage at different scales for the whole of India. Data dissemination remains highly controlled and thus it is very difficult to obtain full coverage for a given area[25]. Moreover, many maps are outdated or simply unavailable. This is particularly problematic when working in urban areas. For the main big Indian cities, we should underline the recent entry of private companies that have undertaken the publication of detailed maps, such as the Eicher Delhi City maps[26]. The latter provides thematic coverage on a digital format, but the cost remains prohibitive at least for small research programmes. Furthermore, even if their digitalisation is based on the use of remote sensing imaging and fieldwork investigation for data verification, the quality still has to be checked, particularly with regard to georeferencing and exhaustiveness of thematic layers.
Another important source is of course the Census of India because of the publication of their District Census Handbooks, showing location of all towns and villages with administrative boundaries corresponding to each census unit. However, the quality of these documents is very poor. Georeferencing is missing and boundaries are approximate. Again, recent change in the data dissemination policies of the Census of India and its plan to facilitate their accessibility are making things move very quickly. It is more than likely that we will be able to get accurate maps in the coming years[27].

This brief overview of constraints in the use of GIS, illustrated through the Indian example, has highlighted the inherent difficulties in building and exploiting a GIS in a developing country such as India, especially when working in the field of health and, furthermore, when focusing on the intra-urban problematic. In order to do so, it clearly appears that there is a need for users to resort to specific tools and methodologies to work around these problems. This will be, in part, the purpose of the next section.

[25] As explained by GUILMOTO C.Z. and OLIVEAU S., "Survey of India, created by the British, is a derivation of the military administration. The map was a strategic object and its public diffusion was prohibited until the beginning of the nineteenth century. Still today, the production of maps is a matter of the state, and a series of places held to be sensitive continues to be excluded from cartography, among which are hydroelectric projects, dams, steel plants, installations under All India Radio, telecommunication installations and water purification/supply installations, etc. Moreover, for a coastal strip of more than 50 km inland, the obtaining of maps classified as "restricted" is subject to special requests to the administration of the Survey of India". (GUILMOTO, OLIVEAU & AL. 2004)

[26] At the time of publication of this paper, only Delhi, Chennai, Bangalore and Mumbai maps are available.

[27] Recently, the publication of the CD-Rom entitled *CensusInfo India 2001* opened the way. It helps in presenting and analysing census data through a variety of presentations and scales in the form of maps, tables and graphs. For further details, see http://www.censusindia.net

RESEARCH POSTURE, METHODOLOGY AND SETTING-UP A GIS

1. Research Posture of the Project: Towards the Complexity Approach

To start with, it would be relevant at this point to note that this GIS has been primarily developed in the context of a health geography research project on access to pharmaceuticals in Delhi[28]. At that time, the purpose of implementation of such a tool was manifold:

Firstly, at the beginning of the project in January 2002, there was an acute lack of documentation precisely describing the spatial organisation and functioning of the city. The study on socio-spatial differentiation and residential segregation[29] conducted by V. Dupont was one of the rare examples of such studies. Thus, integrating detailed census data in a GIS was a first step to better assess socio-spatial dynamics taking place in the Indian capital. Furthermore, the idea of comparing the recently released census 2001 datasets with already available census 1991 datasets was clearly a very promising way to obtain a dynamic picture of the city, which has not been attempted till now.

Secondly, in order to work on access to pharmaceuticals and more generally on health topic as geographers, it was necessary to set up a spatial database enabling us to visualize the spatial settings of healthcare infrastructure in the city and its periphery, identifying actors, their localisation and spatial organisation. Furthermore, cross-checking this layer of information with census data was seen as a way to better understand the location strategies of healthcare system actors. In the field of health geography, our posture was thus essentially to rely on the spatial analysis of healthcare infrastructure locations as presented in the first part of this paper.

Thirdly, given the two above-mentioned objectives, this tool seemed to be a very promising one for sampling purposes:

- To select samples of health infrastructure, in particular those distributing medicines, for our fieldwork survey according to their location in the urban agglomeration;
- To select urban areas according to their profile (socio-economic, demographic, as well as according to the healthcare delivery system) for further investigations (survey of households);

As soon as we started conceptualizing our spatial database, given the variety of data available in the census database it was soon obvious that it could be very useful for any researcher working on Delhi, particularly in the field of social sciences, urban development, or health studies. This led us to design this GIS in order to ensure that it could be re-used. Moreover, as we have seen above, since the main limitation in the use of this kind of tool in the social sciences often stems from the difficulty to feed the system with data, we also had to ensure that it could be quickly updated and completed with fresh datasets coming from other research projects. This led us to base our databases on a common georeferenced framework and to develop tools for easy updates[30]. Besides, the inevitable imperfections of datasets led us to resort to methodological devices to check the bias generated by relatively poor data quality.

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[28] As part of a PhD research project conducted by P. Chapelet, University of Rouen (France) and Centre de Sciences Humaines (India).

[29] See (DUPONT 2004).

[30] As explained in one of the following sections (Part 2 - 3.i.b), one of these tools is a GIS layer helping researchers to geocode their datasets (such as personal surveys). This layer now includes 2300 localities or locations, not only in the National Capital Territory, but also in the ring towns (Ghaziabad, Faridabad, Noida, Gurgaon, Loni, Bahadurgarh). This layer is constituted of georeferenced punctual entities located at the geometric centre of each locality/location.

This conceptual approach adopted when designing our tool has led us to a broader research posture relying on the emerging concept of complexity. Indeed, contemporary epistemology compels us to take into account the complexity of the world globally. As explained by H. Chamussy, during the last decades, a majority of scientists abandoned positivism, independently of their research domain, to enter the new paradigm of complexity[31] (CHAMUSSY 2003).

In this approach to complexity, cartography has always been one of the most convenient ways to represent the geographical space and the world surrounding us. The human response to the not easily understandable complexity of the world often consists of breaking it down and making it simpler through simplified and intelligible representations. These representations can be maps. One could say that breaking down a complex object such as a city into a series of maps typically resembles a positivist research approach. On the contrary, we feel that such an approach helps in understanding and representing the complexity of a research subject.

As pointed out in an article published in Cybergeo (ANTONI, KLEIN & AL. 2004), if we look at the evolution of cartographic sciences this research posture is at the heart of its most recent developments. After an initial period known as “topographic cartography”, where maps were tools to accurately represent the physical space, a second period emerged, called “thematic cartography”, where cartographers tried to superimpose phenomena which were taking place, on it. Maps were mostly pictures illustrating the spatiality of the phenomena studied. Nowadays, a new approach is emerging, which not only attempts to represent our world, but also tries to reveal phenomena which are not directly visible, or which are badly perceived. Moreover, it aims at better studying spatial structures organizing the world. The idea is to multiply views and representations of the subjects studied through an in-depth active exploration of the dataset’s spatial structures.

This emerging approach through complexity relies on different methodological tools used in cartography that we will now introduce namely the Contextualization Concept and the Exploratory Data Analysis.

2. Methodology: From GIS to Cartomatic and Exploratory Data Analysis

a) *The contextualisation concept and the play of scales*

As seen above, the integration of spatially organised datasets in GIS constrains us to use a perception level of analysis adapted to the scale of the spatial units studied.
This constraint is in fact a crucial point in cartography, which can be positively used in our research posture. One assumption in geography says that each scale unveils a given spatial organisation of a phenomenon: a change in scale leads to a change in the perception level of a phenomenon and consecutively reveals several levels of its spatial organisation. For instance, a concentration appearing at a given scale can, in fact, be seen as a uniform distribution at another scale. Hence, by choosing several perception levels corresponding to the relevant working scales (i.e. adapted to the scale of available datasets), the researcher can work around the thematic discontinuity of GIS datasets and unveil new dimensions of the subject studied.

This leads us to the contextualisation concept. Here also, the idea is that a phenomenon can be properly analysed only if studied at different scales in order to understand in which context its spatial organisation takes place. Furthermore, one can work around the problem of data weakness (limited accuracy or limited spatial range) when a dataset is contextualised using

[31] For further information, see the European Programme MCX “Modélisation de la compléxité”. (http://www.mcxapc.org/)

other working scales, themselves unveiling other levels of spatial organisation. The results of a study at a given scale will reveal a trend in the spatial organisation of a phenomenon which may or may not be confirmed when contextualised with other scales.

In turn this implies an answer to two questions (SANDERS 2001):
- What are the adequate perception levels to answer a given question?
- What are the available bridges (semantic and methodological) between each perception level?

Answers to these questions can easily come from the context of the space studied, namely Delhi, and from the subject of the study, namely the healthcare system organisation.

After taking the decision to set up a GIS in Delhi, an important question arose: What is Delhi? What is the spatial definition of Delhi? Where are Delhi's borders? These questions were very important at time. They had a deep impact on our methodology and the way we developed our GIS.

What is Delhi? Is it the Urban Agglomeration defined by the Census of India? Then, what about the rural area where peri-urbanisation is going on? Is it the National Capital Territory (NCT) of Delhi, which includes this rural area? This administrative unit is maybe the most convenient, but can we then leave Delhi's ring towns such as Faridabad, Ghaziabad, Gurgaon and Noida? The Delhi Metropolitan Area (DMA)[32]? The NCRPB[33] itself had difficulties in specifying for us the exact spatial definition of this urban development area. Should we then have to consider the National Capital Region (NCR) itself?

It quickly appears that there is no clear answer to what is Delhi as a geographic object. It does not only depend on the research topic; it also depends on the sources of information tapped: The definition of Delhi as an Urban Agglomeration used by the Census of India is different from the one used by the NCRPB.

The definitions, even when they pretend to be most scientific and realistic, are sometimes not put into practice. The Census of India defines an Urban Agglomeration[34] as an aggregate of census towns and outgrowth areas (OG). Firstly we can criticize each criterion defining a Census Town[35]. In the case of the Delhi Urban Agglomeration this definition is not respected.

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[32] The Delhi Metropolitan Area (DMA) is a tool for planners and consists of the National Capital Territory of Delhi and the first ring of towns around the capital plus their rural hinterland.

[33] The National Capital Region Planning Board was constituted in 1985 with the mandate for preparing a Plan for the development of the National Capital Region and for coordinating & monitoring the implementation of such a Plan.

[34] Urban Agglomeration: Urban agglomeration is a continuous urban spread constituting a town and its adjoining urban outgrowths (OGs), or two or more physical contiguous towns together and any adjoining urban outgrowths of such towns. Examples of Outgrowth are railway colonies, university campuses, port area, military camps etc. that may have come up near a statutory town or city but within the revenue limits of a village or villages contiguous to the town or city. For the Census of India, 2001, it was decided that the core town or at least one of the constituent towns of an urban agglomeration should necessarily be a statutory town and the total population of all the constituents should not be less than 20,000 (as per 1991 Census). With these two basic criteria having been met, the following are the possible different situations in which urban agglomerations could be constituted.

i) a city or town with one or more contiguous outgrowths;
ii) two or more adjoining towns with or without their outgrowths;
iii) a city and one or more adjoining towns with their outgrowths all of which form a continuous spread

[35] The classification of an area as an urban unit in Census of India 2001 is based on the following definition:

1. All places declared by the state government under a statute as a municipality, corporation, cantonment board or notified town area committee, etc.

2. All other places which simultaneously satisfy or are expected to satisfy the following criteria:
* A minimum population of 5,000;
* At least 75 per cent of the male working population engaged in non-agricultural economic pursuits: and
* A density of population of at least 400 per square kilometre (1,000 per square mile).

Indeed, towns like Noida, Gurgaon, Ghaziabad or Faridabad, which are in a continuum with the Delhi Urban Agglomeration, and which should therefore belong to the Delhi Urban Agglomeration, are not integrated with it and constitute their own Urban Agglomeration. In fact, political norms prevail over the technical and "classical" definitions of towns and urban agglomerations. There is always a gap between physical realities of an urban agglomeration, the way the citizens are living in it and the political and administrative ones. These realities do not have the same spatiality and each of them even has a changing spatiality when taking temporality into account. Political territories are always trying to catch up with the territories created by citizens but it takes time and the political context sometimes makes it impossible to achieve[36].

To be independent from these unending questions of borders, we decided to develop a multi-scalar approach, designing our system in order to be able to easily contextualise findings at local scale in larger dynamics. All definitions of Delhi are relevant. Delhi is an urban agglomeration, a Union State, but also a fast growing metropolis at the head of a dynamic region. The multiplication of scales and angles could be of real help in visualising and catching the complexity of the objects studied on. In order to do so, we developed the following four databases corresponding to four perception levels of our research objects, namely Delhi and the Healthcare system:

- The National Capital Territory perception level;
- The Delhi Metropolitan Area perception level;
- The Urban System in North West India
- An example of a large-scale[37] perception level: Gurgaon.

The last part of this chapter will present each of these databases.

b) Cartomatic and Exploratory Data Analysis

In order to facilitate contextualization and visualization of the phenomena studied, using cartomatic processing of statistical variables, especially exploratory data analysis, can be very interesting.

Cartomatic is the whole set of mathematical and graphic procedures that translates the spatial variation of a statistical variable on the map. In this context, new developments in statistics have opened new ways for the analysis of spatial data. Exploratory Data Analysis[38] (EDA) is particularly relevant when dealing with big datasets and helps in manipulating and modelling complexity.

EDA is a way, even a philosophy, of data analysis, which uses numerous techniques (mainly graphic ones) to reveal the underlying data structure, to extract important variables, test hypothesis… Conceived by a statistician called J.W. Tukey, EDA is a way of data analysis, which uses numerous techniques (mainly graphic ones) to reveal the underlying data structure, extract important variables, test hypothesis… Rather than searching at all cost appropriateness to classical statistical tests, EDA is indeed an intuitive approach consisting in scrutinising datasets in order to find what is happening in data series without a priori. This radiography is often done through maps, creating customized visual representations of the phenomena being studied. Furthermore, this approach attempts to take into account statistical anomalies or

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As in the past censuses, well-defined outgrowths (OGs) of statutory towns have also been included in the extended urban area. Any area, which is not covered by the definition of urban, is rural.

[36] For a review of the difficulties to conduct demographic analysis of urbanization processes using administrative limits in metropolises such as Delhi, see (DUPONT 2003).

[37] Large-scale has to be understood from a geographical point of view, meaning "a zoom on a small area: Gurgaon".

[38] For an in depth view of Data Exploratory Analysis, see (CLEVELAND 1993).

extreme cases considered as aberrations because they do not conform to the "laws of statistics". Finally EDA establishes a real closeness between the analyst and his data.

Through an increase in the number of views, the researcher not only tries to choose a representation amongst a set of solutions, but also favours the emergence of hypotheses regarding the underlying spatial organisation of the phenomena studied. EDA finally appears as a kind of Interactive System of Thoughts Assisted by Computer (ANTONI, KLEIN 2003).

The following table introduces a broad view of the main characteristics of Exploratory Data Analysis, compared with the classically used Confirmatory Data Analysis.

Exploratory Analysis	**Confirmatory Analysis**
Descriptive Approach	Inferential Approach
Robust Statistics	Sensitive Statistics
Flexible Research Program	Rigid Research Program
Graphic Expression	Numerical Expression
Intuitive Vision	Deductive Vision

Source: (WANIEZ 2002)

Table 2 – Comparison Criteria between Exploratory Data Analysis and Confirmatory Data Analysis

Graphic expression remains the key factor of such an approach. However visualisation is not limited to the simple representation of a given data. Indeed, many classical statistical tools are used to help visualize the data. Amongst the methods used to process statistical variables[39], we can mention:

- Factor analysis;
- Hierarchical Agglomerative cluster analysis;
- Linear regression and Scatter plot analysis;
- Spatial autocorrelation coefficients such as Moran and Geary coefficients.

To conclude our research posture and methodology, we use GIS only as a starting point for spatial analysis and Exploratory Data Analysis. GIS, as a tool for managing geographical information, merely enables us to quickly update datasets and add new data layers. Regarding EDA, GIS does not allow us to do in-depth exploration. As seen in part one, GIS still lacks many functions. Thus, we had to rely on specialised software[40].

3. Presentation of selected Perceptions levels: objectives, sources and results

In this part we present perception levels selected to approach the subjects being studied, namely the Delhi agglomeration and the Delhi healthcare system[41].

The selected perception levels are presented in their order of conception:

- National Capital Territory of Delhi;
- Delhi Metropolitan Area;
- Gurgaon: an example of large scale perception level;

[39] As this is not the place to go into the details of such methods, the reader can consult some books for further explanation of these statistical tools in (SANDERS 1990) for example. A good introduction to such methods can be found on http://www.epa.gov/bioindicators/primer/multivariate.html

[40] In fact a very powerful software exists in order to apply these analyses. We would like to highlight one developed by a French geographer. This software, called Philcarto, has the enormous advantage of being freely downloadable for research purposes. For further details and to download Philcarto, see http://perso.club-internet.fr/philgeo/

[41] In the following section, each perception level is presented as a standalone GIS. However, georeferencing guarantees the link between each perception level, whose aggregate could be considered a GIS as such.

- Urban System in North West India.

For each of them, we will first describe the primary objectives justifying their conception. We will then present cartographic and statistical sources used and the consecutive limitations, and lastly present results and current applications as well as possible future developments.

i. National Capital Territory of Delhi

a) GIS objectives

The National Capital Territory GIS was the first to be developed in January 2002. It was primarily set-up to map the accessibility of health infrastructure for the distribution of medicines. Where is the infrastructure (hospitals, nursing homes, dispensaries, chemists) that distributes pharmaceuticals located in relation to the population? The accessibility of healthcare is in fact a crucial issue. Of course, in urban areas cost limits access to healthcare and pharmaceuticals more than physical distance does. But space still matters given that the distance to health infrastructure generates a movement, which in turn affects cost. The spatial organisation of health infrastructure can also reveal some interesting aspects of a territory, especially an urban one. Why a dispensary is located at this specific spot? Does its location correspond to the spatial settings and dynamics of the agglomeration? Does it reflect planning policy?
Of course, GIS as such cannot answer this kind of question. However it may guide us to make our questions more pertinent by better understanding the spatial organisation of the context in which this health infrastructure is found. Moreover, in order to move from the concept of accessibility to access, which implies scrutinizing the effective use of infrastructure, we needed to select a sample of health infrastructure. Instead of using a random selection method, GIS was also supposed to help us selecting specific areas and infrastructure for more in-depth field research.

b) GIS sources

Maps from the Survey of India were used as a starting point. Indeed, they have the advantage of being spatially georeferenced. However, it was rather difficult to find up-to-date maps with a common scale. If most of the urban agglomeration has been covered using 1991 maps with a scale of 1:25 000, as we were digitalizing further and further away from the centre, we were forced to use older maps dating back to 1975 drawn to a very small scale (up to 1:100 000). Keeping in mind the rapid growth of Delhi, these maps of course become quickly obsolete, particularly the periphery.

We also digitalized the main roads, railways and canals. These last layers were particularly useful for digitalizing the census spatial units, which were using these features as borders. First we digitalized the 1991 census urban charges and villages. Unfortunately, some borders between the rural areas and the census urban charges did not match. We solved the problem by merging a few spatial units. The problem of compatibility between rural and urban census units lies in the statistical tables. The infrastructure tables presenting data on the availability of amenities in villages and the Census Town do not have the same structure. Some information given in the village infrastructure table is not available in the infrastructure table of a Census Town. For example you can know the number of financial institutions (banks, credit agency) in a town but not in a village. In order to check the validity of our georefencing, we used a remote sensing image (IKONOS) on which we superimposed digitalized objects. We then had to rectify the digitalized objects to make them perfectly fit on the satellite image.

Then, we added a new layer mapping the Census Charges of the last Census (2001). Unfortunately, the census charges were redrawn between 2001 and 1991, making the comparison almost impossible between the two periods. Some accuracy was lost in the rural areas (villages merged), whereas in the core of the urban agglomeration the census units were shaped differently too. In order to be able to compare data from 1991 and 2001, we plan to use interpolation techniques. These techniques will allow us to compare trend surfaces generated for a given data on each census date. Interpolation being done using point data, we generated a geometric centre for each spatial unit. As we had a remote sensing image for the urban areas, we finally generated a more accurate second layer of point data: it uses the geometric centre of built-up areas in urban zones and the geometric centre of the villages in rural areas. This method will be illustrated in the third part of this paper in the case of population density maps. Census data was then linked to these point entities.

Finally, we also needed a layer to integrate the health infrastructure. Instead of attaching the health infrastructure directly to the Census Charges, a method which implied a loss of accuracy in location given the size of the concerned spatial units, we preferred to create a new layer containing the location of localities with the help of the Survey of India maps. We had to use the Delhi Eicher City Map 2001 to refresh and standardize the name of the localities and their locations[42]. This layer now includes 2300 localities or locations, not only in the National Capital Territory, but also in the ring towns (Ghaziabad, Faridabad, Noida, Gurgaon, Loni, Bahadurgarh). This layer is constituted by georeferenced punctual entities located at the geometric centre of each locality. Specific points have been created for big hospitals (as we were interested in this subject). In the case of widespread localities, we decided to put a point for each block (ex: Janakpuri, B1 Block). In some cases, we also had to add an extension to the locality name as some of them shared the same name. We used an extension, either east or west (in case they were both on different side of the Yamuna river), or the name of a neighbouring locality. Of course one might observe that this base is not regular and a point entity corresponding to a locality is not very accurate as it is a punctual representation of a surface. But working to the NCT scale, this irregular spatial cover is not such a problem. Our primary objective was to build a layer enabling us to easily integrate other information such as an address database, for example, in the case of healthcare infrastructure. As we are not studying some specific area of the NCT (as we did later for Gurgaon), the clustering of data at this scale isn’t such an important issue. Instead, as mentioned earlier, it was a way of gaining accuracy in infrastructure locations, whereas it was still possible to group such locations by census charges for statistical compatibility.

With regard to statistical data, we initially planned to use the results of the last Census (2001). But at the time we started to develop the GIS, the population tables were the only ones available and moreover only at the district level. As we wanted to work on the infra-metropolitan social context, we needed to wait for new publications. Fortunately, Census of India gave us a map and a set of data at the Census charges scale. But available datasets were too limited (only population and Sex Ratio) and the spatial units too heterogeneous. We finally decided to use the same base as in 1991. As we were interested in health topics, and given that the urban core charges have a particular set of data that does not include information regarding amenities, we collected the complete list of health infrastructure from the Directorate of Health Services. The tables pertaining to public hospitals and dispensaries are as exhaustive as we could expect but as far as private nursing homes are concerned, most of them were still unregistered in 2002. A study conducted in 2003 revealed that only one fourth of the nursing homes in the NCT were effectively registered. In 2004, around 800 nursing homes were in the process of registration[43].

c) ***Results and future development***

Until now, this base has been used in three different health geography projects.

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[42] Based on remote sensing analysis and fieldwork investigations, the Delhi Eicher City Map is an exhaustive location map.
[43] Interviews with officials from the Directorate of Health Services, conducted by Bertrand Lefebvre, April 2004.

With the help of maps produced by this GIS, M. Clerc worked on the access to healthcare for HIV positive people[44]. Thanks to the GIS, she pointed out the concentration of NGOs and their activities in very specific areas, leaving out a large section of the population and Delhi from their schemes.

B. Lefebvre worked on the spatial organisation of health infrastructure in the context of a metropolitan area[45]. Some maps will be presented in the third part of this paper. The GIS will be used in his new research project on corporate hospitals and nursing homes.

P. Chapelet is currently working on access to pharmaceuticals and distribution networks in Delhi. This database has been used for fieldwork during the summer of 2004 in order to select some healthcare facilities and areas as samples for interviews. Data characterizing chemist shops and wholesalers has been collected along with data on pharmaceuticals' consumer mobility. All this information is actually in the process of being integrated in the GIS.

Finally, this database should also be part of a project coordinated by S. Tawa-Lama Rewal and J. Ruet on urban governance in India[46]. It will be the cartographic base of the Delhi team.
This base may also be used for a project on peri-urban dynamics conducted by V. Dupont at the *Centre de Sciences Humaines* to have a retrospective view of this process in Delhi from 1981 to 2001[47].

In the coming years we would like to integrate data from the last Census of 2001. We have already collected some datasets but only at the charge scale. If possible, we would like to integrate data at the enumeration block scale in order to make the comparison with the 1991 census easier and to have a better perspective on the peri-urbanisation process. As the DHS is integrating the newly registered nursing homes, we are also waiting for the next set of data.

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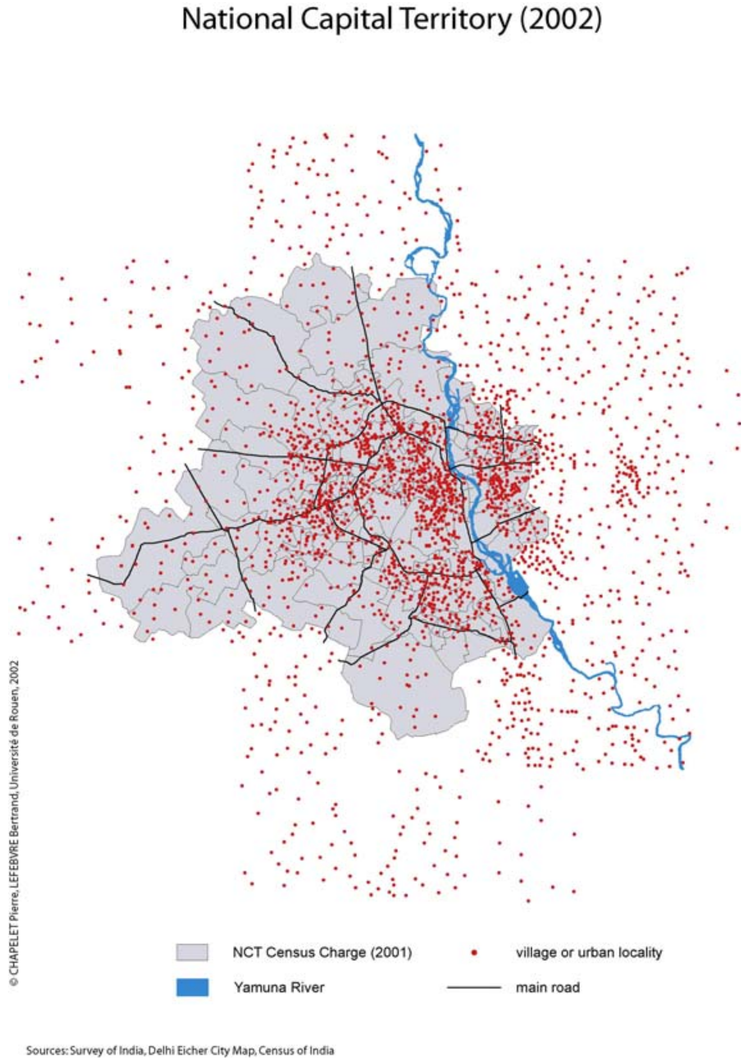
[44] See (CLERC 2003). Available in India at the Centre de Sciences Humaines library, New Delhi.
[45] See (LEFEBVRE 2003). Available in India through the library of the Centre de Sciences Humaines, New Delhi.
[46] For further details about this project, see http://www.csh-delhi.com/UAPG/.
[47] For further details about this project, see http://www.csh-delhi.com. Go on the research project's webpage.

Map 1



ii. Delhi Metropolitan Area

a) GIS objectives

We began developing this GIS in March 2002. Inspired by Véronique Dupont's work[48], we thought at first that the NCT would be the most relevant area for our questions. We came to develop this new base after realising that the NCT perspective might not offer the best scope to reflect upon health questions in view of Delhi's status of a fast growing metropolis. The daily life space of Delhi's inhabitants is often larger than the political territories. Ring towns like Gurgaon, Ghaziabad are truly part of Delhi even if they are not part of the NCT. Thus, we did not want to depend on the political and administrative framework that would have, admittedly, been more convenient. The idea was also to portray the spread of Delhi over the neighbouring states of Haryana and Uttar Pradesh. This GIS was conceived as a starting point to cover the entire National Capital Region.

b) GIS sources

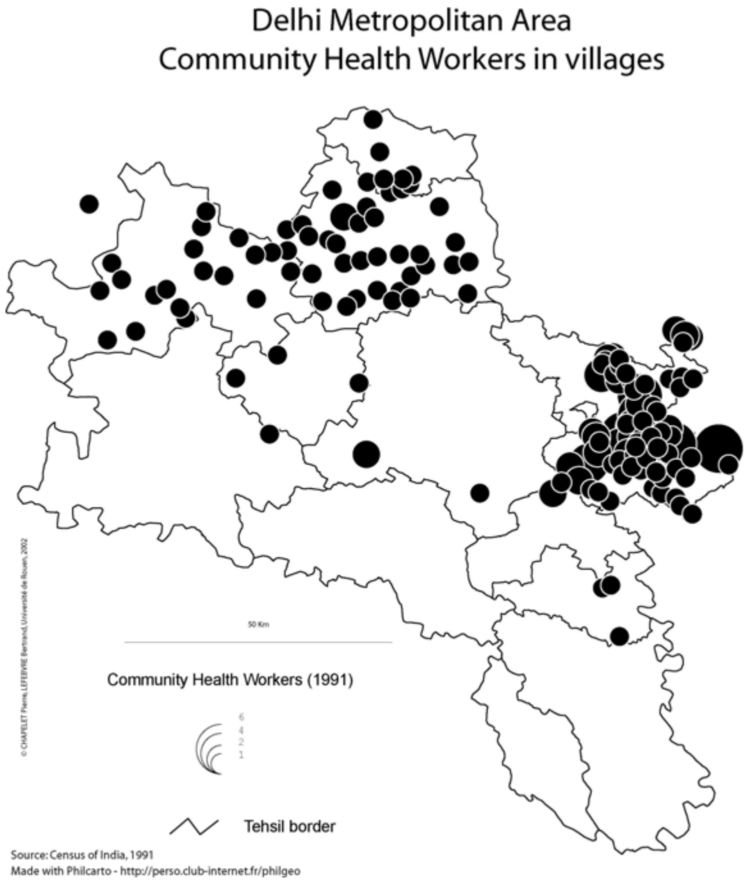
The 1991 Census Handbooks were our geographical sources. Unfortunately, the quality of the drawing was not very neat and maps were not georeferenced. We digitalised this area using the NCT (which was georeferenced) as a starting point. With the help of a tracing system, we tried to adjust the census handbooks maps to the NCT. We added census handbooks maps one

[48] See (DUPONT 2004), (DUPONT 2003).

after another. We drew areas corresponding to the Census spatial units and points corresponding either to the village or to the barycentre of the spatial unit in the case of an urban charge. We also drew roads and railway networks. As we have already mentioned, some Census Handbooks in Uttar Pradesh were not published so we were unable to extend this GIS to the east. It concerns mainly the Meerut District.

The source of statistical data is the Census of India. As with the NCT we used the same results from the 1991 Census presented on a digital support. If, regarding social, demographic and economic tables there was no particular problem to combine urban and rural areas, on the Primary Census Abstracts tables the infrastructure and amenities categories were too varied to build a common table. In the case of the Delhi urban charges (DMC and NDMC) the information on infrastructure was not available at all. As we have already noticed, the poor quality of data makes the exploitation of the results almost impossible with regard to health topics. The map of the Community Health Workers is clear enough on that point. The spatial organisation of the Community Health Workers (CHW) is far from achieving spatial equity. However, variations in the number of CHW observed across administrative boundaries give us an idea about the inefficiency of the survey more than about the implementation of this public health program[49].

Map 2



The GIS of the metropolitan area looks rather unbalanced as we move 100 km away from Old Delhi to the east and only 40 km to the east from the same starting point. We cover almost all the DMA but we are still far from covering the entire NCR. Another limitation lies in the absence of census charge maps for urban agglomerations like Ghaziabad, Noida, Faridabad. We were consequently unable to map the infra-urban variations of these units. In 1991, the population size of a spatial unit started with 4 inhabitants and went up to 511 000 inhabitants (Ghaziabad).

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[49] As observed on this map, there is clear underestimation of the number of CHWs in Uttar Pradesh. We first thought that this picture was representative of different implementation levels of this health scheme in the northern states. However, interviews with Census of India officials conducted in Delhi refute this hypothesis (Interviews conducted by Bertrand Lefebvre, April 2004).

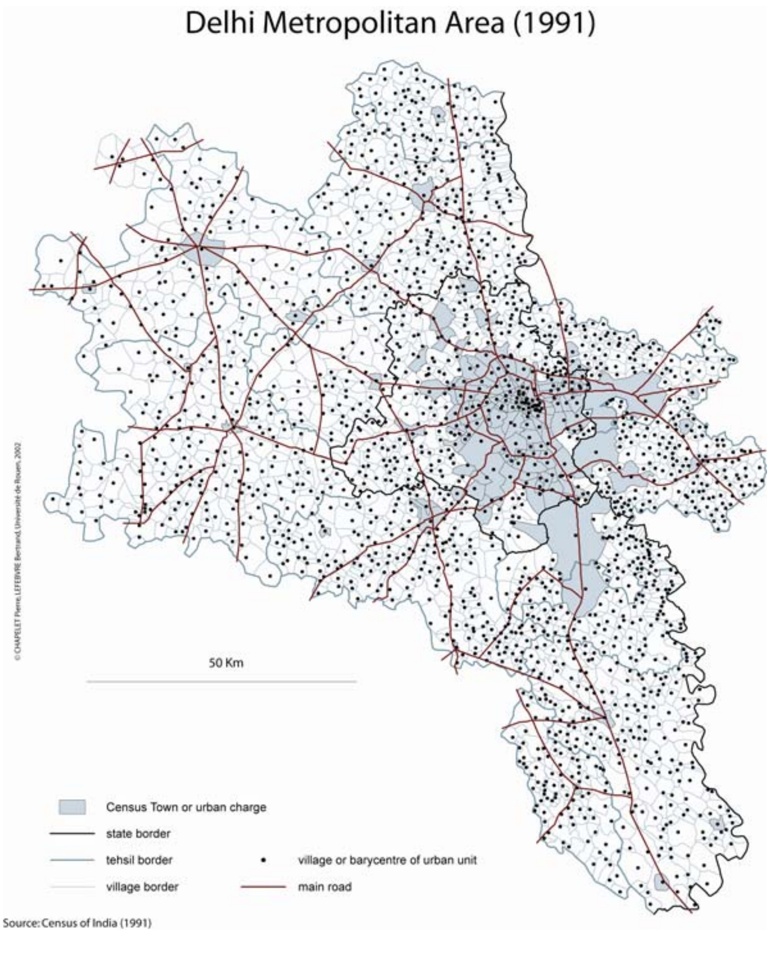
The GIS is actually covering an area of 11 707 km2, including 15.2 millions inhabitants in 1991. 67% of the total population lived in urban areas, as defined by Census of India. We digitalized a total of 1919 census units. Out of them, 95 were not surveyed by Census of India (4,95%).

c) <u>Results and future development</u>

Until now, the base has only been used to study the metropolitan dynamics around Delhi. Using economic and demographic tables, we drew a picture of the economical and social context around Delhi.

In the near future, we would like to add the results of the 2001 Census. The database should also be extended to the east, in order to first cover a 100 km radius from Old Delhi. Our final objective is to cover the NCR. We have just purchased the necessary maps (district maps showing village boundaries) to achieve this agenda. If it is possible, we would like also to include the urban charges for the biggest ring towns (Faridabad, Noida, Ghaziabad). As with the NCT, we hope that the spatial units will not be re-modelled between 1991 and 2001. As most of our spatial units are rural, we can assess that the risk is less important than in the case of our NCT database. But, again, the peri-urban area would probably have to be re-modelled, as in the case of our NCT database. All these add-ons would help us to study the urban spread between 2001 and 1991, so that we can view the metropolisation process from a dynamic perspective. If possible, the study of the evolution of the workforce composition would be also a great help to better understand the process of metropolitan integration and internal deployment. This question would also be interesting for research programs on peri-urbanisation and mobility. From the health perspective, we would like to use the GIS to map the movement of patients coming to the NCT private nursing homes or public hospitals. Another option would be to better understand the development of satellite clinics linked to corporate hospitals in the core of the city.

Map 3



iii. Gurgaon

a) GIS objectives

Although the NCT and the Delhi Metropolitan databases were very helpful in outlining the socioeconomic and the healthcare context of Delhi, the limitations were also considerable. With regard to the locality layer, we were able to work at the level of the metropolis on the spatial organisation of the healthcare services. But still, we were unable to understand and insert the healthcare infrastructure and services in the urban landscape. What areas are attractive for healthcare services? Moreover, many health actors were missing in our database, like private doctors, medical shops, specialists… Depending on the type of actors, do we observe different location strategies? Is there any autocorrelation effect between healthcare actors and with other activities? Do we observe the development of healthcare spots/cores? With these new questions in mind, the only solution was to develop a new base. In the context of a multiscalar approach, we felt that it was necessary to develop an infra-metropolitan database.

Due to time and resource constraints, we decided to first focus our database on a particular area. We decided to work on Gurgaon. According to us, this ring town was an excellent area for studying the insertion of healthcare services in the urban landscapes. Undergoing rapid growth since the seventies, this town presents a wide range of urban landscapes. Being a district capital, the town core is a typical legacy from the British period (civil lines, railway station, and commercial activity). The town benefited from the industrial dispersion program developed in the sixties and attracted industries (Maruti, Hero Honda…). Informal houses also started to mushroom. Then, in the eighties, the Haryana Urban Development Authority (HUDA) decided to create a modern town along the National Highway crossing Gurgaon, selling lands to real estate promoters. In this area there are still some small villages. This diversity of landscapes in Gurgaon can help us to better understand the effect of the urban environment on the location of healthcare services.

b) GIS sources

Our starting point for setting up this base was the Delhi Eicher City Map 2001, which presented the advantage of indicating the land use (commercial activities, industrial area, green park…)[50]. After scanning the maps covering Gurgaon, we readapted them to Arcview and digitalized the road networks and the built-up areas. Then, we went for fieldwork investigations in Gurgaon for a few days in May 2002. We rode on motorbikes along the streets of Gurgaon to check land-use and location of the health infrastructure. We covered almost all Gurgaon, only a few specific areas were left out when there was strong evidence that no health infrastructure existed. In order to have the most exhaustive picture of health landscapes, we looked at the location of chemists, dispensaries, nursing homes, doctors, specialists (gynaecologists, dentists, eye specialists…) and hospitals.

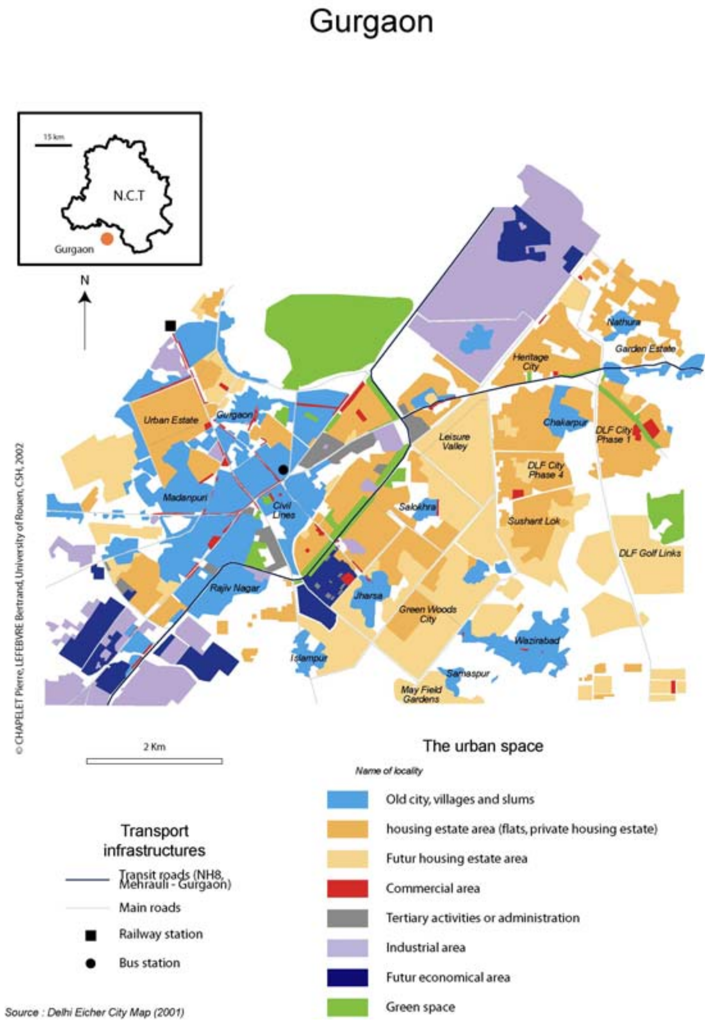
c) Results and future development

Until now this base has only been used for health infrastructure location studies (see the Atlas). However, this base can be used not only for health research but also for new research programs studying other commercial activities and the urban development of Gurgaon.
The quality and the outcome of this study being very satisfactory, we decided to reiterate this experience in other parts of Delhi. This work has been conducted in August and September 2004. Using the NCT GIS as a starting point, a few census charges were selected according to their socio-economic profile and existing public health infrastructure. Then fieldwork

[50] After the first treatments of satellite images, which allowed them to map road and build-up areas, they sent teams to check street numbers, locality names and land use.

investigations were launched in order to systematically survey every healthcare infrastructure. We are now in the digitalisation phase of these new datasets.

Map 4



iv. The Urban System in North West India

a) GIS objectives

The set-up of this particular base began in January 2003. Keeping in mind all the problems we faced in 2002, this time we tried to develop a very simple tool. The primary objective was to understand what the role of Delhi was and what the effects of metropolisation were in North West India. Due to lack of time, we limited our study to the urban system and towns with more than 20000 inhabitants. Studying metropolisation, an urban phenomenon, we considered that we could use these towns as strong evidences to represent the impact of Delhi's metropolisation on a regional scale. As presented by François Moriconi Ebrard mapping for example the demographic growth and its spatial organisation can help us to understand how a metropolis interacts with its hinterland (MORICONI EBRARD 2001).

b) GIS sources

We used the 1991 and 2001 Census results for the statistical data. The 1991 Census data is not available for Jammu & Kashmir due to the political context at that time. The *Nelles Verlag Northern India* road map is our spatial base (NELLES VERLAG 2001). This map covers around 410 000 sq. km all around Delhi, including 381 Census Towns or Urban Agglomerations with more than 20 000 inhabitants in 2001. Unfortunately the road map is not accurate enough to mark all the existing towns. Eleven of them are missing in the GIS: four in Rajasthan, three in Punjab, two in Uttar Pradesh, one in Himachal Pradesh and one in Haryana[51]. If we total their population the error rate is limited to 3% of the total urban population considered here. 53 million inhabitants reside in the 370 remaining towns representing 18.7% of the urban population of India in 2001. We tried to work with a constant perimeter using the 2001 list of Census Towns and Out Growths (OGs) constitutive of any Urban Agglomeration in order to control the effect of the spread on the total demographic growth between 1991 and 2001. If it was rather easy in the case of small towns, the difficulties we faced were greater in the case of the biggest agglomerations like Amritsar where we were not able to find the exact values for 1991. We also added the Uttaranchal border in the GIS. Even if this boundary is not accurately drawn, it gives us an idea of the new political map in this part of India. Apart from the towns, we digitalised railways, road networks and rivers. Until now, we only used them as location features but in the case of the road network we may soon be able to exploit it using spatial analysis tools and models in order to study specific aspects of urban dynamics, such as levels of relatedness.

c) ***Results and future development***

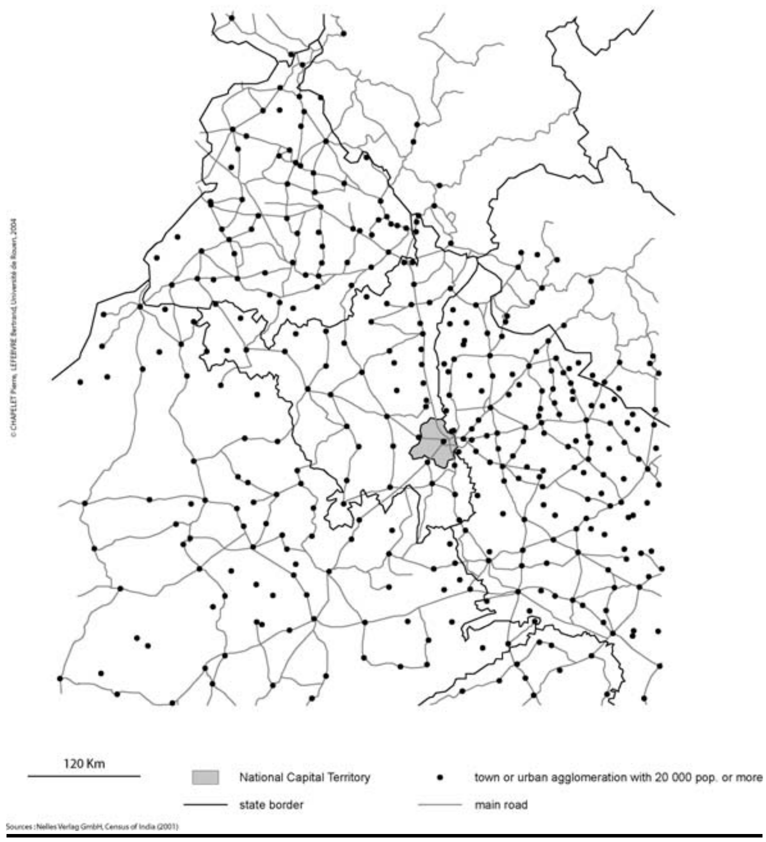
At first this GIS was only used to study the metropolisation process and the dynamics of the local urban systems and some regional resilience in the urban system. It was very helpful to describe the role of Delhi from a regional point of view. It was also used to create location maps for water management studies. With the help of these maps, A. Maria (PhD Student, CERNA, Paris) will be able to stress the need for regional cooperation in water management, particularly for Delhi. P. Chapelet, conducting research on the pharmaceutical industries in India, will also use it to study the spatial organisation of pharmaceutical factories and commercial networks in North West India. The GIS will also be used in 2005 to study the regional development of corporate hospitals. The North West has recently emerged as a hot spot for the healthcare market (life insurance and middle class). We want to show the spread of clinics in this high potential area. We also need to map the previous spatial organisation of public and private hospitals in order to be able to compare their dynamics.

It would be interesting to widen the GIS either by including smaller towns (10 000 inhabitants) or by extending its spatial coverage. The inclusion of smaller towns is an interesting option as we could obtain a more exhaustive view of the metropolisation effect in North West India. Using the road network to study the relation between distance, demographic growth and urban hierarchy would also be an interesting option for metropolisation studies. By including new spatial elements, like districts or tehsils, it will be also interesting to compare urban and rural social contexts. To what extent do rural neighbourhoods influence towns? Or on the contrary do towns have an impact on rural areas? We are in the process of purchasing state-wise maps of the urban system in north-west India. Another interesting option in the future would be to extend the GIS on the other side of border, i.e. in Pakistan, to study the changes in urban dynamics and hierarchy after the Partition of 1947.

Map 5

[51] Vijainagar, Kekri, Bhander, Babiyal, Khekada, Warhapur, Basni Belima, Pattran, Zirakpur, Karoran, Baddi (see in annexure for more details)

Urban System in North West India (2001)



ATLAS: CONTEXTUALISING DELHI'S HEALTH CARE SYSTEM

This part is intended to show some of the outputs we can generate with our tool. Moreover, it aims at implementing the research posture presented in the second part of this paper. Through an active research posture based on Exploratory Data Analysis, we will address the issue of healthcare system organization in the context of an agglomeration such as Delhi.
The idea underlying the following exercise is not to fully detail the organisation and functioning of the health system in India[52], but rather to examine the spatial organisation of the healthcare system alongside the social and economic context in which it takes place. In order to better assess phenomena taking place in the Indian Capital, it is relevant to contextualise its situation in broader perspectives. That is why, before directly presenting its organisation at the Delhi scale, we will first contextualise Delhi's situation in larger perspectives. The starting point of this "exploration" will be to the scale of the North West of India in order to see whether there is any integration of the Indian Capital with its hinterland, either from the socio-demographic or healthcare point of view. Then, we shall focus on the National Capital Territory itself. Here also, the purpose is to contextualise the spatial organisation of the health actors under a broader socio-economic spatial setting. Finally, a large-scale approach to Gurgaon will enable us to deepen our understanding of the spatial strategies of healthcare actors.
The following chapters have been consciously written in a very descriptive way, their purpose being to mostly illustrate the abilities of our tool to reveal spatial phenomena relative to the health system[53].

1. The social and economic context

i. Regional context

a) The impact of metropolisation in North West India

This map (**Map 6**) presents the demographic growth of urban systems during the nineties in North West India.

Only three out of the 370 towns with more than 20,000 inhabitants experienced a fall in population between the last two censuses. Inspired by F. Moriconi-Ebrard work on metropolisation[54], we standardized the demographic growth with the national urban growth for the same period (+31.17 %): Towns growing slower than the average can then be said to be in relative stagnation compared to the Indian situation; On the contrary, towns growing at a faster rate could be considered as taking an active part in the metropolisation process.

Looking at this map, it is clear at first sight that all the bigger agglomerations are growing faster than the other towns: Almost all agglomerations with more than 500,000 inhabitants experienced rapid growth between 1991 and 2001 (Delhi, Amritsar, Jalandhar, Jaipur, Agra, Chandigarh, Ludhiana…). The only exceptions were the isolated agglomerations such Bikaner, Jodhpur, Gwalior and Bareilly.

At the bottom of the urban hierarchy, small towns (20,000-50,000 inhabitants) have very low demographic growth rates. 60% of them have a growth below the national urban average. This might confirm their inability to attract rural migrants who reach directly the bigger towns to find

[52] For a very brief overview of the principal landmarks of the development in health services in India, one could refer to (BANERJI 2001). Another interesting work contextualizing the recent developments in Indian healthcare systems: (VAGUET 2004).
[53] See in annexure for more details about the discretisation methods or the spatial autocorrelation coefficients used in the following maps.
[54] See (MORICONI-EBRARD 2001).

more employment opportunities. The contrast between the high growth of Jaipur and other Rajasthani towns is a clear example of this contrast between the top and bottom end of the urban system.

Another conclusion from this map concerns the metropolitan spread. All towns in a 60 km radius around Delhi are growing quickly, even when compared to Delhi itself. Ring towns, like Noida or Bahadurgarh, have doubled their population within ten years. This spread can also be observed around Chandigarh (Kharar, Panchkula, Pinjore) or Jaipur and Agra. On the contrary, there is no particular neighbourhood effect on small towns around the three greatest Punjabi agglomerations (Amritsar, Jalandhar, Ludhiana).

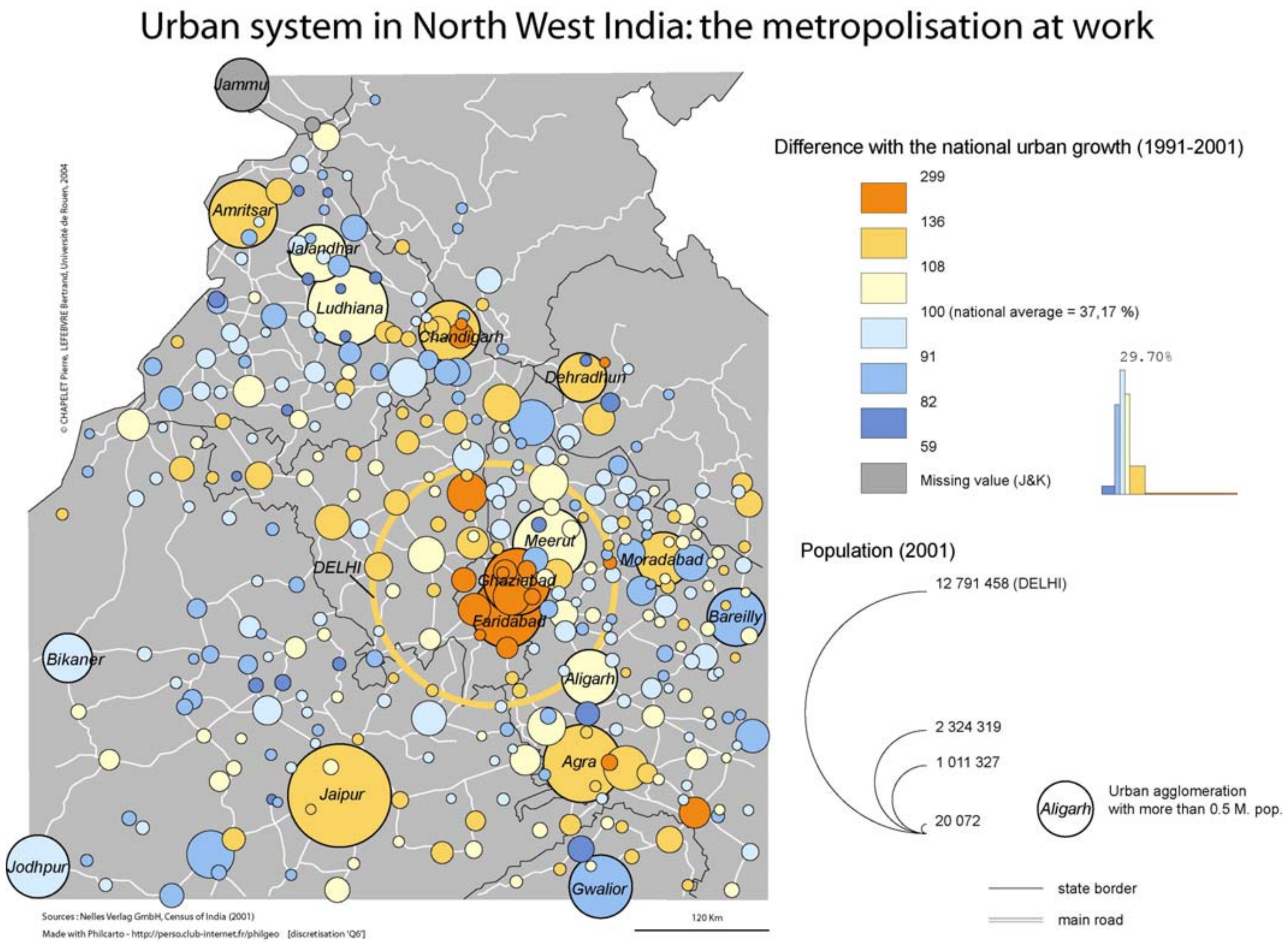
There is yet another lesson to be drawn from this map. We can represent some hub and spoke processes[55]. The in-between position does not guarantee a strong demographic growth. Instead there are many examples where small towns between major agglomerations register a slow growth: Between Amritsar and Ludhiana, between Delhi and Chandigarh, big fast-growing towns alternate with small slow-growing towns. This hub effect can also affect bigger towns such as Alwar or Saharanpur, which are not on dynamic road networks (Jaipur-Delhi or Delhi-Chandigarh).

Another interesting observation concerns the different profiles of urban hierarchy growth according to the state under consideration. For example, Haryana's demographic growth rate seems to be more homogeneously distributed among the urban hierarchy when compared to other states where the demographic dynamics of the principal agglomerations contrasts with their rural hinterland. This remark is a first evidence of various state policy trends that we shall have to keep in mind during our exploration.

To conclude, this map gives us strong evidence of the metropolisation process at work in North West India. Former local urban systems are in the process of integration. Delhi and its nearby metropolitan area are the leaders of this trend. Some recent planning developments (highway projects, real estate projects) could reinforce the metropolisation process. We must keep in mind that metropolisation means more integration and development for a group of towns. Some towns take a positive role in this process, others do not.

Map 6

[55] See (BASSAND 2001)



b) The social context in North West India

If we found some evidence of integration of the urban system across state borders when considering the demographic growth, can we find any other clue to this movement?

The 2001 Census population tables give us indicators such as Sex Ratio (number of women per 1 000 men), Child Sex Ratio (number of girls per 1 000 boys in the under 7 years age group), Child Woman Ratio (number of children below 7 years per number of women 7 years and above), Literacy rate of the population aged 7 years and above and Literacy rate of women.
Using this dataset and factor analysis[56], we tried to see whether metropolisation had a social impact or not. This data is also instructive in terms of health. Indeed, a disproportionate child sex ratio shows neglect of girls in the early years while a high child woman ratio indicates a need for more efficient family planning and specific needs in terms of paediatric care. Similarly, a high literacy rate among women is a good indicator of the potential success of health prevention schemes. Of course, this data can not replace more accurate data regarding these questions; however, they can help us to contextualise the health scenario in this area.

Instead of mapping each indicator successively, we thought it would be a good opportunity to summarize their global trends using a powerful statistical tool, namely factor analysis.
The factor analysis done on this set of data is in fact very instructive. The first two components total 82.76% of the total variance. The first principal component itself gets a good result of 65.91%, which is mostly explained by the small number of indicators used.

[56] Factor analysis is a statistical tool that aims at reducing the number of variables and detecting structure in the relationships between variables. It facilitates summarizing of the entire set of data. For a brief overview, see http://www.epa.gov/bioindicators/primer/multivariate.html

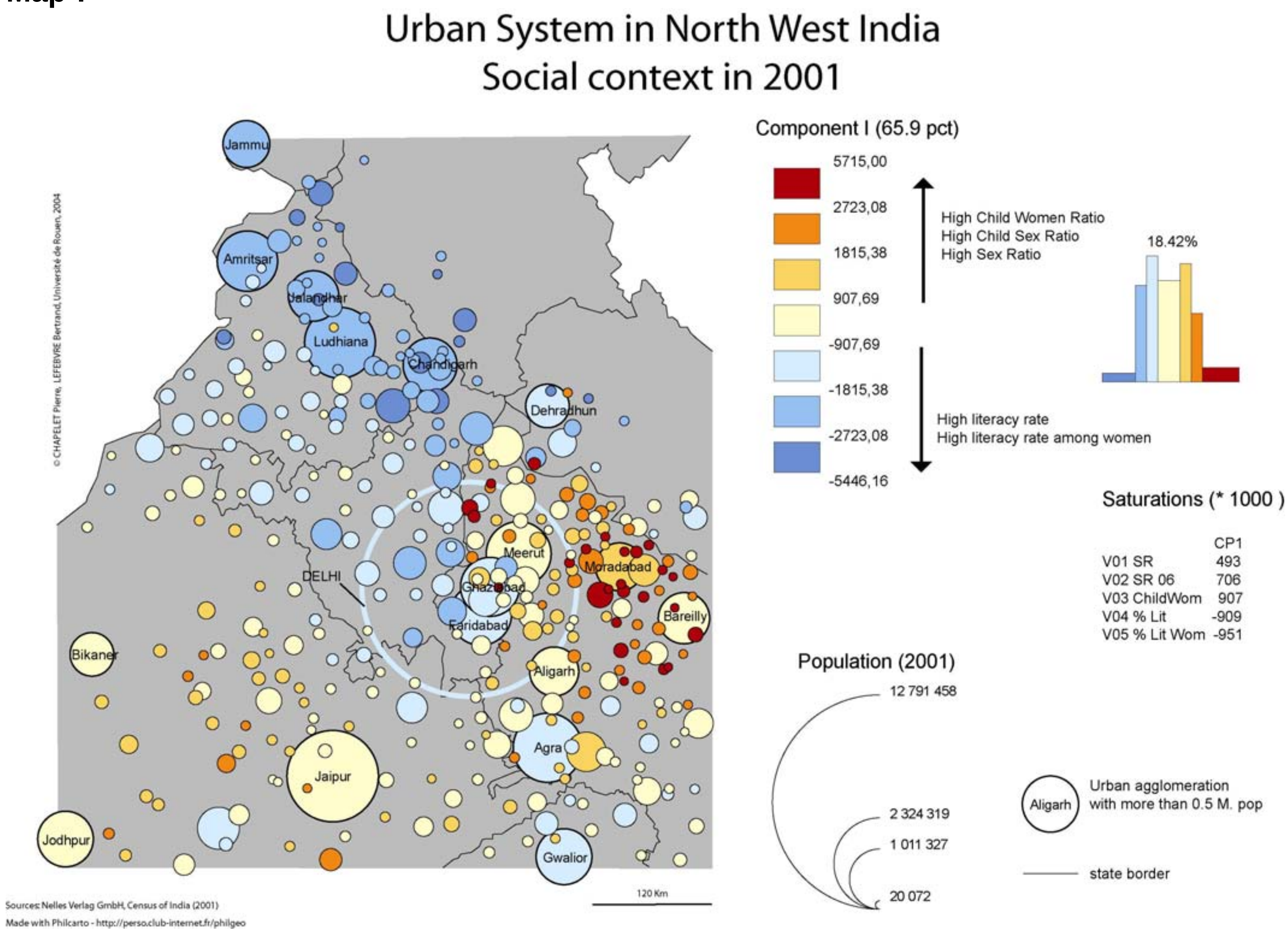
Taking the saturation table (see **Map 7**), we can see an opposition between literacy rates and child woman ratio in the set-up of this first principal component. The higher the literacy rate is, the lower the child woman ratio is. To a certain extent we can also see that a high woman literacy rate correlates negatively with a high child sex ratio. These correlations do not mean that there is a clear negative link between these variables. Indeed, as pointed out by C.Z. Guilmoto, regions with a high literacy rate such as Punjab and Kerala behave differently in terms of child sex ratio (GUILMOTO 2005). However, mapping the contribution of each town in the setting up of the first factor would give us a picture of the spatial organisation of this statistical opposition unveiling two social models (**Map 7**).

In fact, these two models present a very particular geography. Metropolisation, as previously observed (see 1.i.a), doesn't seem to have any impact on the spatial organisation of this component. It seems to be more a matter of regional effect than of urban hierarchy.
The first social model (high literacy rates, low sex-ratio) corresponds perfectly to the historical Punjab (present states of Punjab and Haryana). Towns in present Punjab and Haryana have high literacy levels even among women but at the same time present a very low Sex Ratio, not only among children but also among the general population. Jammu and the hilly towns of Himachal Pradesh and Uttaranchal also belong to this model. Within this region, we can observe a gradient from north to south. The social model seems stronger on a diagonal from Jammu to Yammunagar, going through Ludhiana and Chandigarh. As we go away from this line and closer to Rajasthan or Uttar Pradesh, the model becomes weaker. The opposition between towns on both sides of the Haryana-Uttar Pradesh border is very instructive on this point and could be another clue leading us to interrogate ourselves on the differential efficiency of state policies with regard to social and family health matters.
The second model (low literacy rates, high sex ratio) concerns towns in other states. This model is very strong in the small towns of Rajasthan and within the triangle linking Aligarh, Bareilly and Saharanpur. In this model the urban hierarchy seem to weigh more: small towns are closer to a rural model (high fertility, low literacy rates). Maybe we can also explain their high sex ratio by their lack of attraction for migrants (male). The greatest urban agglomerations (Delhi and its ring towns, Agra, Gwalior) have a profile very like the Punjabi model.

Finally, metropolisation cannot be defined as a movement of social progress. The integrative trend visible in growth rates should be tempered. Indeed, as shown in this second map, strong underlying regional bases still remain and clearly indicate that spatial fractures remain, particularly when considering socio-cultural practices.

This context will have to be kept in mind in our understanding of the organisation of Delhi's healthcare system. It compels us to consider it not only by itself but also in relation to a much larger operational system.

Map 7



ii. The National Capital Territory of Delhi

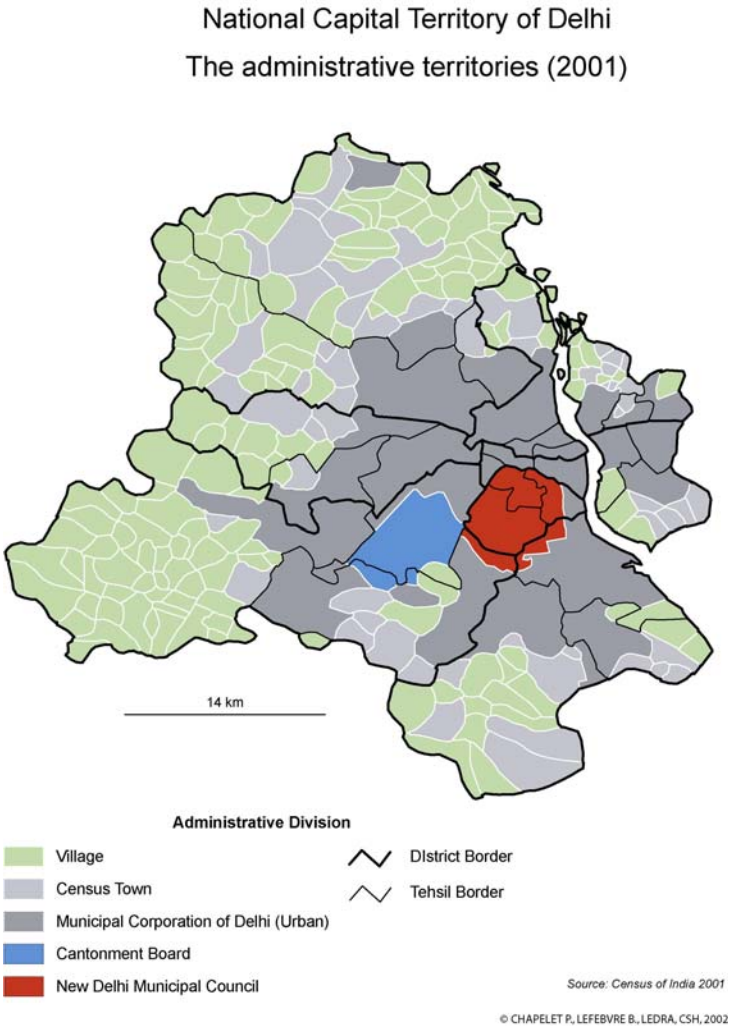
a) An introduction

Before presenting results at the National Capital Territory (NCT) scale, we will make a short presentation of its administrative organisation and its spatial structure.

The administrative organisation of the NCT is quite complex compared to other Indian metropolises. Until the decentralisation reform of 1993, the NCT was a Union Territory (since 1956) under the direct authority of the Central Government, represented by the Lieutenant Governor. In 1993 the situation changed and Delhi became a state. Its elected assembly, headed by a Chief Minister (since 1998: Sheila Dixit, Congress) now has to take control of new areas of competence such water, electricity and health. However, Delhi being a city as well, we also find some local bodies, such as the Delhi Municipal Corporation (1957), the New Delhi Municipal Council or The Cantonment Board. These local authorities were supposed to meet the needs of local democracy after the States Reorganisation Commission recommended giving Union Territory status to Delhi in 1953 (PINTO 2000). The Delhi Municipal Corporation controls both rural and urban areas (except New Delhi and Cantonment). Dating from the time when Delhi was under the strict control of the Central Government, whose aim was to make Delhi into a modern capital in a modern India, we also find a group of central government agencies wielding power in specific domains such as real estate, urban planning and environment. The Delhi Development Authority (1957), the National Capital Region Planning Board (1985)… With such a large number of administrative territories, Delhi is a prime example of complex metropolitan governance.

The multiplicity of actors and the corresponding imbroglio of overlapping territories should definitely have an impact on the management and organisation of the healthcare system. Again, this element will have to be kept in mind when looking at the Delhi healthcare system, as it could be an important explanation to its spatial organisation and functioning.

Map 8



b) *NCT: Density in 1991*

Now that we have an idea of the administrative set up of the NCT, another important element that needs to be examined in order to better contextualise the spatial setting and functioning of the healthcare system is the population distribution.

Population density is sensibly significant, as 35 census units alone (representing 18% of NCT acreage) have a concentration of one fourth of the total population (**Table 3**).

Population Size	Population	Census units	% Population	% Census
< 1 000	13 150	27	0,1%	7,8%
[1 000-2 500[	126 817	72	1,4%	20,9%
[2 500-5 000[	223 004	61	2,4%	17,7%
[5 000-20 000[	610 523	54	6,5%	15,7%
[20 000-50 000[	1 986 266	55	21,1%	16,0%
[50 000-100 000[	4 185 106	56	44,6%	16,3%
>100 000	2 247 151	19	23,9%	5,5%
Total	9 392 017	344	100,0%	100,0%

Table 3 – Population Distribution in the Census Spatial Units, 1991

Source: Census of India, 1991

The map below (**Map 9**) shows population density in 1991. Before commenting on this document, we will briefly explain how we generated it.

Instead of mapping density calculated on the basis of census units, we preferred to be more precise in representation by using a remote sensing image to automatically calculate density based on real land use. For each census charge, we assigned a point entity at the barycentre of each built-up area. The figure below presents the accuracy gain of such a method (**Figure 4**).

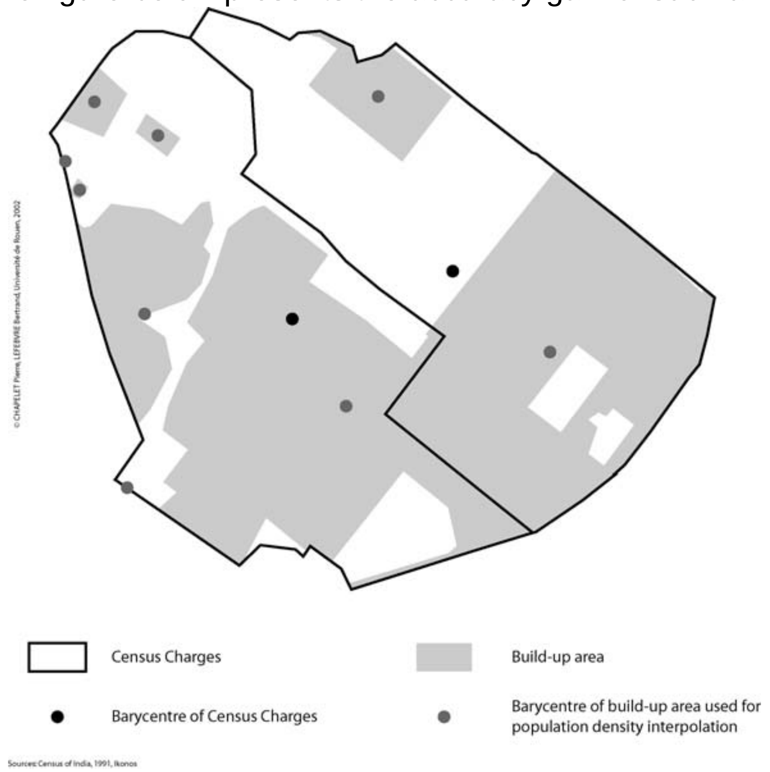
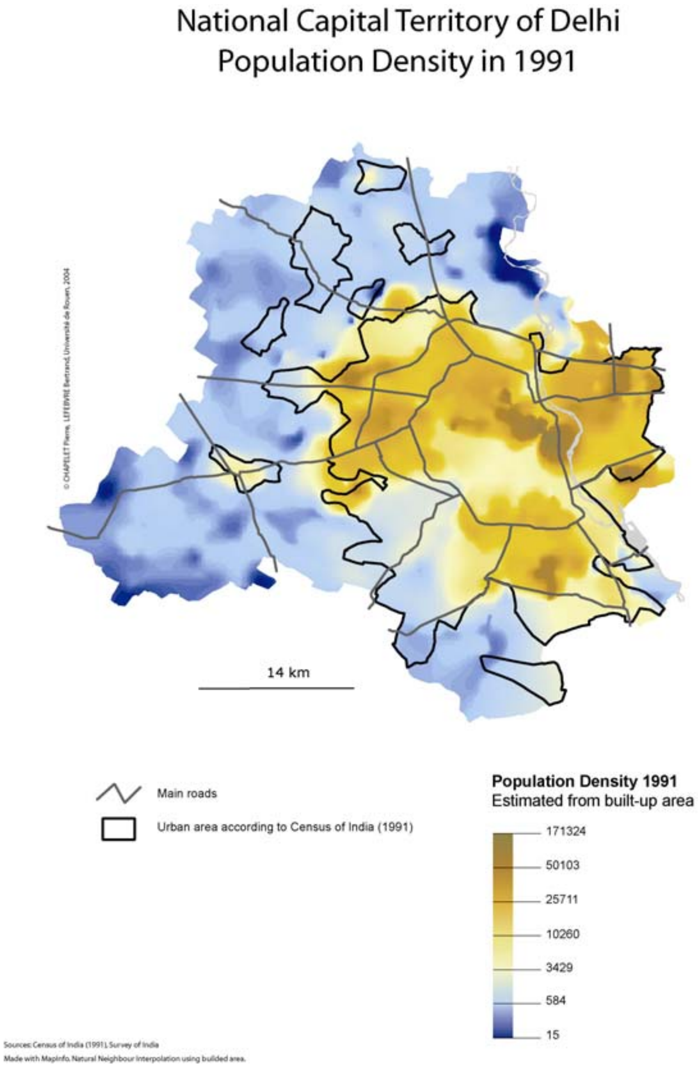


Figure 4 - Location of new barycentres in Census Charges according to built-up area

The number of inhabitants has then been divided between each built-up area according to its spatial share in the census unit. We then calculated density by dividing the total number of inhabitants by the surface measurement of each built-up area (and not by Census charge area). Finally, we generated a trend surface. This enabled us to better grasp the pattern of population distribution.

Lastly, this map clearly shows the heterogeneity of NCT space, constituted of thinly populated rural areas and the city itself, densely populated and spreading outwards from the NCT towards Ghaziabad in the west (out of this map). The main core of high density is centred in the historical city, Old Delhi with its bazaars and its dense habitat. Population density is also high in the Shahdara area on the east bank of the Yamuna. It clearly contrasts with New Delhi in the south, with its large avenues and spacious built-up areas where density falls drastically. We then find high concentrations in residential areas in the south and the west, as they attract migrants in large numbers. In the middle of the rural area in the west, we find pockets with high density, constituted by fast growing satellite towns in the process of integration with the city, such as Najafgarh.

Map 9



c) <u>***Household size in 1991***</u>

After this initial perspective on density it would be interesting to question another measure of density. Dividing the population by the number of residential households can give us an idea of the size of the household. Again it is not a perfect indicator, as the average value calculated for each census unit can obscure the differences between one household and another. The household size can be explained by many different factors (wealth, family model, culture, density…). Assessing the household size is also interesting with regard to some vector diseases like malaria where promiscuity is an important factor of diffusion (SALEM 1998).

The positive spatial autocorrelation revealed by the spatial autocorrelation coefficients[57] leads us to think that a strong spatial organisation exists (**Map 10**). With very high values in the rural part of the National Capital Territory, this map of the household size is the negative of the density map presented above.

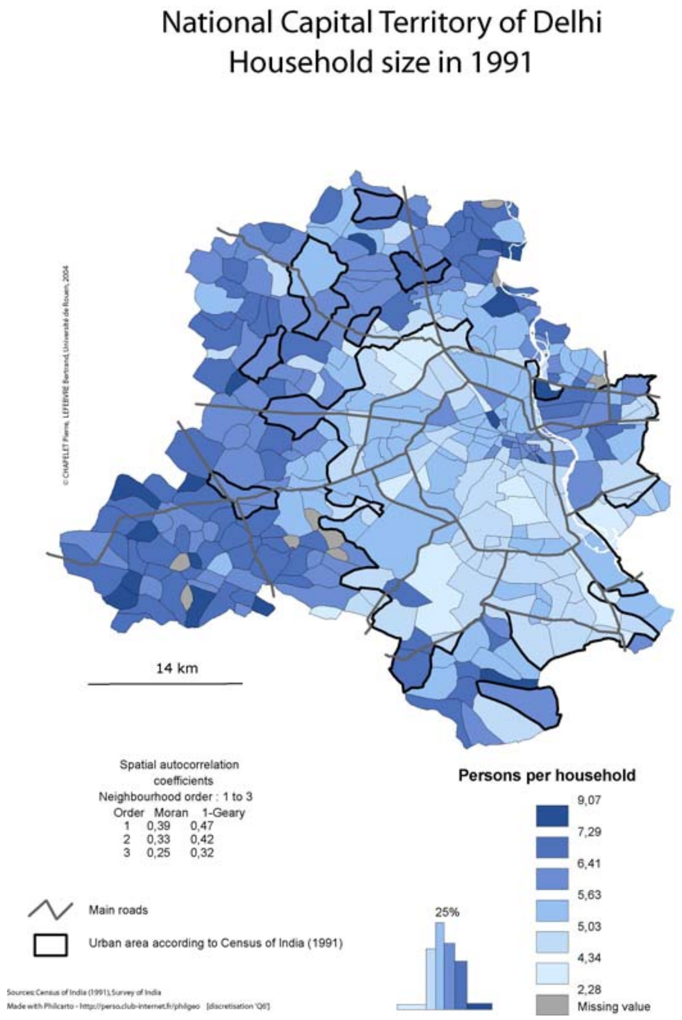
Focusing on the rural parts of the NCT, we observe that most of the villages have an average household size exceeding 5.6 persons per household. The model of a joint family is far more common in rural area. The size of houses and farms can permit such a model. In urban areas, due to housing constraints, such a model cannot be sustained. 45 % of the households of Delhi Urban Agglomeration reside in one room[58]. Villages along the Yamuna even have an average

[57] See in annexure the definition of these spatial autocorrelation coefficients.
[58] According to the Census of India (1991) House & Household amenities in the National Capital Territory

household size exceeding 7 persons per household. Urban areas outside the Delhi Urban Agglomeration (Narela, Alipur, Pooth, Khurd, Najafagarh…) have a rural-like profile. On the contrary, some villages on the urban agglomeration fringe have a more urban-like profile. This includes villages such as Tikhri Khurd or Bhatti, known for their non-agricultural activities (mining, factories).

As far as the Delhi Urban Agglomeration is concerned, the picture is one of contrasts, which can be linked to urban planning history. New Delhi and South Delhi have small household size, mostly under 5 persons per household with some areas even under 3 persons per household. Urban or industrial areas like Rohini, Vasant Kunj or Okhla can be easily identified by their small household size. On the contrary we can draw a belt from Old Delhi to the Shahdara area where the average household size exceeds 5.6 persons per household. Most of this area was the core of Delhi during the early post-independence urban development period. At this time, there was no question of urban planning in this zone. The timeworn buildings and high population density can explain the high number of persons per household. Some studies have also shown that these areas received temporary migrants who were ready to live in more constrained conditions (DUPONT 2000).

Map 10



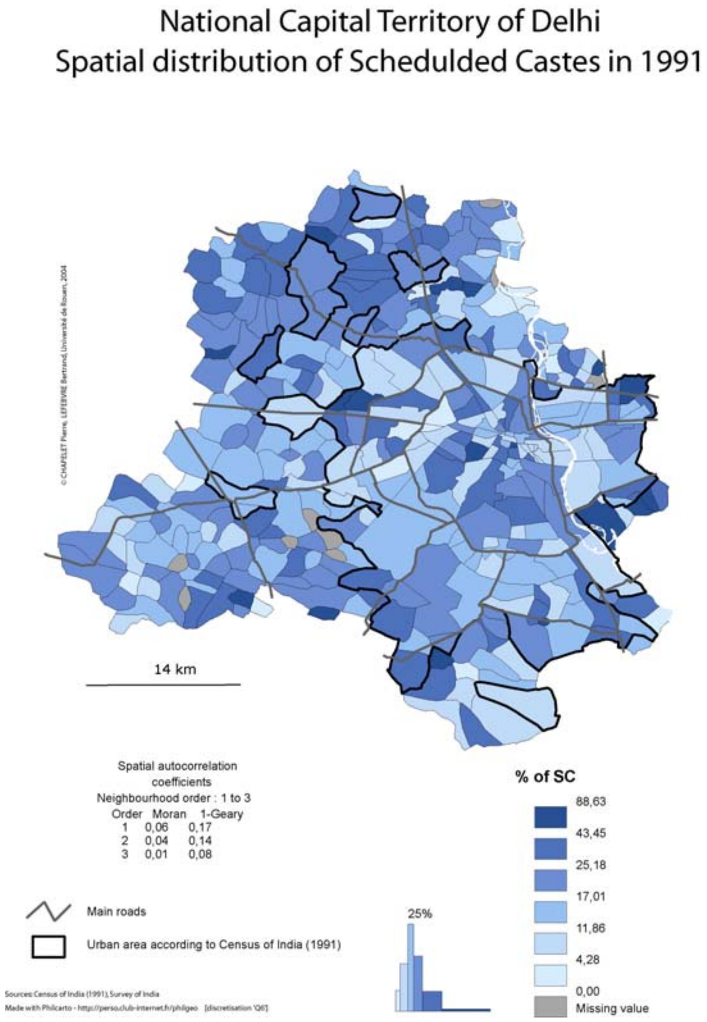
d) <u>*Scheduled Castes in 1991*</u>

Mapping the share of Scheduled Castes (SC) in the general population can help us to represent the level of social segregation in the National Capital Territory. 19% of the total population are scheduled castes (SC). Some very important contrasts are noticeable given that the share of SC communities in census units ranges from 89% to 0%. The SC population is rather concentrated in the urban agglomeration (DUPONT 2000). 35 spatial units out of 355 have 50%

of the total SC population. 155 spatial units have a SC percentage exceeding the National Capital Territory average.

No clear rural-urban frontier appears (**Map 11**). The high percentages of SC are dispersed. New Delhi, northwest and southwest villages have a high percentage of SC in their population. The situation in New Delhi can be explained by the location of government accommodation for government employees in some colonies of New Delhi, including for SC employees who benefit from the reservation policy. With regard to the villages it is more difficult to find an explanation. The high percentage in some villages can be explained by the presence of traditional communities like Jatav. The autocorrelation coefficients are around 0, reinforcing the impression of a weak spatial structure.

Map 11

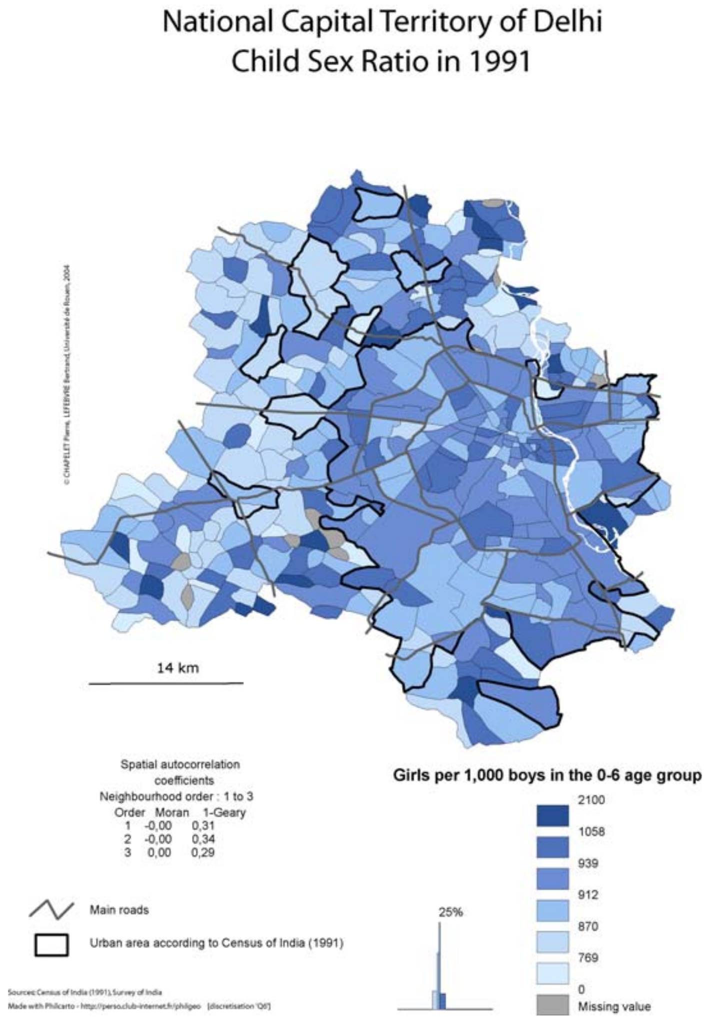


e) <u>*Child Sex Ratio in 1991*</u>

The Child Sex Ratio is another good example demonstrating that, sometimes, mapping data does not necessarily reveal any strong spatial structure or neighbourhood effect. As the autocorrelation coefficient shows us, there is no specific spatial effect on the organisation of the data. The National Capital Territory average is around 907 girls for 1 000 boys. 185 spatial units out of 355 exceed the average. The sex ratio rises up to 2 100 girls per 1 000 boys. Only 34 spatial units present a positive sex ratio for girls.

Perhaps at first sight we can consider that the child sex ratio is higher in urban areas (914 girls per 1000 boys) than in the rural part of the National Capital Territory (904 girls per 1000 boys). But looking carefully at the map (**Map 12)**, one can observes high contrasts within the rural areas and urban agglomeration. The reasons for a low or high child sex ratio may be too complex: biological, economical, social, cultural… In short, individual choices do not necessarily reveal spatial structure.

Map 12



f) ***<u>Female literacy and fertility in 1991</u>***

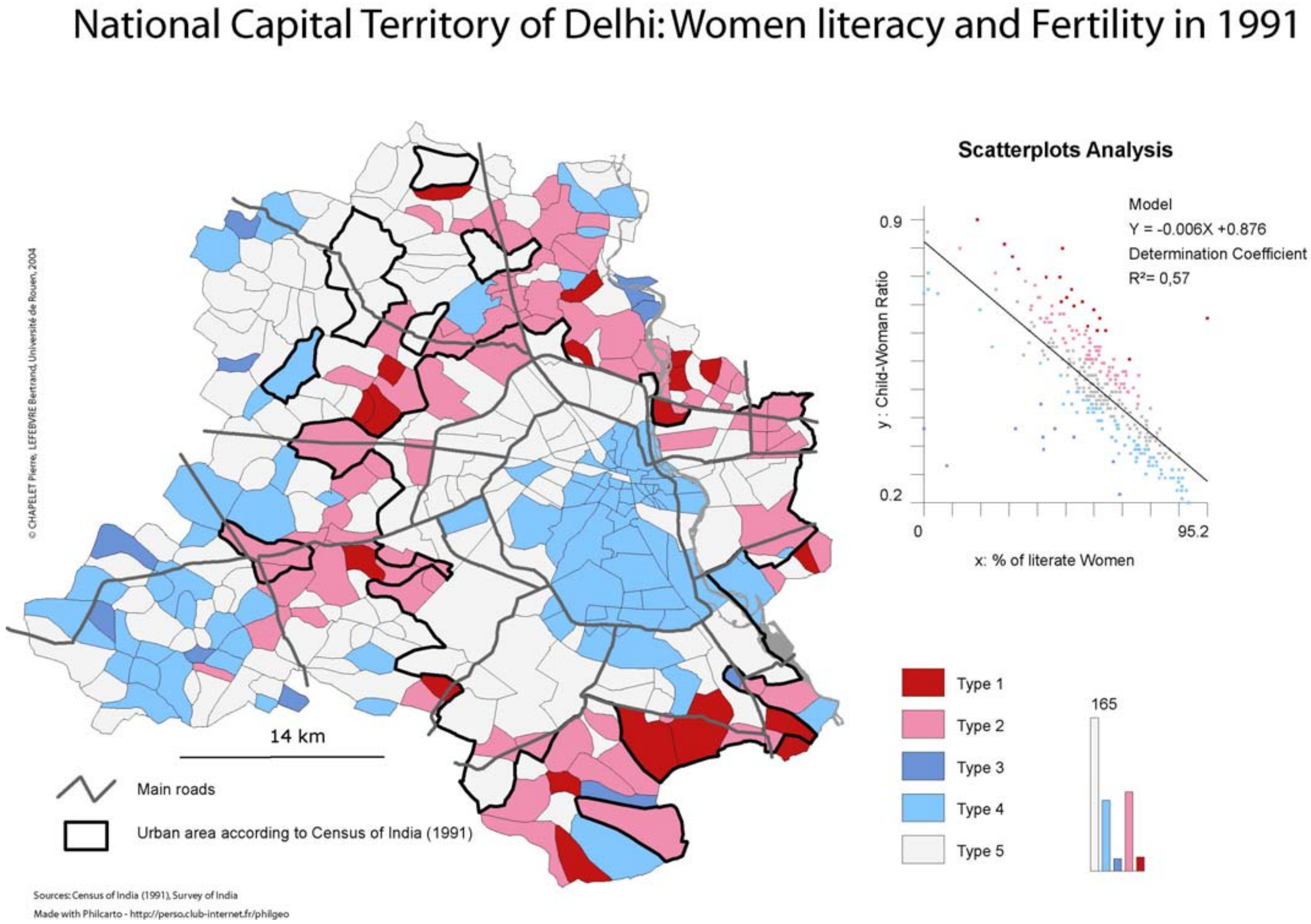
It has often been observed that literacy among women helps in reducing the fertility rate. The factor analysis of the social context in the North West urban system was quite explicit about this. Using a linear regression, we tried to have a better picture of this relation in the context of a fast growing agglomeration such as Delhi. What can we learn from a comparison of these two variables to understand the socio-spatial organisation of Delhi?

The statistical relation between these two variables in the National Capital Territory is strong enough to let us proceed in this direction. Indeed, this relation explains 57% of the total variance of both data. The correlation coefficient is negative: it means that the higher the female literacy rate, the better the chances of finding a low child-woman ratio. 165 out of the 355 spatial units correspond to this model. Otherwise, we can consider two different situations: Either the relation is stronger, meaning that the child-woman ratio is higher than what the literacy rate would lead us to expect; or the relation is weaker, meaning that the child woman ratio is lower than what the female literacy rate would lead us to expect.

Same as in factor analysis, it might be interesting to map the position of spatial units and the location of the exceptions to this model (**Map 13**).

Villages and much of the urban agglomeration are similar to the model found (Type 5). In fact, exceptions concern two specific areas: The core of the urban agglomeration (New Delhi and Old Delhi) and the urban fringe. In the case of the urban core, women are well educated and birth control is the norm (Type 3 and 4). On the contrary, the child-woman ratio is particularly high on the fringes of the urban agglomeration and female literacy much lower (Type 1 and 2).

Map 13



g) <u>***Primary sector and commercial activities in 1991***</u>

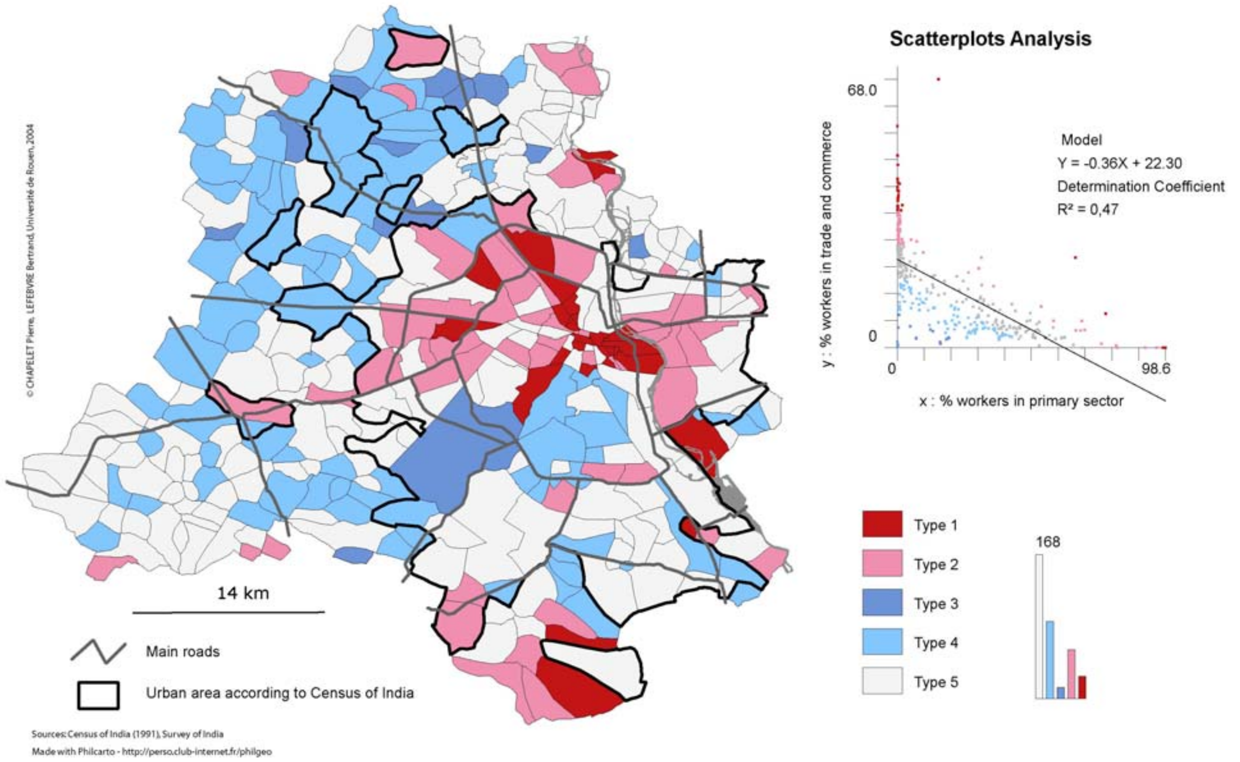
From our understanding of the socio-spatial structure of the National Capital Territory we compared the share of workers involved in the primary sector (agriculture, mining, livery) with the share of workers involved in commercial activities (trade and commerce) as defined by the Census of India. These two sectors of activity can be defined either as "rural" or "urban". This might help us to understand where the limits of the urban agglomeration stand.

The statistical relation is rather strong (47%). 168 spatial units correspond to this model. It concerns either villages or urban units. This model reveals some very specific areas (**Map 14**). In the case of Old Delhi and the Shahdara area, commercial activities are very well represented, much more than expected from the model. This might be explained by the traditional role played by the bazaar as a commercial centre, a role reinforced by the development of the two railway stations in early 20^{th}. Even now, Old Delhi remains an important commercial centre. Outside the urban agglomeration we can find some remote villages where the primary sector concerns more than 70% of workers (along the Yamuna or around Bhatti) but also some commercial centres (Najafgarh, Narela).

There are two different explanations for areas that present a different profile to this model. First, some of them develop other ranges of activities like New Delhi or the Cantonment (services, administration…) or some industrial area. The other explanation comes from the change of activity in rural areas. The primary sector becomes less and less important. New activities are being developed (household industry, transport and storage…). But, at the same time, trading and commercial activities are not yet developed. This in-between situation is a good indicator of peri-urbanisation. It concerns mainly the northwest part of the National Capital Territory.

Map 14

National Capital Territory of Delhi: Primary sector and commercial activities in 1991



h) Social Context in 1991

Using different angles and points of views, the Exploratory Data Analysis was very useful in visualizing the spatial structure of the National Capital Territory. With the help of simple maps, linear regressions and spatial autocorrelation coefficients we highlighted many different aspects of the spatial structure of Delhi. Some specific areas were revealed by particular data or exceptions to a statistical model. But territories revealed by the economy are not the ones revealed by social data. How can we have the most comprehensive and realistic (as far as possible given the quality of Census of India data) view of the National Capital Territory? Where does the border of the urban agglomeration lie? Where does the rural area begin? Can we represent the peri-urban area? What is the spatial implication of the socio-economical structure of the National Capital Territory of Delhi?

To try to answer these questions, we will now use a factor analysis and a hierarchical agglomerative cluster analysis. In order to do so, we selected the following demographic and social indicators: density, household size, participation rate, SC %, sex ratio, female workforce participation, child-women ratio, female literacy rate. We left out some data when it was redundant (literacy among women and in general population are highly correlate) or when it lacked clear spatial structure (like the child sex ratio). We also added data regarding the professional composition of the working population: primary sector / transport, storage and communication / trade and commerce / other services (mainly administration) / manufacturing and processing in household industry / manufacturing and processing outside household industry / construction workers. We decided not to detail the primary sector as we were more interested in the development of the urban agglomeration and urban activities. These 15 variables should give us the most comprehensive picture of the socio-spatial organisation of the National Capital Territory in 1991.

The first step in factor analysis is to examine how the information is organised from a statistical point of view (see **Table 4**).

Total inertia = 15,00				
Principal Component	Eigenvalue	Percentage	Accumulative	Bar chart
1	3,20	21,35	21,35	I******************************
2	3,12	20,81	42,16	I*****************************
3	1,75	11,65	53,81	I****************
4	1,54	10,28	64,09	I**************
5	1,21	8,03	72,12	I***********
6	0,89	5,92	78,04	I********
7	0,78	5,20	83,24	I*******
8	0,70	4,68	87,92	I*******
9	0,60	3,99	91,91	I******
10	0,37	2,48	94,39	I***
11	0,32	2,14	96,53	I***
12	0,26	1,76	98,29	I**
13	0,15	1,02	99,31	I*
14	0,10	0,69	100	I*
15	0,00	0	100	I*

Table 4 – Principal Component Analysis Diagonalization

Source: Census of India, 1991

64% of the total information is summed up in the first four components. Considering the number of data used, this result is rather good. Each of the first two factors totals around 20% of the total information. The third and the fourth factor are around 10%, meaning they weigh less in the statistical composition.

		Principal Components			
Variable	Name	CP1	CP2	CP3	CP4
V01	Density	**-629**	219	**405**	172
V02	% Workers	191	**786**	-310	323
V03	Persons per Household	221	**-704**	**397**	275
V04	% SC	240	371	-69	-92
V05	Sex Ratio Population	-327	**-578**	121	-29
V06	Workforce Sex Ratio	-113	164	**-583**	**453**
V07	Child Women Ratio	**701**	32	265	**-392**
V08	% Literate Women	**-837**	-325	-187	37
V09	% Households Manufacturing	-158	92	**580**	-24
V10	% Manufacturing (others)	-247	**673**	318	45
V11	% Construction	39	362	-186	**-623**
V12	% Trade/commerce	**-768**	339	208	40
V13	% Transport/storage	-11	**-444**	22	**-560**
V14	% Other Services	-327	-378	**-591**	-290
V15	% Primary sector	**754**	**-437**	24	**418**

Table 5 – Principal Component Analysis Axe Saturations (*1000)

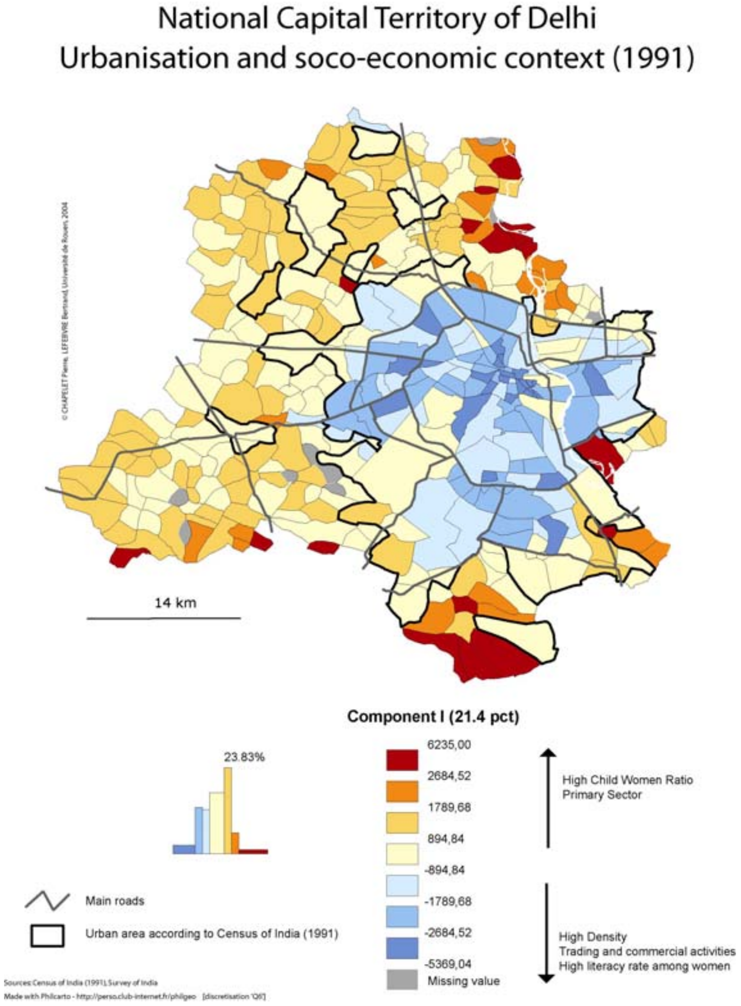
Source: Census of India, 1991

The saturation table (see **table 5**) helps us to understand which data weighs the most in the composition of each component. We also learn for each component what the positive and negative data contributions are in their set-up.

Just as we did for the social context of the urban system in North West India, we will first map the contribution of each spatial unit in the set-up of each factor. This would tell us what the main spatial structures of the National Capital Territory are. Then, we will summarize these results using Hierarchical Cluster Analysis.

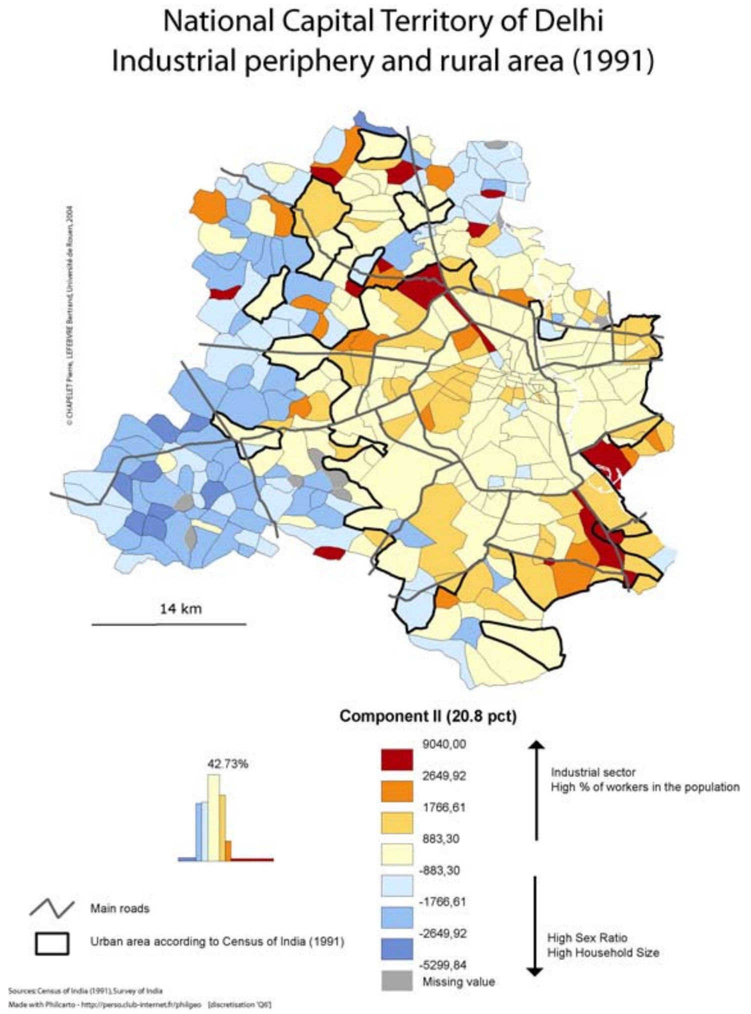
The first component represents 21.4% of the total information. On the one side we find primary sector and child women ratio, whereas we find female literacy, trading and commercial activities along with density on the other side. We can observe the two linear regressions we have already presented (primary sector-trade commerce, child women ratio-female literacy) on this axis. The spatial organisation is not surprising given the data (**Map 15)**. The rural areas and the urban fringes are in opposition to the core of the agglomeration. This is clearly a centre-periphery model.

Map 15



The second component, representing 20.8% of the total information, is based on the opposition between the percentage of workers in the population and industries vs. household size and high sex ratio in the population. The spatial organisation of this axis introduces two new types of areas (**Map 16**). Compared to the first axis, the remoter rural areas are more specifically pointed up (size of household, low presence of industries). The planned industrial areas and North West urban villages are also particularly well represented (Oklha, Pitampura, Rohini).

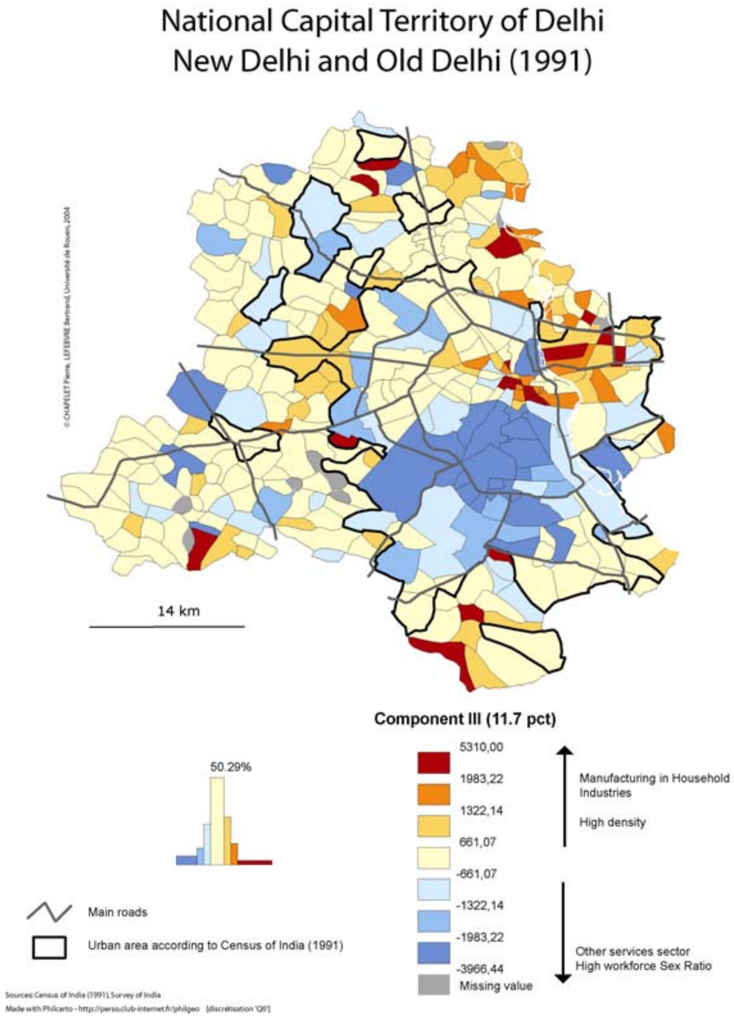
Map 16



The third component, representing 11.65% of the total information, is based on the opposition between: household industries and density on the one hand, and female workforce participation (workforce sex ratio) and other services on the other hand. "Old Delhi vs. New Delhi" could be a good title for this map (**Map 17)**. In fact, this opposition is not surprising if we look at the data entering in the drawing of this axis. Old Delhi is still well known for its high population density and the presence of small-scale industries[59]. The western urban fringe along Rothak Road and Shahdara also corresponds to this model. On the other side, New Delhi, Cantonment and South Delhi offer another model with a workforce more involved in services and with greater participation of women. Civil Lines and some planned areas like Rohini or Janakpuri also belong to this model.

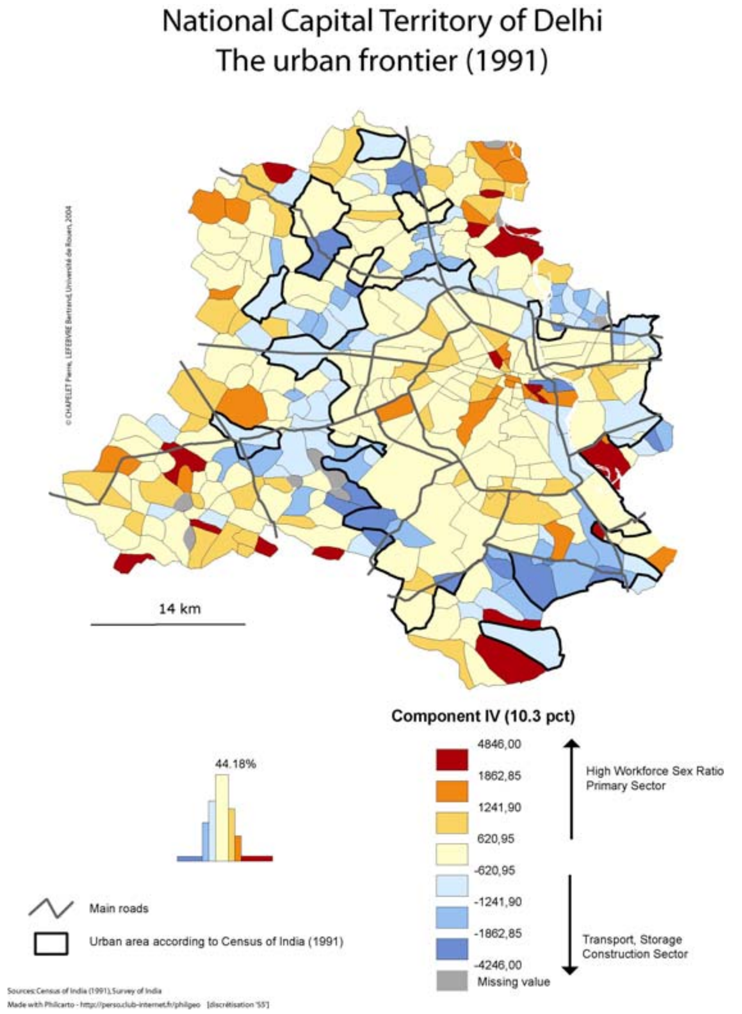
[59] This situation of small-scale industries may not be the same in 2001, as recent court decisions forced polluting or non-conforming small-scale industries settled in the core of the old city to move out to the periphery.

Map 17



The fourth component represents 10.28% of the total information: transport and storage, construction vs. workforce sex ratio and primary sector. The urban front is well represented (**Map 18**). Construction, storage and transport are indeed the kind of activities developed at the gates of the agglomeration. These activities are also very attractive for rural or temporary migrants as they don't demand any particular skills but need a large workforce. At the same time, low female workforce participation can be explained by the presence of male migrants. Men come to Delhi to work, and women who accompany their husbands, unless they remain in the village, have to tend to domestic work. Here there is no agricultural work.

Map 18



i) ***Hierarchical Agglomerative Cluster Analysis***

Now that we have drawn an initial picture of Delhi's socio-economic-spatial structure, it is time to launch the Hierarchical Agglomerative Cluster analysis, based on the four previously presented axes. Using this analysis we can generate a more comprehensive and synthetic picture (**Map 19**) of the economic and social context of the National Capital Territory, as attempted by V. Dupont and A. Mitra ten years back (DUPONT & MITRA 1995). We also acquire greater accuracy with regard to the rural areas, which were taken as a whole in the Dupont and Mitra study.

The resulting typology is as follows:

Old Delhi
This area presents a very high population density, and a significant presence of trade and small-scale industries. This profile is clearly inherited from the bazaar features.
The urban core
This area presents some features similar to the "Old Delhi" profile but not as excessive (density, trade and commerce, female literacy). It extends from Old Delhi to the east (Rohtak road), north and west (Shahdara).
New Delhi
This area is defined by the modern social context (low child women ratio, high women literacy), services activity (administration) and high female workforce participation. It covers New Delhi and Cantonment territories.
The extensions of New Delhi

This area is similar to the "New Delhi" profile (high female literacy, low child women ratio) but with a more industrial feature. It mainly concerns the South Delhi area.

The industrial area

The high involvement of the workforce in non-household manufacturing leads us to define these areas as industrial. Planned industrial areas like Okhla belong to this model.

The urban front

The poor social context (high child women ratio, low women literacy, unequal Sex Ratio) and the type of activities (transport, storage, construction, and small scale industries) lead us to think these areas are receiving new migrants. It could be seen as the urban front of the Delhi agglomeration in 1991. Since the last 2001 Census most of them are part of the agglomeration.

The peri-urban fringe

In this area the primary sector remains strong and the social context has a somewhat rural profile (Child Women Ratio). But the household size is now different from the rural average and the diversification of activities is going on. In 2001 some of them were included in the urban agglomeration.

The upper peri-urban fringe

Some indicators are close to the peri-urban fringe profile (household size, primary sector) but the high involvement of the workforce in services suggests that another kind of population is living in these areas.

The rural fringe

From the activities (primary sector) and the social context (household size, literacy rate…) these areas are rural.

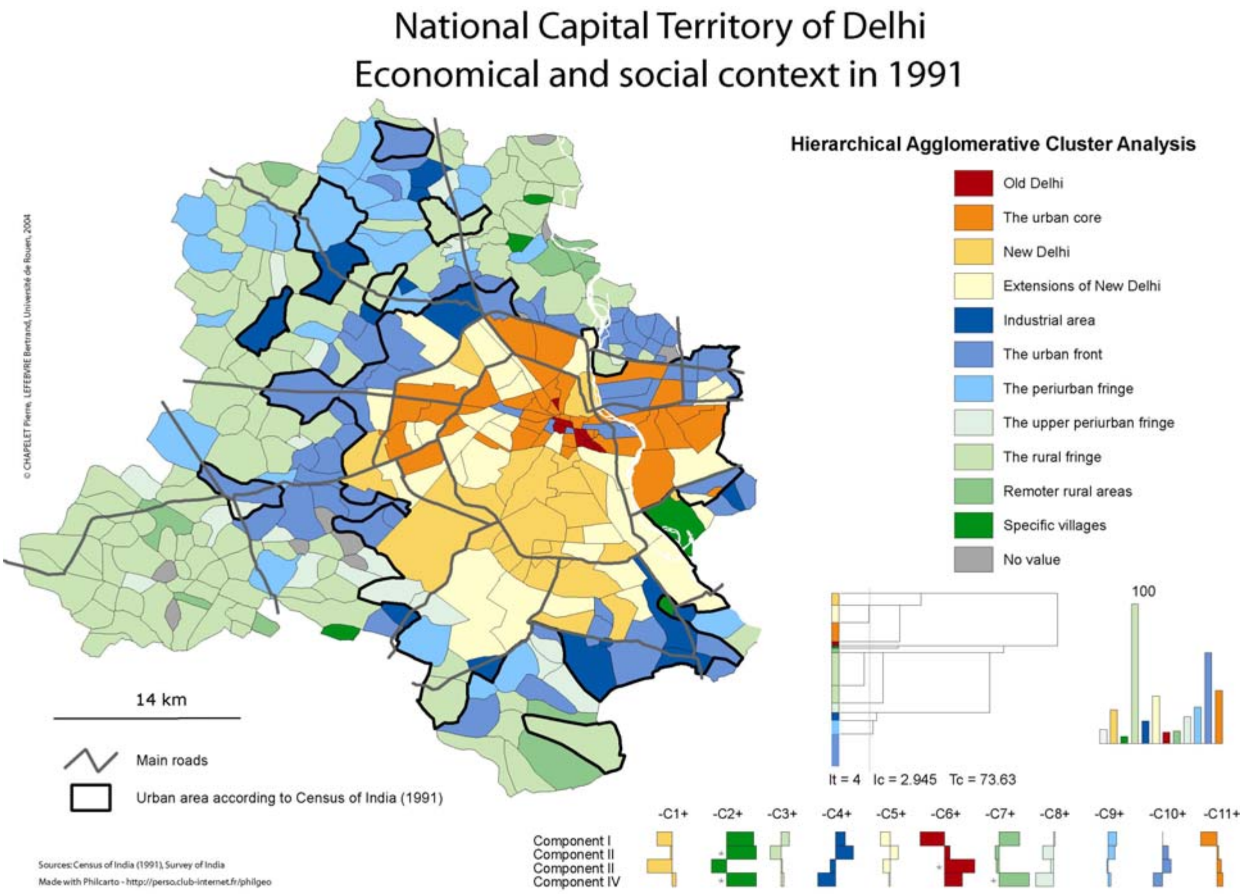
The remoter rural areas

These villages are close to the former profile but with much more intensity.

Specific villages

We find in this last category specific profiles from some spatial units with very few inhabitants. They are rural as per their activities but the social context is different from other villages.

Map 19



2. The healthcare system

i. Regional context

Before reverting to the National Capital Territory and its healthcare system, we shall first introduce the position of Delhi in a regional context in order to contextualize the healthcare situation of the Indian capital.

Using Census of India datasets, we were able to map the coverage of public and charitable hospitals in North West India in 1991 (**Map 20**). Again, if we have to be careful when using this data on health, we are much more confident about the number of public and charitable hospitals surveyed. 19 beds per 10 000 inhabitants is the North West urban system average. One can clearly see the differences, depending on the size of agglomerations: Agglomerations below 100 000 inhabitants have an average of 17 beds per 10 000 inhabitants; agglomerations between 100 000 inhabitants and 500 000 inhabitants have 26 beds per 10 000 inhabitants; and more than 500 have 22 beds per 10 000 inhabitants.

This map also clearly shows that the different state policies seem to matter in the spatial organisation of the public bed strength:

In the Himalayan states (Himachal Pradesh and Uttaranchal), the number of beds is very high when compared to the town sizes. This observation could perhaps be explained by the relative fragility of the urban system in these regions and by low density in rural areas leading to a concentration of public bed strength. The average ratio in Himachal Pradesh is around 104 beds per 10 000 inhabitants. In Uttaranchal the ratio is 30 beds per 10 000 inhabitants.

In Rajasthan (21 per 10 000 inhabitants), Haryana (18 per 10 000 inhabitants) and Punjab (21 per 10 000 inhabitants), the situation is more uneven. In Punjab, the bed strength seems to be concentrated at the top of the urban system. Amritsar, Jalandhar and Chandigarh (24) have greater public bed capacity. Some towns also present some very impressive rates, exceeding 56 beds per 10 000 inhabitants (Ambala…). In Haryana, the capitals of the southern districts, such as Rohtak or Hissar are well equipped when compared to the northern districts (Panipat, Sonipat…). Chandigarh being the official capital of Haryana and Punjab, perhaps the policy was to provide more beds in southern district capitals to balance the public bed capacity.

In western Uttar Pradesh (11 per 10 000 inhabitants) the bed coverage also presents contrasts. Some agglomerations like Aligarh and Bareilly are very well equipped in beds. In fact, some of the neighbouring towns are also well equipped. In Agra the number of beds per 10 000 inhabitants is very low. This situation is the norm in the north around Meerut, Moradabad and Saharanpur, where all towns, no matter of their size, have less than 14 beds per 10 000 inhabitants.

The situation in the Delhi Metropolitan Area is not very favourable in terms of public bed strength. Delhi (20 per 10 000 inhabitants) is above the average because its status of capital has favoured the establishment of many hospitals. But all the ring towns have a very poor bed capacity. The good ratio observed in Noida can be explained by the fact that this new ring town is the direct product of planning. This situation, coupled with the poor public capacity in Uttar Pradesh, probably explain why ten years after the 1991 Census, one third of the patients of the biggest public hospitals of Delhi come from outside the National Capital Territory[60].

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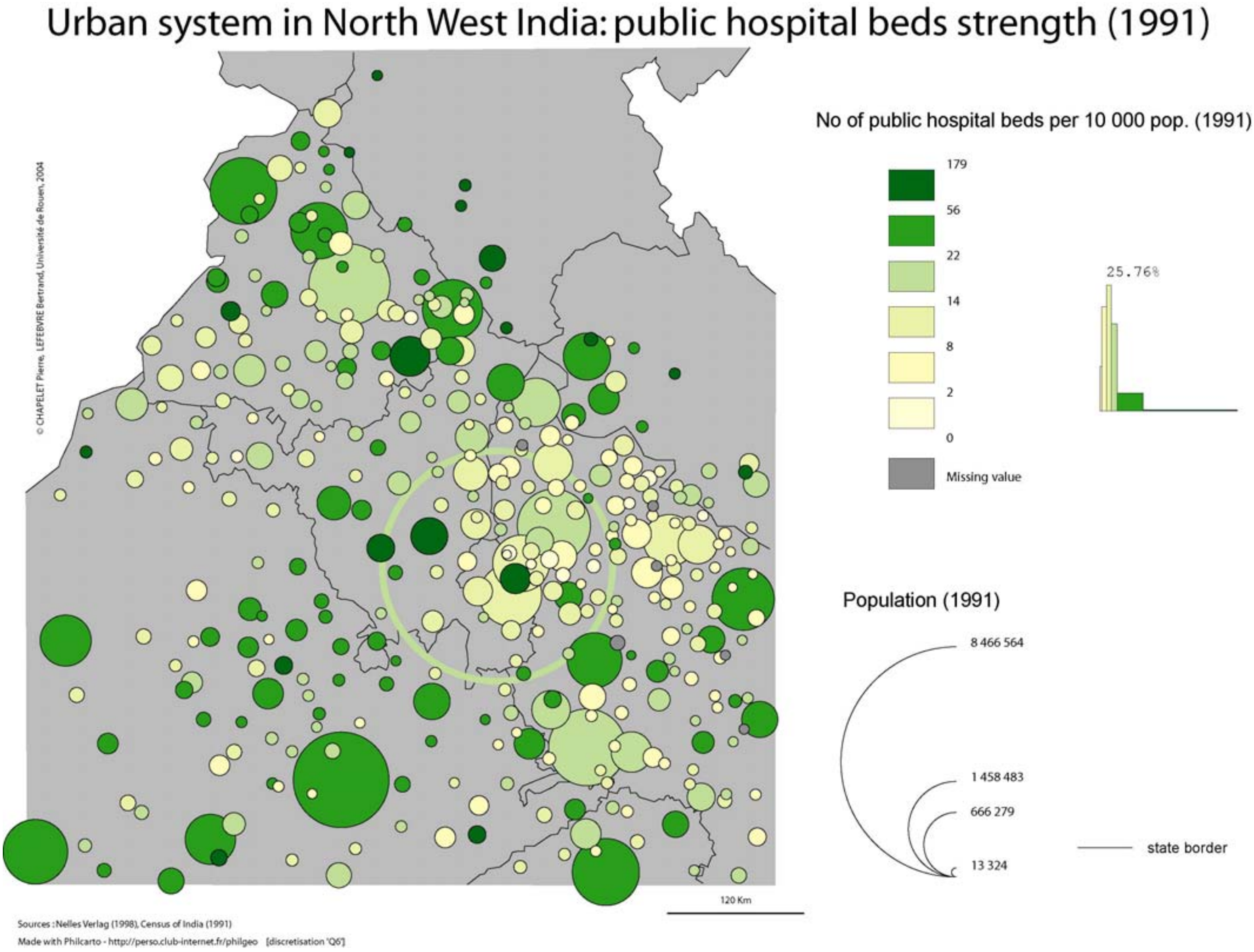
[60] Economic Survey of Delhi (2002). See (http://delhiplanning.nic.in/Economic%Survey/Ecosur2001-02/Ecosur2001-02.htm).

Map 20



ii. The NCT Healthcare System

a) The Health Scenario in the NCT

With a mortality rated around 6.6 per 1 000 inhabitants (India: 9) and a child mortality rate of 31.3 per 1 000 births (India: 72), Delhi's health is rather good in comparison with the rest of India. This situation is confirmed when looking at the per capita health expenditure. In 2001, it was around Rs. 436 (India: Rs. 180) and during 1999-2001, it rose faster in Delhi (+22.2 %) than in India (+17.9 %)[61]. As always when dealing with health issues, the average masks the huge gap that exists between poor sections of the population and the middle and upper classes.

Being the capital with an impressive economic growth rate (+8.5 % per year in 1994-2001), Delhi offers a wide range of health facilities. As mentioned earlier, Delhi has an impressive number of authorities and we find the same situation in public health: Central Government (through Ministry of Health and Family Welfare – MOHFW), Government of NCT, Directorate of Health Services (DHS), Delhi Municipal Corporation (DMC), New Delhi Municipal Council (NDMC), Employment State Insurance (ESI), Central Government Health System (CGHS), Northern Railway (NR), Delhi Jal Board (DJB), Delhi Transport Corporation (DTC)… They all manage their own infrastructure, composed of a network of dispensaries and hospitals.

In fact most public health policies are implemented by the Central Government via the MOHFW, the Government of Delhi and the municipal bodies. Even if the MOHFW manages several

[61] Economic Survey of Delhi (2002) ibid.

important public hospitals (Safdarjung, Dr. Ram Manohar Lohia…), the NCT government is really the key player in the public health sector. After becoming an Union State in 1993, the local government became responsible for health. Through the Directorate of Health Services (DHS), it manages not only hospitals and dispensaries but it also implements different health programs: the Mobile Health Scheme targeting the slum population, the School Health Scheme targeting children and other specific schemes targeting specific diseases (dengue, polio, hepatitis…) and malpractice (in application of the Delhi Nursing Home Act). The municipal bodies are managing their own healthcare infrastructure networks and also handle some schemes for children, mothers and slum dwellers (with the support of the World Bank). The DMC has the authority to build any new infrastructure (like any other commercial activity).

b) ***Location of Dispensaries***

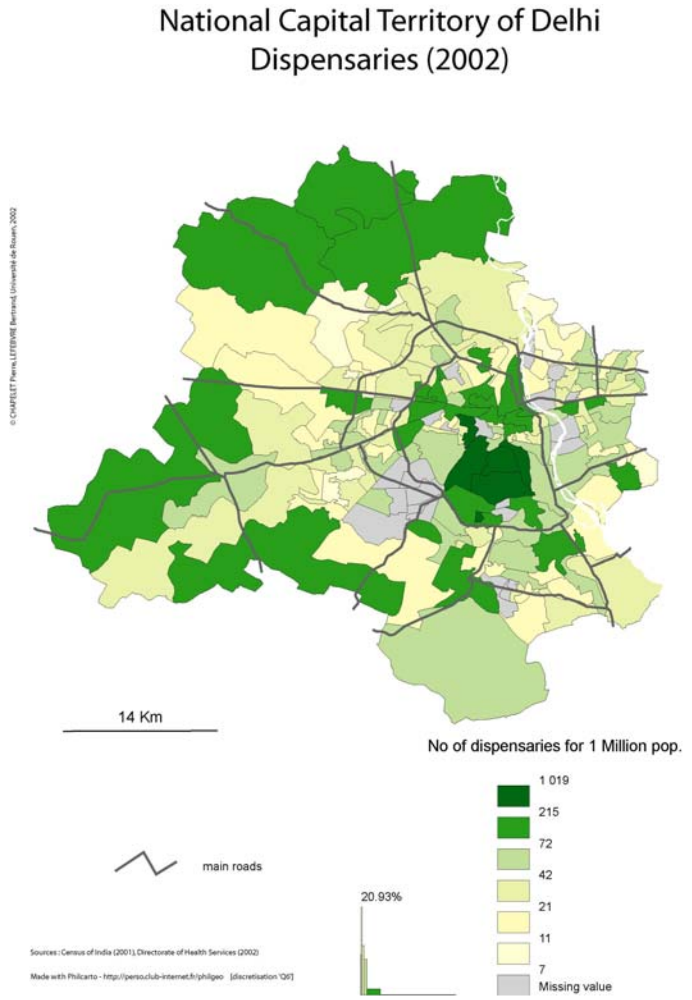
After the WHO conference in Alma Ata (1979), the central government announced the "Health for All in 2000" programme. To achieve this goal, local authorities made massive investments in primary healthcare. Primary Health Centres and dispensaries are the basis of any public health policy. They are the first entry point to get treatments and medicines from a small medical team, to broadcast some health prevention messages and education. According to the Economic Survey of Delhi, the total number of dispensaries has increased by 2.3 between 1977 and 2002 (from 352 to 808). According to the Directorate of Health Services, their number was 640 in 2002. This hiatus may be due to a different definition of dispensary. The Economic Survey most probably included other primary healthcare infrastructure like the one depending on the Mobile Health Scheme. Using our locality database we were able to locate 618 out of 640 dispensaries (error rate: 3.4 %). We then used GIS tools to calculate the total number of dispensaries per Census Charges (2001), so that we could examine the relation between population and dispensaries and the spatial equity in the covering of the population. Of course this analysis tells us nothing about the quality of dispensaries (commitment of the medical team, equipment…). We can also discuss about the size and delimitation of spatial units, which are not as accurate as for the 1991 Census (where is the rural area? where is the urban area?) but we preferred to use more updated demographic data (**Map 21**).

On an average there are 45 dispensaries for one million inhabitants in the National Capital Territory. New Delhi is very well covered (almost five times more than the National Capital Territory average). This is where we find the maximum value for 1019 dispensaries per million inhabitants A section of Old Delhi and its neighbourhood also has a very high dispensary rate compared to the population. This area stretches to the Civil Lines and the western urban belt.

As we go away from these two centres, the coverage decreases. Some Census Charges along the Yamuna did not have a dispensary as late as in 2002. The Trans-Yamuna area does not have an impressive cover, but in most cases it is above the average (around 60 per million inhabitants). In South Delhi the cover is also quite good in the concerned Census Charges (more than 50 dispensaries per million inhabitants). But once we cross the Ring Road to the west and the north, the situation turns out to be rather poor in terms of equipment. Most of the Census Charges are below the average.

Surprisingly, the decrease in the dispensary coverage stops as we come to the most rural census charges. The number of dispensaries per million inhabitants is at least the double of the average in these zones. In the case of the northwest census charges it is triple (145). What can explain this contrast between the rural part of Delhi and the fringes of the agglomeration? Perhaps the fact that this kind of in-between area is not in keeping with the Indian administrative tradition, where a spatial unit is either rural or urban: too close from the centre to be considered a deprived rural area, not too far from the centre (and what centre!) to benefit from a more equitable distribution program. If it is easy to open a new structure it is often difficult to close one and open it elsewhere.

Map 21



c) *Spatial Organisation of Primary Health Sector*

We have already noticed the diversity of players involved in public healthcare management. What are the spatial consequences of this multiplicity? Does it really affect access to health? Is there any specific spatial strategy for each agency?

Using the 2001 Census Charges, we agglomerated the number of dispensaries and calculated the weight of the dispensaries possessed by each player in the total. We defined four different kinds of actors: The municipal bodies (Delhi, New Delhi), the parapublic system (ESI, Northern Railways, Delhi Transport Company…), the Delhi Government and the Directorate of Health Services. We used a common legend for all maps in order to make the comparison easier between each type of actor[62] (**Map 22**).

The dispensaries depending on a parapublic agency are the most numerous (213, i.e. 35% of the total) but their mission is not to serve the entire National Capital Territory. Only company employees and their families have access to this infrastructure. Dispensaries are often within the place of work (bus depot, railway station…) or close to an industrial area. This may be why their presence is so weak in rural Census Charges. In more than one third of the Census Charges the parapublic dispensaries represent more than half of the total infrastructure. Their coverage is particularly good outside the Ring Road (South Delhi, Rohini). New Delhi and the Old Delhi centre are in a position similar to rural Census Charges.

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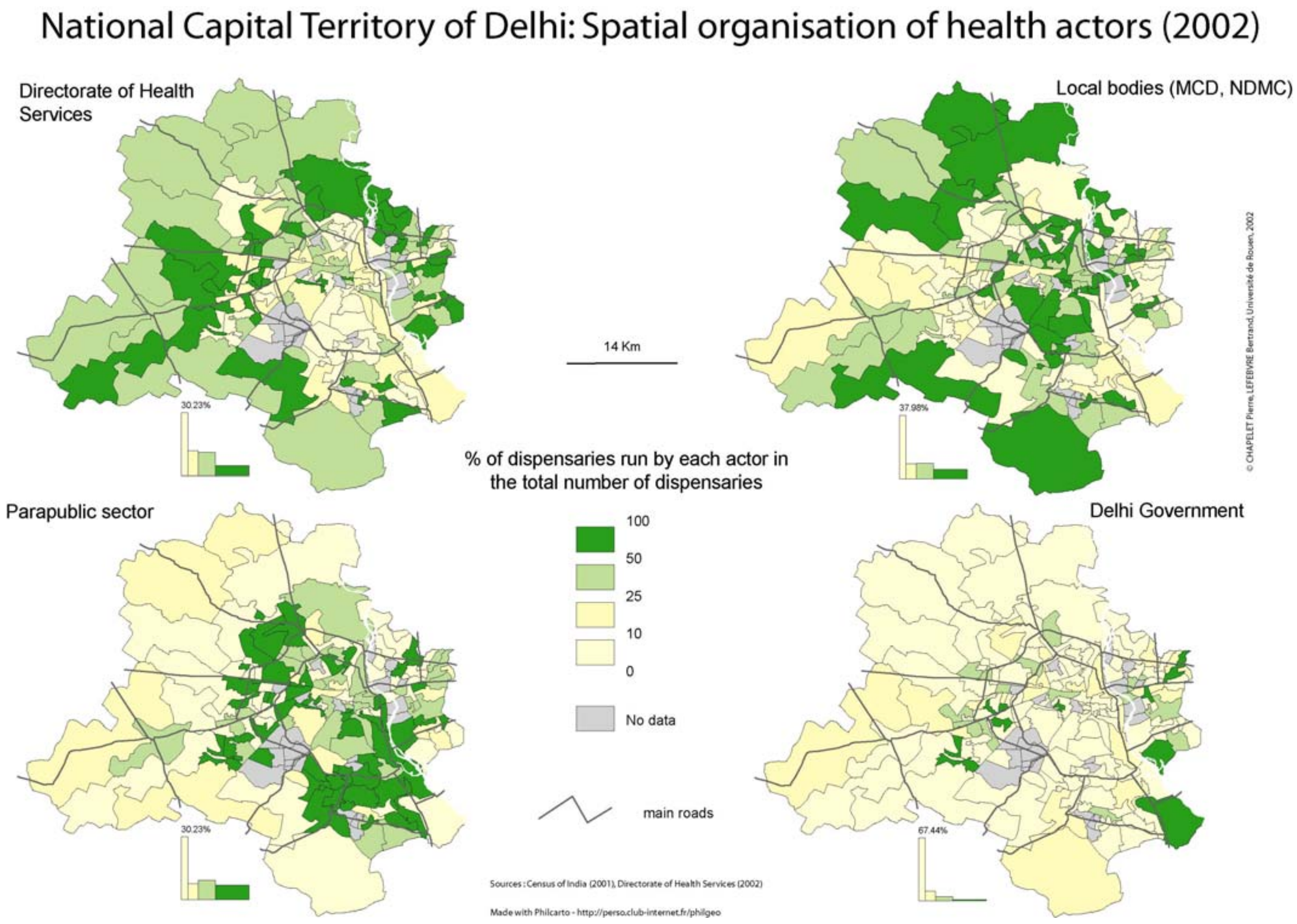
[62] In graphic semiology, legends must be created using common colors and value scales in order to enable visual comparison between maps.

The 189 municipal dispensaries represent 31% of the total number of dispensaries in the NCT. In one fourth of Census Charges, more than half the dispensaries are managed by a municipal body. If this result is close to the one found for parapublic dispensaries, the locations are different. This is particularly true for peripheral Census Charges (North West, South West, South) and the core of the agglomeration (New Delhi, Old Delhi).

The 156 dispensaries depending on the Directorate of Health Services (25% of the total) again have a different spatial organisation from the first two categories. Even if they are fewer than the municipal dispensaries in one fourth of the census charges, they also weigh more than half the total dispensaries. The DHS dispensaries are less concentrated than the municipal ones. Indeed, if only 10% of the municipal dispensaries are located in villages, this rate goes up to 20% for DHS dispensaries. Half the rural dispensaries are managed by the DHS. We have to keep in mind that the DHS is responsible for the application of Health for All programs. The DHS dispensaries are also very important for new urban fringes.

The Government of Delhi directly manages 59 dispensaries (10%). In two third of the Census charges the weight of these dispensaries is below 10%. In fact, no particular spatial strategy appears on the map.

Map 22



d) Location of Public Beds

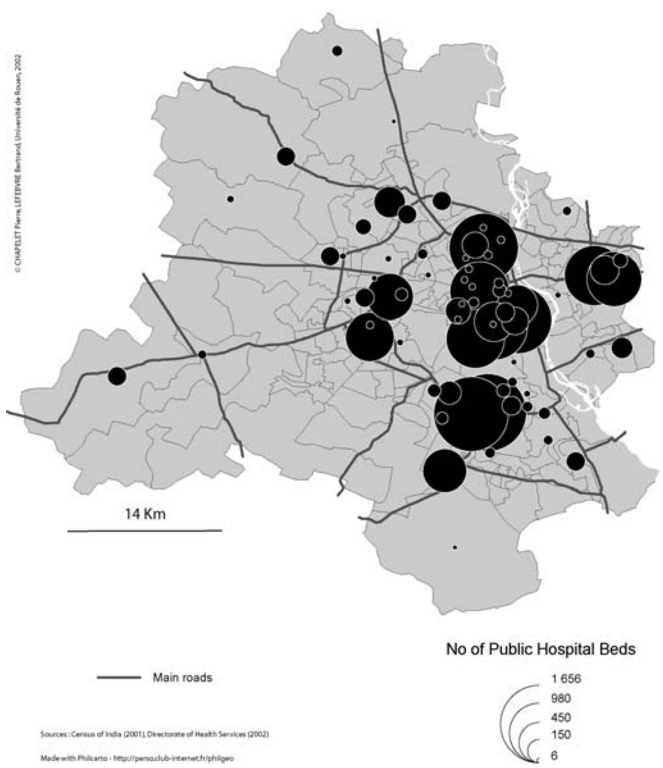
In the ideal healthcare system designed by the administration, hospitals are at the top of the hierarchy. According to the National Family Health Survey (1999), 19.4% of the population goes there to receive treatment, however serious the illness is. This infrastructure is not reserved only for emergency cases and surgery. The population seems to prefer going for treatment to this type of infrastructure than to dispensaries (9.4%): the reputation takes precedence over the pyramidal logic. This reinforces the idea of the problem of efficiency in the first line of public healthcare in terms of manpower and equipment management. They represent 16,581 beds, 60% of the total registered bed strength in the NCT. We did not include two military hospitals, as they are reserved for a specific population.

This map reinforces the idea of a centralised public system (**Map 23**). It may be less important for hospitals than for dispensaries. But in view of the expansion of the agglomeration, this question still matters as more and more inhabitants move to the periphery. Most of the public hospitals in Delhi are a legacy from the British Raj (Lady Hardinge Medical College, Irwin Hospital…). More than fifty years after the independence, is the location of these hospitals still the best in terms of access and equity? The problem is just that the peripheral hospitals are few and maybe too small. The question is also about genuine cooperation between hospitals. The AIIMS hospital is under the direction of the ESIC and the Safdarjung is under the Directorate General of Health Service.

From central government to municipal bodies the number of key agencies involved in public healthcare makes an integrated health system quite impossible. Each agency limits its concern to its own healthcare network (dispensaries, hospital) without any regard for the others. Their lack of coordination has led to a concentration of public infrastructure in the core of the metropolis, which does not meet the spatial equity objectives claimed by the different agencies. As we shall now see, this situation is reinforced by the spatial strategy of the private sector.

Map 23

National Capital Territory Of Delhi
Public Hospital Beds (2002)



e) <u>The Private Sector</u>

As all over India, the private sector is omnipresent in the NCT[63]. According to a NFHS report[64], 70% of the population prefers the private sector for healthcare. 52.6% visits a private general

[63] For an overview of the private healthcare system, see (BARU 1998).

practitioner (GP) when they are sick. The Private sector has a good reputation compared to the public sector and is growing quickly. Hence, the number of registered Nursing Homes in the NCT increased by 5.4 between 1982 and 2002 (from 85 to 460 nursing homes). Every new nursing home is supposed to conform itself to the regulations set by the Delhi Nursing Home Act. But many nursing homes and GPs are not registered. According to a study conducted by the Directorate of Health Services in 2003, the number of unregistered Nursing Homes is close to 1 600[65]. Most of them are small and have limited facilities. Of course it could be considered strange to present results which do not represent the reality of the private nursing home market. But we can assess and put forward the hypothesis that registered Nursing Homes will show the same trend as any test population. If we cannot a priori guarantee the quality of this test population in terms of representativeness, we have to nevertheless rely on this sample, as it was the only available at the time of writing this paper. Furthermore, we conducted fieldwork in September 2004 in different parts of the city based on the typology previously described and we are now verifying the relevance of this test population across the city[66].
The total number of beds is about 10 978 in the private sector (40% of the total registered beds strength). The average number of beds in a nursing home is around 24 but the median is around 10, meaning that 50% of the 460 registered nursing homes have less than 11 beds. This value is probably underestimated because of the unregistered sector.

The table below (**Table 6**) presents the distribution of the nursing homes according to their bed strength. 60% of the nursing homes have less than 15 beds representing 10% of the total private bed strength. 91% of the nursing homes have less than 50 beds. They represent only 51% of the total registered bed strength. The concentration of the private bed strength is certified by the fact that 2% of the Nursing homes weigh 34% of the total bed strength. This organisation confirms and follows observations in other metropolises like Mumbai[67]. Small structures require less investment and less manpower and are therefore growing faster compared to others.

Beds size	Nb Nursing homes	Nb beds	% Nursing Homes	% Beds
<5	41	147	9%	1%
[5-10[	136	899	30%	8%
[10-15[	99	1 045	22%	10%
[15-20[	64	1 029	14%	9%
[20-30[	59	1 328	13%	12%
[30-50[	31	1 123	7%	10%
[50-100[	12	780	3%	7%
[100-200[	7	887	2%	8%
[200-610]	11	3 740	2%	34%
Total	460	10 978	100%	100%

Table 6 – Profiles of Nursing Homes in the National Capital Territory

Source: Directorate of Health Service, NCT Government, 2002

However, Delhi is also becoming an interesting market for corporate hospitals such as Apollo, Escorts or Fortis and Max. How does the private sector cover the National Capital Territory?

f) Spatial Organisation of the Private Sector

64 IIPS and ORC Macro (2002), *National Family Health Survey (NFHS-2), India, 1998-99: Delhi*, IIPS, Mumbai, 296p.
65 Interview with Directorate of Health Services authorities, conducted by Bertrand Lefebvre, April 2004
66 Survey conducted by P. Chapelet in September 2004. This will allow us to check whether the quality of this database varies according to the socio-economic status of areas across Delhi.
67 See (YESUDIAN 1994).

Again we have to keep in mind that we are only using the registered nursing homes, which can create a bias in the final interpretation. We will first study the nursing home sites and then look at the distribution of bed strength (**Map 24**).

Not surprisingly, the rural area is not at all covered by registered private nursing homes. Some peripheral Census Charges have no registered nursing homes. However, according to the NFHS survey 18% of the villagers interviewed go to this type of infrastructure when they need treatment (NCT average 16%). So we can make out that this population living on the periphery have to move to the agglomeration. But even within the agglomeration, the distribution of nursing homes is leaving large area without any registered nursing homes.

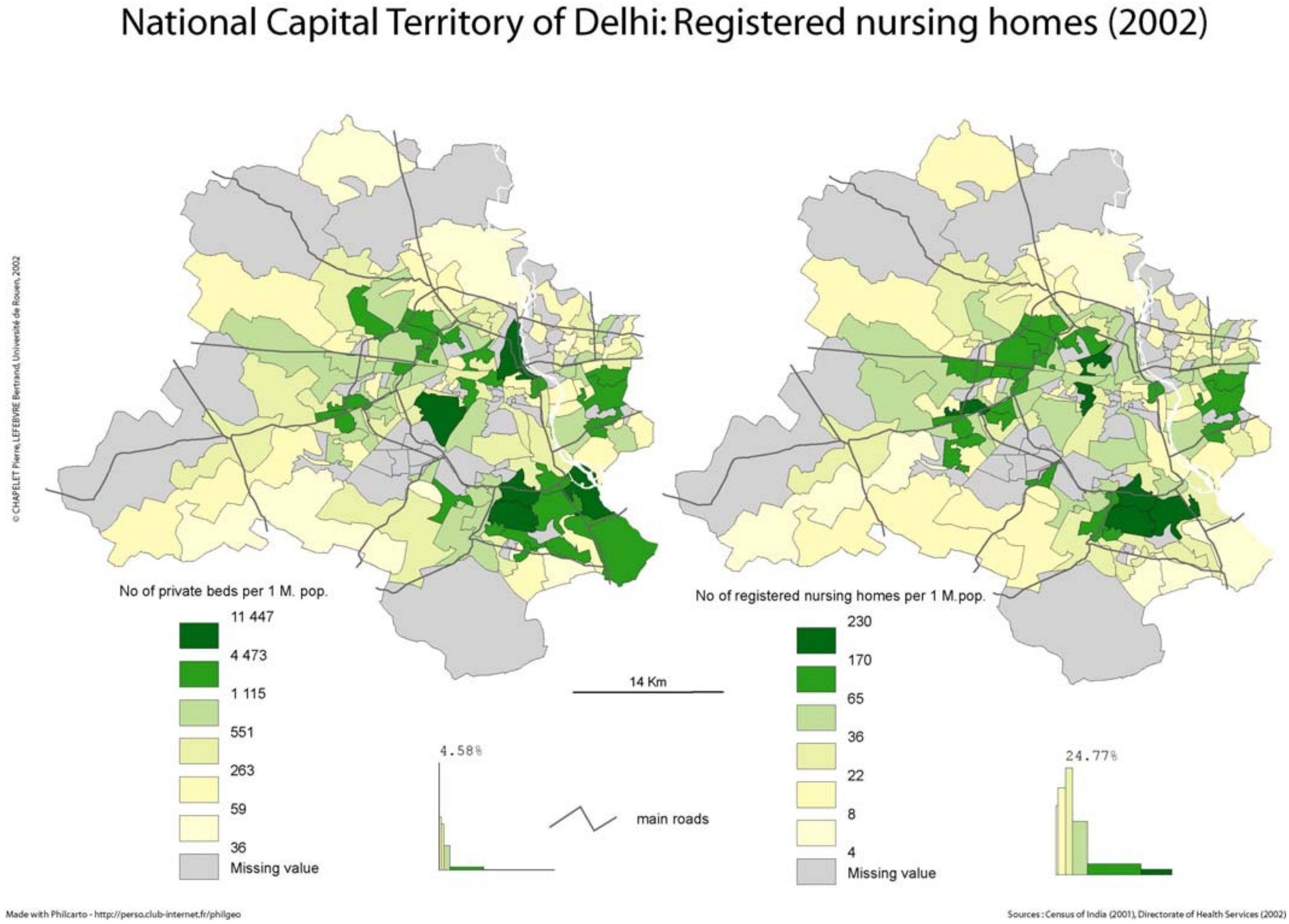
The South West, the North and a large section of the Trans-Yamuna area have coverage below the NCT average (33 nursing homes per 1 M. inhabitants). Surprisingly, New Delhi is not attractive for nursing home stakeholders. The lack of land, competition with high value activities (CBD…), and the presence of most of the administrative buildings, are curbing the development of nursing homes. The land is the big issue in terms of investments and profitability. The DDA should also be more active in New Delhi and ensure that the nursing homes sites are in the right location.

Nor is Old Delhi in a better position. Some Census charges do not even have a single registered nursing home. Shahjahanabad is in dilapidated surroundings. The representation of a space is an important element, which explains why a nursing home will open in a place or not.

Finally, South Delhi seems to provide a friendly environment for nursing homes. As already noticed in the 1991 Census data, this area welcomes middle-class population. This segment has enough money to choose the private sector. The money attracts health professionals who settle close to their customers. We find the same phenomenon in the North West area between the Ring Road and the Outer Ring Road. Again, this space has a middle class population.

The spatial organisation of the private bed strength is similar to the one observed for the nursing homes location. The rural area and the urban front are still being covered. The average in the NCT is around 794 beds per 1 m. inhabitants. Only 41 Census Charges are above this average. The statistical concentration of beds also holds with regard to space. The territory is also different. The advantage goes to Census Charges with big hospitals. In South Delhi, nursing homes seem to be bigger in terms of beds. The presence of big hospitals like the Apollo (610 beds), the Escorts Heart Institute (210 beds) reinforces this point. It is the same for the Shri Ganga Ram Hospital.

Map 24



g) *Comparison of Spatial Strategies*

To study health issues in their social and spatial dimension we would now like to use the results of the urban typology previously developed.

The first constraint concerns dates, as more than ten years separate the health infrastructure data and the Census results used for the typology. In the coming year we of course plan to use the results from the last 2001 Census. However, the comparison is still very interesting given that the time gap introduces a dynamic angle: After ten years, what is the situation of the health infrastructure in peri-urban areas or in the urban front of 1991.

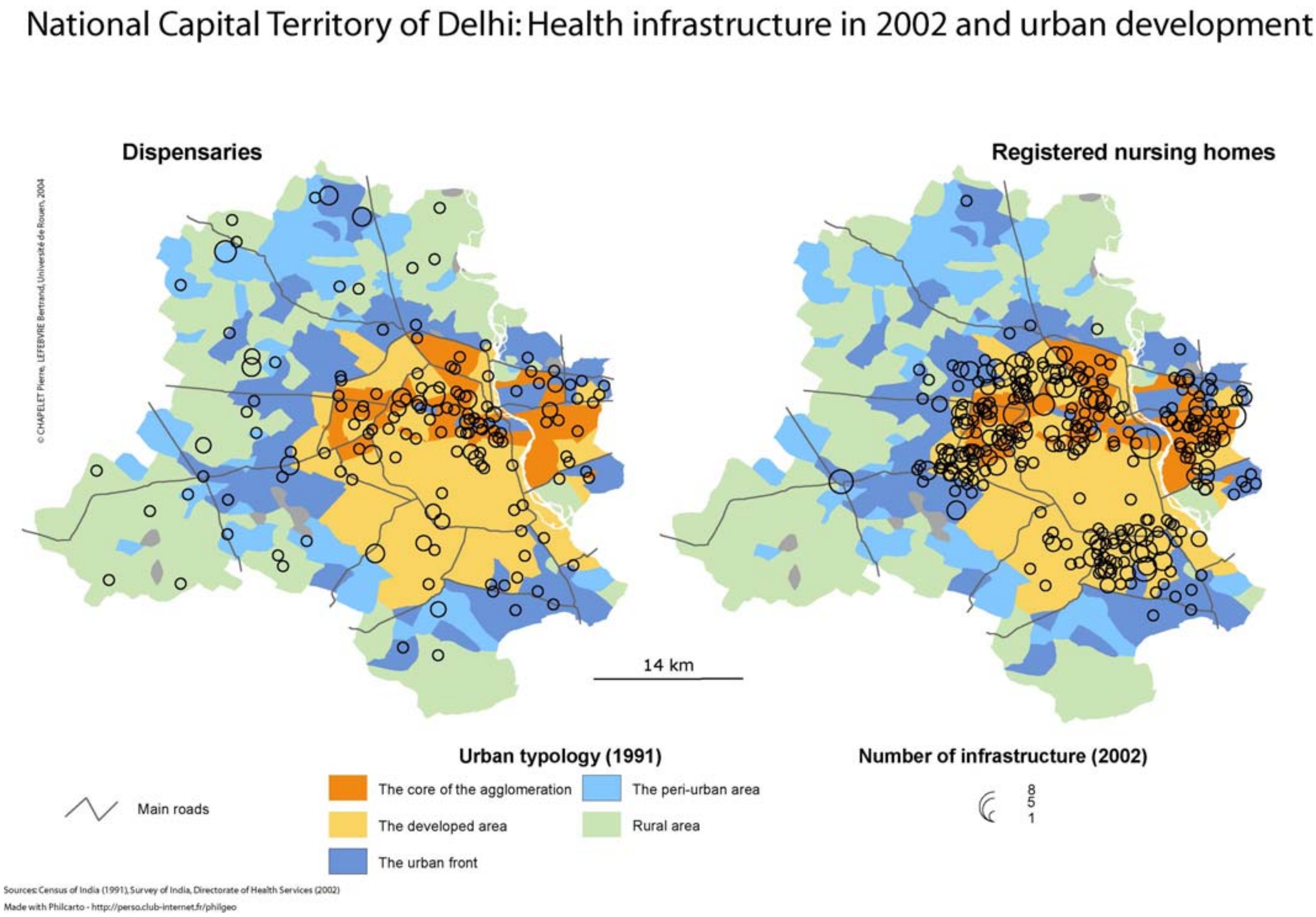
Based on the Hierarchical Agglomerative Cluster Analysis previously presented and its eleven classes, we did reduce the typology down to five types of area by comparing the average profiles and specificities of each class. Finally, the remaining classes are as follow: The rural area, the peri-urban area, the urban front, the core of the agglomeration and the developed area. To make the comparison of the spatial strategy easier and more accurate, we used our locality database as a unique entry point in our GIS for these two datasets.

We compared the number of registered nursing homes and the number of dispensaries to understand their respective strategies at their own location level (**Map 25**). What is their strategy on that point?

Firstly, even if their number is smaller, dispensaries provide a more regular coverage of the NCT than registered nursing homes. Private nursing homes appear to be an exclusive urban activity when compared to the dispensaries and their "Health for all" mission. Within the urban agglomeration itself, we can also observe some differences: Old Delhi is not attractive for private nursing homes contrary to dispensaries. On the other side, South Delhi, where dispensaries are few, is a hotspot for private nursing homes. We encounter more or less the same situation in the Trans-Yamuna area or the Rohini area.

Still ten years later, the urban front of 1991 is not very well covered by dispensaries or by registered private nursing homes. We can observe few diffusion processes at work, along Rothak road for instance, or on the fringe of south Delhi. But there are still very few registered nursing homes on the urban front. The peri-urban area also lacks public health infrastructure. If the regular private sector is deficient so are the dispensaries.
Finally, the in-between situation we have already mentioned is confirmed with greater accuracy. A more exact dispensary location coupled with the use of urban typology helped us to represent the shortage of dispensaries in the urban front. It is probable that given the absence of spatially fixed structures providing basic health facilities, the public authorities are relying on alternative solutions such as the Mobile Health scheme, to make up for this.

Map 25

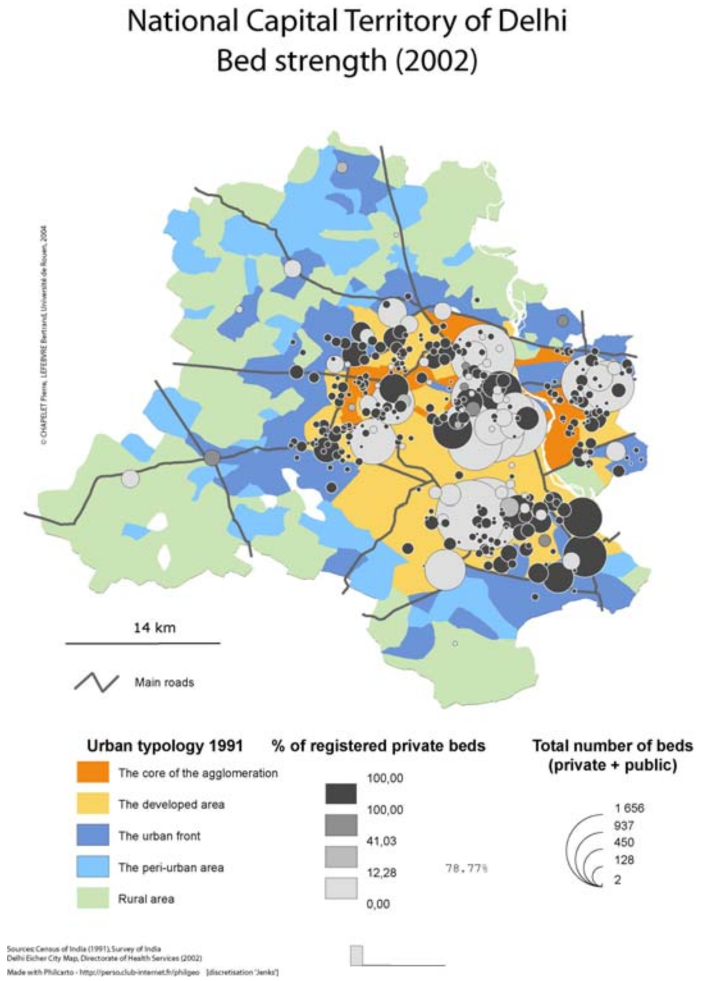


h) ***Influence of Public Healthcare on Private Healthcare Locations***

The comparison of the spatial strategies of public and private sectors might be more relevant if we compare the nursing homes and the public hospitals, as they both offer the same level of health services. The total bed strength by locality is also a good indicator of its specialisation in the medical sector. What's the weight of the private sector in this supply?

The general organisation of bed strength is not very new (**Map 26**): the centre and three peripheral localities (Shahdara, South Delhi, North West of the agglomeration) corner most of the beds. Wards with the highest number of beds are the ones with big public hospitals. The periphery, either rural or urban, is completely devoid. We can notice the formation of areas where the bed offer is important. The neighbourhood effect works perfectly to explain this concentration of private beds. Perhaps more interesting are the nebulas circling around the localities hosting big public hospitals: Public hospitals attract some small private nursing homes in their vicinity. The reputation of hospitals attracts other medical professionals in their surrounding. In a health planning posture, this link between public and private sector locations could become a powerful weapon to fight the concentration of the healthcare system. If the private sector follows the big public hospitals, perhaps the authorities should erect a new public hospital on the periphery, particularly on the fringes of the urban agglomeration.

Map 26



iii. A large scale analysis: Gurgaon

After this brief overview of the healthcare system at the NCT and northwest scales, we were able to build up an initial picture of its spatial organisation. In order to better grasp the reality, we will now zoom on a large scale to better understand the spatial logics of the players involved. This close look will enable us to identify the healthcare players with greater precision, from general practitioners to medical shops and specialists. In order to do so, we could have taken any area in the NCT. However, given the spatial structure of the Delhi agglomeration (described earlier), we decided to focus our attention on a peri-urban area. Indeed, this area is at the heart of the most dynamic settlement processes, whether considering population or healthcare infrastructure. As we shall now see, Gurgaon is perfect for this purpose.

a) Presentation of Gurgaon

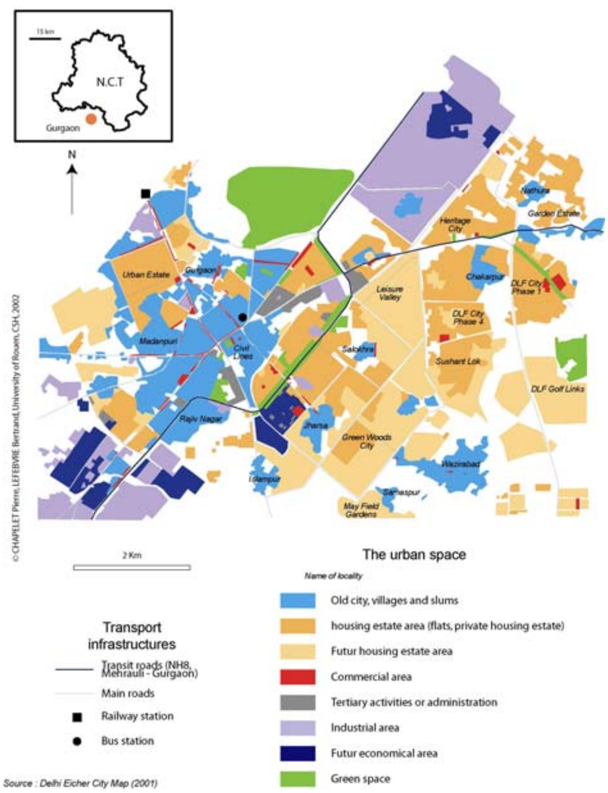
Gurgaon is a town like many others that surround Indian metropolises (Navi Mumbai, Salt Lake (Kolkata), Withfied (Bangalore), Madhapur (Hyderabad)). At thirty kilometres from New Delhi, along a National Highway (NH 8), Gurgaon, the district capital, has some 230,000 inhabitants (2001). At the end of the eighties, the Harayana Government decided to better control the development of Gurgaon. Under the management of HUDA (Haryana Urban Development Authority), planned urban development was endorsed. One of the main objectives of the real estate developers was to tap Delhi's middle class. The green area and the ecological preservation concepts were used to attract customers. In the urban plan, 10% of the area is expected to become either park or garden. Gurgaon, because of its distance from Delhi, is also offering cheaper lands, a major factor of attraction for potential commuters driving by car daily to New Delhi or South Delhi. It is also interesting from a sociological point of view to note the commercial strategies of promoters trying to give feel of the United States of America to their projects with names such as "Beverly Park", "Ridgewood Estate" or "Garden Villas"[68]. The planners also tried to develop economic activities, to attract Foreign Direct Investment and global companies (Honda, Daewoo, Nestlé…) because of its location close to the national and international airports.

But behind the scene of this ideal "global township", reality is not so bright. The water shortage and power cuts are only two of the main problems. The development of the city was not successful until recently. Some unauthorized buildings were razed to the ground. Moreover, the contrast between the real estate projects and the rest of the agglomeration is also creating difficulties in terms of social segregation. This contrast is particularly clear on the map (**Map 27**): on one side of the NH 8 we find the "Indian town", the typical district capital with its bus and railway station, its dense commercial centre; on the other side, a well-planned project with straight avenues and shopping malls is emerging.

Finally, Gurgaon is a good example of the urban fragmentation phenomena: fragmentation between an old and a new city; land use fragmentation inside the new planned city; socio-spatial segregation; various mobilities and metrics between local inhabitants and daily commuters. We are clearly in Bassand's definition of the effects of metropolisation on segregation[69].

Map 27

Gurgaon: a dual city?



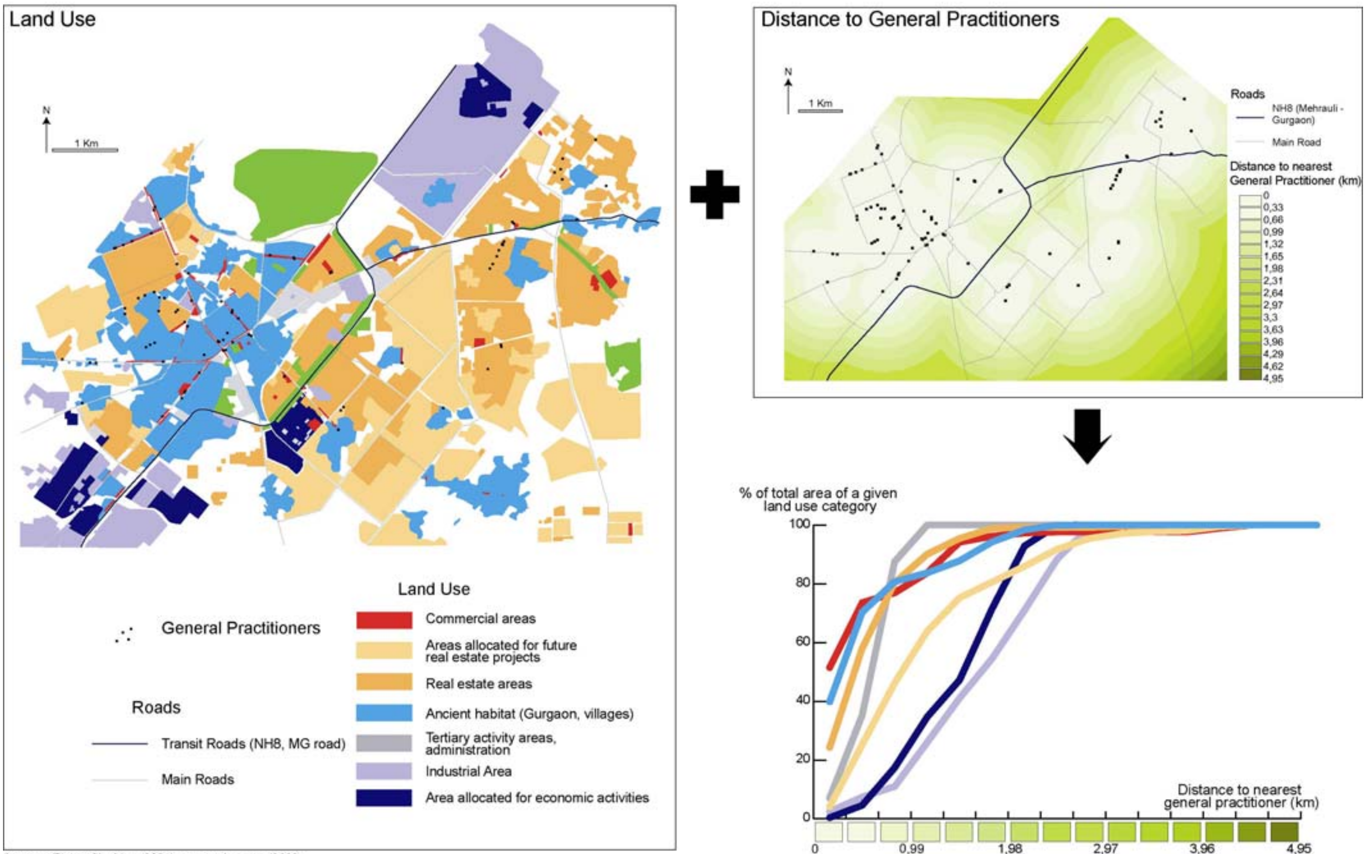
[68] See (KING 2002).
[69] See (BASSAND 2001)

b) Healthcare players and land use

In the context of metropolitan fragmentation, where are the healthcare system actors located? This question is all the more important as in India there is no legislation constraining private healthcare infrastructure, such as general practitioners or medical shops, in their location choice. Does the divide that seems to split Gurgaon also affect the healthcare system? Does its location reinforce such fragmentation? The emerging solvent demand has sharpened some appetites perhaps.…

To answer these questions, we developed an analytical method crossing two layers of information collected during our fieldwork: a land use typology taken from the Delhi Eicher City Guide 2001 and a location database for each actor. From these two layers, we generated a graph showing the attractiveness of each kind of land use for a given actor, enabling us to gauge the extent to which urban environment can influence its establishment.
Figure 5 illustrates this technique in the case of general practitioners. We can see on the graph that 75% of the commercial areas are at less than 600m from a general practitioner. On the contrary, industrial areas do not attract general practitioners as much as commercial areas do: less than 10% of these areas are at less than 1km from a doctor.
Figure 5

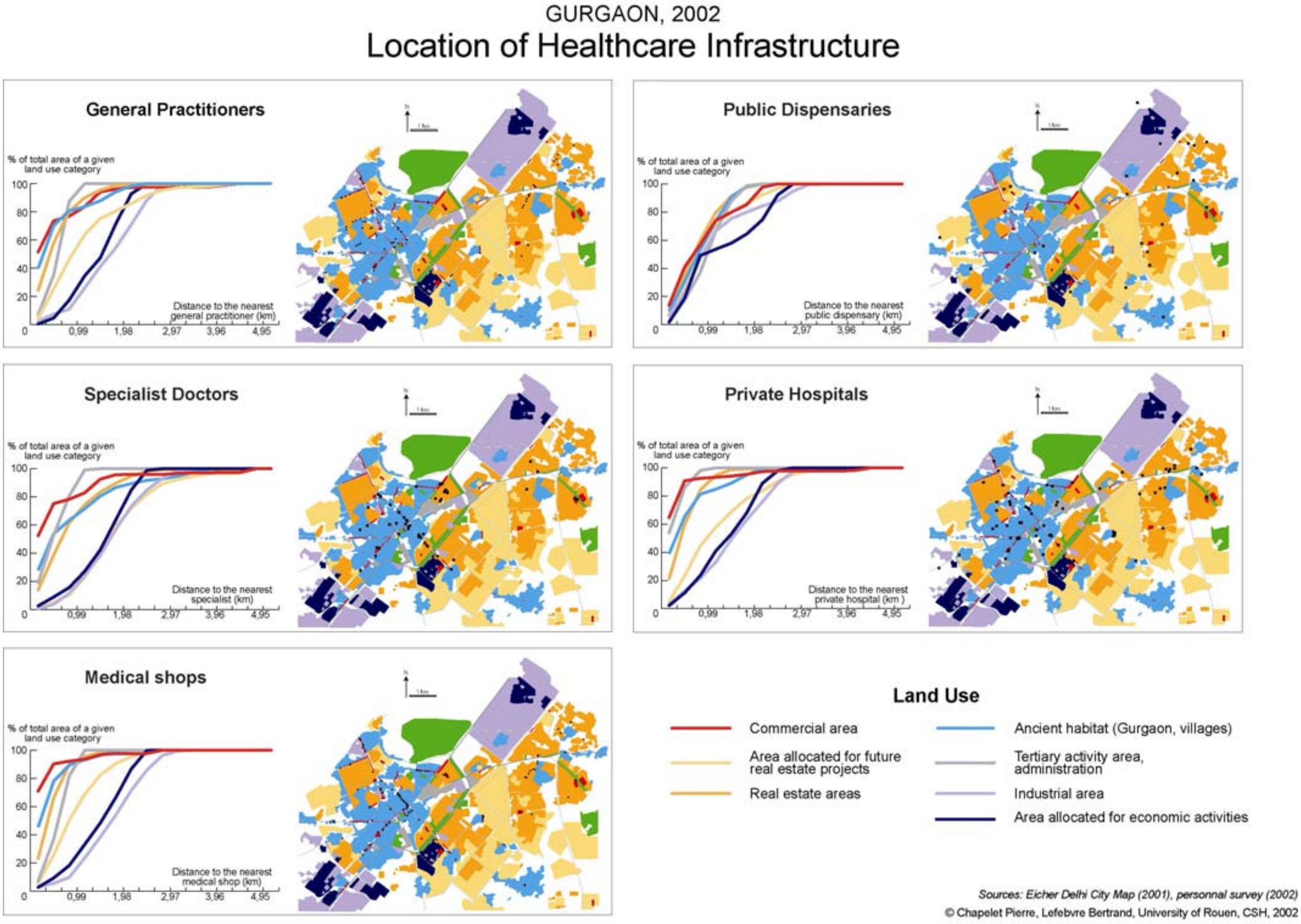
LOCATION OF GENERAL PRACTITIONERS - GURGAON, 2002
Distance to General Practitioners and Land Use



Sources: Eicher City Map (2001), personal survey (2002)
© Chapelet Pierre, Lefebvre Bertrand, University of Rouen, CSH, 2002

Applying this analysis to each actor, we can highlight the different localisation strategies (see **figure 6**). Using these graphs, another possible way to look at localisation strategies is to classify each land use category according to its potential attractiveness/repulsion for healthcare system actors (see **figure 7**).

Figure 6



Looking at these figures, industrial areas (developed or undeveloped) have a really limited attraction when considering healthcare infrastructure. Often, around 20% of these zones are at less than a kilometre from an infrastructure. Spaces made viable for future real estate are better served. Generally, nearly 60% of this kind of land is less than a kilometre from a health facility. If the lack of patients in these zones is still a handicap, the development potential could attract certain actors. The private healthcare strategy followed by professionals is not to precede demand but to follow it.

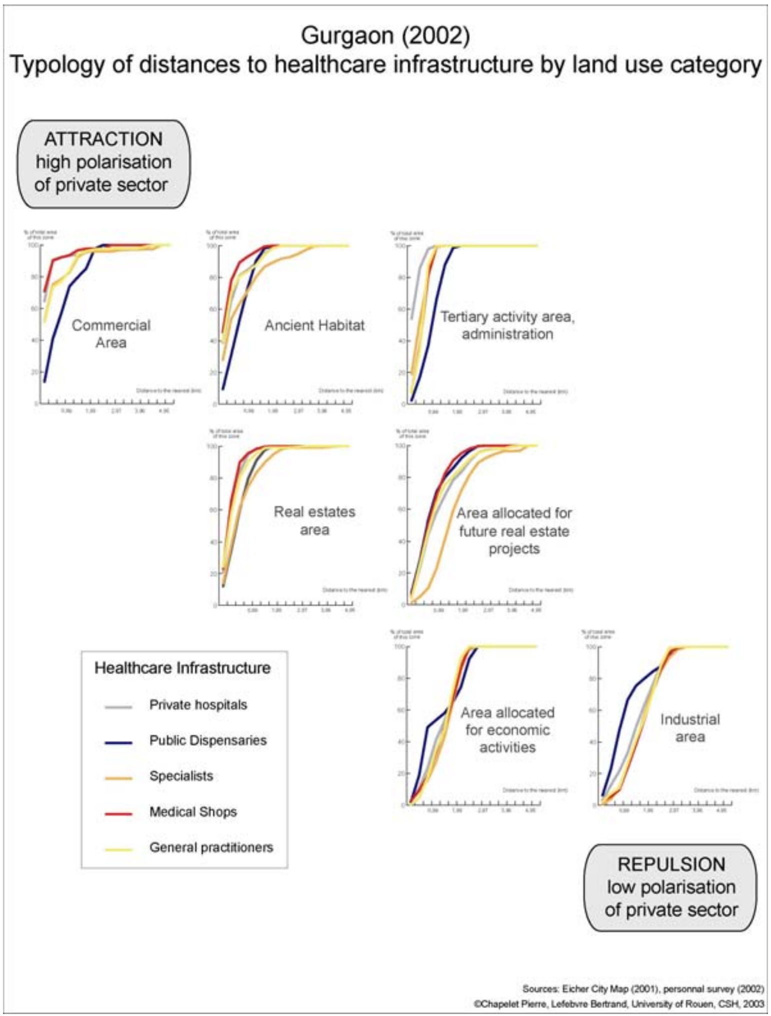
This could suggest why areas developed by real estate promoters are attractive. Twenty years after the first building sites, 60% of this kind of habitat is at less than 600m from a healthcare infrastructure. It is especially very clear with regard to medical shops, general practitioners and private clinics. This last category is authorized to establish itself in the new part of Gurgaon. However, it must meet the norms fixed by HUDA: each sector is equipped with plots for three to four clinics and one maternity[70]. The construction of a specialised hospital is conditional to the hospital reserving 10% its beds for the underprivileged.

We can also imagine that for a general practitioner or small clinic owners, the place of work is often the place of residence. Because of their incomes and social status, they belong to the middle class and are therefore targeted by real estate promoters. This hypothesis of a mix between place of work and place of residence is reinforced when looking at their significant presence in the old township. 60.7% of general practitioners are found in the old city.

70 http://www.huda.nic.in

Globally, healthcare system players find the old habitat space really attractive: 70% of its area is at less than 600m from a healthcare facility. This could be explained by the overlapping of the old habitat and the commercial areas, which polarise the healthcare offer. 70% of the commercial areas are at less than 330m from a medical shop and 56% of the medical shops are in commercial areas. This observation merges with a study conducted in Coimbatore (Tamil Nadu) on spatial diffusion of medical shops in the city[71]. Tertiary activity and administrative areas are also very attractive poles for clinics and specialists. This environment, whether commercial or tertiary, seems to indicate that healthcare professionals favour circulation spaces, playing on the interaction with other services. Residential areas are also attractive for healthcare providers, particularly general practitioners. It is perhaps an expression of the desire to be near customers as suggested by R. Bhat[72]. 91% of the physicians interviewed by him in Ahmedabad were of the opinion that the correct choice of a residential area could be very good for turnover, as distance and cost is much less for the patient. It is in fact very interesting to now compare the situation of previously observed actors with public sector actors. The graph for dispensaries indeed shows a totally different picture: within a radius of 600m none of the different kinds of urban land use categories are privileged. Even industrial areas are not too far, perhaps because of the ESI dispensaries[73]. Finally, spatial distribution of public health infrastructure, such as dispensaries, seems to tend much more toward spatial equity.

Figure 7



71 See (CHAPELET 1998)
72 See (BHAT 1999)
73 The Employment State Insurance (ESI) is an agency giving access to healthcare for employee paying fees and their family.

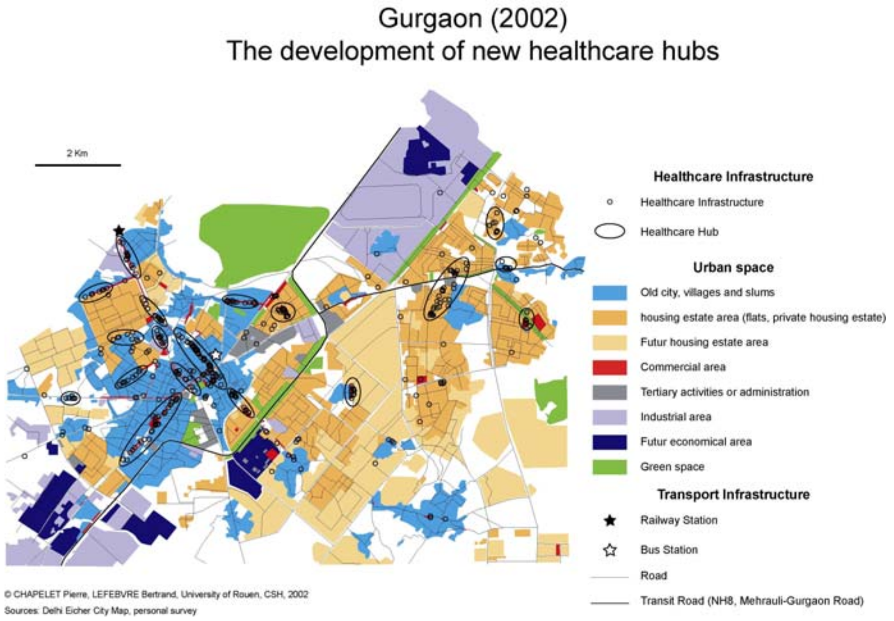
c) *Towards emergence of healthcare hubs*

Plotting all the healthcare infrastructure on a single map shows the global spatial setting of healthcare system players and reveals the Gurgaon's duality, by opposing the old city on the west of the NH 8 with the new city on the east flank (**Map 28**).

The old city, a commercial as well as an administrative zone, located between the railway station and the bus stand, shows a plethoric and diversified number of healthcare actors. Focusing on this area, we note a concentration of actors around main healthcare facilities, such as general hospitals or maternity hospitals. These locations indicate spatial strategy aimed at attracting customers. In the downtown area, we also note the medical specialization of some neighbourhoods. In a residential area like Madanpuri, we find general practitioners and private clinics. A commercial area such as Subhash Nagar (particularly along New Railway Road) has more than 20% of Gurgaon's medical shops.
Nevertheless, even if the density of healthcare actors in the new city is less, six health hubs have however emerged in the last twenty years.
Focusing on DLF, the number of health professionals is not as impressive as in downtown Gurgaon. If there is diversity, we can however observe the specialization of certain axis. On the west side of Chakarpur we find a street with only doctors (8). Between the Mehrauli-Gurgaon road and DLF Phase 1, a commercial centre has a concentration of clinics around it. Numerous healthcare facilities locate in an interface position between village hubs (Chakarpur, Nathupur, Sikandarpur Ghosi…). Given the mitigated success of DLF; do professionals prefer proximity to already well-established residential areas, waiting for better days? The similar situation that can be found near Salokhra village makes this hypothesis credible.

If a dual pattern is evident from the geography of healthcare in Gurgaon, the polarity observed is the inverse of the neighbourhood standing. The old city remains the prevailing pole of healthcare infrastructure. Its inhabitants have easy access to a diversified offer. On the other hand, in the new city new poles are slowly emerging. Of course these residential areas are relatively new with a motorized population able to move easily to other healthcare hubs. The Marxist rhetoric underlying Sujata Patel's analysis of the dualisation of Indian urban space[74] should not lead us to think that links are broken between globalized enclaves on the one hand and an irremediably sinking Indian city, on the other. The spatial repartition of healthcare infrastructure demonstrates that, potentially, the old city still can afford to capture the middle class and its wealth.

Map 28



[74] Talk given on the impact of globalisation in Mumbai, Department of Geography of Rouen, December 2001

CONCLUSION

After a brief introduction to the GIS and its use in India in the field of social sciences and health studies, in the last part of this paper we tried to compare the spatial organisation of the healthcare system with the social and economic context in which it takes place. The results briefly presented confirm the relevance and the need for such an approach. The spatial angle used in our research gave us a rejuvenated knowledge of the social dynamics of the Delhi metropolis and of the healthcare delivery system. We were able to picture how they both adjust to one another. Moreover we raised the question of efficient metropolitan public health governance.

Still we have to be modest about the results we have presented. There are too many biases with regard to data and the spatial units for us to be completely satisfied. However, as mentioned previously, the main objective of this contribution does not lie in the analysis of the results but rather in the introduction to the GIS tool we developed. We especially wanted to share our own experience of developing a GIS in the context of a fast-growing Indian metropolis. Three main points have to be learnt from this project.

The first important issue is about feasibility. We faced many difficulties during the development of the GIS. The poor quality of mapping cover and the redrafting of borders in metropolitan territory can be dissuasive. The out-of-date data and sometimes the difficulty of procuring it can be discouraging for the development of the GIS. The "Urban Mapping Scheme"[75] under the aegis of the Ministry of Urban Affairs will probably solve this problem in the future. As there were only two persons involved in the making of the GIS, time investment was intense. Still this project was a useful and challenging one. The results we presented are maybe not original in the field of urban studies or healthcare geography. But they provide a depth of knowledge of a territory, its dynamics and the problematic attached to it.

The second main issue is about the methodology. Thanks to a multiscalar approach and the data exploratory analysis, we tried to control and reduce the errors originating from our GIS. The results can always be balanced with a broader perspective. The changes of scale, through contextualisation, help to rethink a phenomenon in comparison with another. The GIS, by its ability to cross layers of information, allows us to shed a new light on the spatial dimension of different phenomena. In the last part of our paper, we aimed at presenting the potential offered by this tool, particularly for hypothesis formulation, and more broadly, its relevance for approaching the complexity in the social sciences.

Finally, the last issue is about the dissemination of results. Information technology development does not only offer new perspectives in the area of methodology but also in the area of communication of results. CD-ROMs, Internet can be a much more efficient media than paper. The shift of information from GIS to these media can easily be done. Using interactivity can help us to remind users that space matters in the explanation of social phenomena. Mapping presentation software gives the opportunity to users to experience by themselves the potential offered by GIS. More and more GIS projects (particularly the ones concerned with local

[75] The Urban Mapping Scheme was taken up as a pilot project during the Eighth Five Year Plan for covering 50 towns from different states. In the first phase, 25 towns from six states were selected for coverage. The Executive Agency for the project, the National Remote Sensing Agency (NRSA) has completed aerial photography for all the towns and they have furnished photographs and aerial maps for almost all of them. TCPO in collaboration with the concerned State Town Planning Departments is undertaking interpretation of aerial photographs and collection of other secondary data/information to generate thematic maps and graphic data base for the development of GIS and processing of information for use of Town Planning Departments, Local Bodies, Development Authorities, PWD, Tax Authorities and other Sectoral Development Agencies, as multi-purpose maps.

development) are now integrating these tools. Thanks to Internet, fast updating and wide dissemination of information can be envisioned. Still, probably a lot more needs to be achieved in this area. We humbly hope this work has helped in reaching this objective and will motivate researchers and policy makers working in Delhi to bring together their datasets within a common framework.

BIBLIOGRAPHY

ADAY, L. and ANDERSON, R. (1981). Equity of access to medical care : A conceptual and empirical overview. Medical care, 19(suppl.), 4-27

ALBERT D.P., GESLER W.M., WITTIE P.S. (1995), Geographic Information Systems and Health: an Educational Resource. Journal of Geography, 1995, 94, 2. pp. 350-356.

ANTONI J.P., KLEIN O., MOISY S. (2004), Interactive and multimedia cartography: towards help to geographic reflection. Cybergeo: Revue européenne de géographie, N° 288, 21 octobre 2004. http://193.55.107.45/eurogeo2.htm

ANTONI J.P., KLEIN O. (2003), L'animation d'anamorphoses. Un atout pour la communication en cartographie. Revue Internationale de Géomatique, Cartographie animée et interactive. 13/2003. Pp. 81-92

BANERJI D. (2001), Landmarks in the Development of Health Services in India, In QADEER I., SEN K. NAYAR K.R. (eds.) (2001) Public Health and the Poverty of Reforms. The South Asian Predicament. Sage Publications, New Delhi. pp 39-50

BASSAND M. (2001), Les six paramètres de la métropolisation. Cahiers de la métropolisation, n°1, www.metropolisation.org

BARU R. (1998), Private Healthcare in India. Social Characteristics and Trends, Delhi: Sage Publications

BHAT R. (1999), Characteristics of private medical practice in India: a provider perspective. Health Policy & Planning, vol. 14, n°1, pp. 26-47

BURROUGH, P. A. and R. A. MCDONNELL (1998), Principles of Geographical Information Systems. New York, Oxford University Press.

CENSUS OF INDIA (1991), House & Households amenities in National Capital Territory

CENSUS OF INDIA (1998) 1991 Census Data, CDROM

CHAMUSSY H. (2003), Facing up the complexity (a Lebanese example), Abstract of the 13 th Colloqium on Quantitative and Theoritical Geography, 5-9 september 2003, Lucca, Italy, pp. 60-61.

CHAPELET P. (1998), Le médicament en Inde: Une approche par le biais des pharmacies. University of Rouen, France. 170p.

CHARRE J. (1995), Statistique et territoire. GIP RECLUS, 119 pages.

CLERC M. (2003), Les ONG face au VIH/SIDA. Entre institutions internationales, Etat et société civile. L'exemple de Delhi, Inde. M.A. paper, University of Rouen, France.

CLEVELAND J.W. (1993), Vizualizing Data. Summit NJ, Hobart Press, 360p.

CROMLEY, E. K. and S. L. MCLAFFERTY (2002), GIS and Public Health. New York, Guilford Press.

DANGERMOND J. (1990) A classification of software components commonly used in geographic information systems. Introductory Readings in Geographic Information Systems, Taylor Francis, pp.30-51
DENEGRE, J. S., F. (1996), Les systèmes d'informations géographiques. Paris, PUF.

DUPONT V., MITRA A. (1995), Population distribution, growth and socio-economic spatial patterns in Delhi. Findings from the 1991 census data, Demography India, 1995, Vol. 24, N° 1-2, pp. 101-132.

DUPONT (2000), The rurban of Delhi. In GUILMOTO CZG & VAGUET A.(eds), Essay on population and space in India, Institut Français de Pondychéry, pp.133-151

DUPONT V. (2003), Urban development and population redistribution in Delhi: Implications for categorizing population. In CHAMPION T. & HUGO G. (eds) (2003) New forms of urbanization: Beyond the urban-rural dichotomy. Aldershot, Ashgate. Pp 170-190.

DUPONT V. (2004), Socio-spatial differentiation and residential segregation in Delhi: a question of scale?, Geoforum, n°35, pp.157-175

ECONOMIC SURVEY OF DELHI (2002), Government of National Capital Territory of Delhi. http://delhiplanning.nic.in/Economic%Survey/Ecosur2001-02/Ecosur2001-02.htm

FOLLAND S.T. (1983) Predicting Hospital Market Shares. Inquiry, 20, n°1, pp. 43-44

GUAGLIARDO M.F. (2004), Spatial accessibility of primary care: concepts methods and challenges. International Journal of Health Geographics 3(3): 13pages.

GUILMOTO C.Z., OLIVEAU S. & AL (2004), Mapping Out Social Change in South India. A Geographical Information System and its Applications. Pondy Paper in Social Sciences n°31. French Institute of Pondicherry. P. 118.

GUILMOTO C. Z. (2005), A spatial and statistical examination of child sex ratio in China and India. In ATTANE I., VERON J. (2005) Gender discrimination among young children in Asia. IFP/CEPED. Pondichery, **CSS n°9:** 123-154.

Karl Harmsen (2004), Assessment of the use of RS and GIS in India. GIS@development, April 2004. (CSSTEAP). http://www.gisdevelopment.net

HODGKISS A.G. (1981), Understanding maps. Dawson, Folkstone. Kent

IIPS and ORC Macro (2002), National Family Health Survey (NFHS-2), *India, 1998-99: Delhi*, IIPS, Mumbai, 296p.

KAMEL BOULOS M.N., ROUDSARI A., CARSON E. (2001), Health Geomatics: an Enabling Suite of Technologies in Health and Healthcare. Journal of Biomedical Informatics, 2001, 34, 3. pp 195-219.

KUMAR N. (2004), Changing geographic access to and locational efficiency of health services in two indian districts between 1981 and 1996. Social Science & Medicine 58(10): 2045-2067.

MURTHI M., SRIVANASAN P.V., SUBRAMANIAN S.V. (1999), Linking the Indian Census with the National Sample Survey. Centre for History and Economics, Kings College, Cambridge CB2 1ST. Draft paper.

KING A. D. (2002), Speaking from the margins: « postmodernism », transnationalism, and the Imagining of contemporary indian urbanity in R. GRANT & J. RENNIE SHORT (ed), Globalisation and the margins, Palgrave McMillan, pp.72-90

LEFEBVRE B. (2003), Métropolisation et offre de soins. Une approche SIG à Delhi. M.A paper, University of Rouen, France.

LONGLEY P.A., GOODCHILD M.F., MAGUIRE D.J., RHIND D.W. (eds) (1999), Geographical Information Systems: Principles, Techniques, Management and Applications. New York: Wiley.
LONGLEY P.A., GOODCHILD M.F., MAGUIRE D.J., RHIND D.W. (2001), Geographic Information Systems and Science. New York: Wiley

MARTIN D. (1996), Geographic Information Systems: Socioeconomic Applications. 2nd edition. London: Routledge.

MORICONI EBRARD F. (2001), L'émergence de la métropole euro-méditerranéenne, Cahiers de la métropolisation, n°2, www.metropolisation.org

NELLES VERLAG (2001) Nelles Map India: Northern India

O'SULLIVAN D. (2004), Too much of the wrong kinf of data. Implications for the practice of micro-scale spatial modeling. In GOODCHILD F. & JANELLE D.G. (eds) (2004), Spatially integrated social science. Oxford University Press. pp 95-107

PARKER, E. B. and J. L. CAMPBELL (1998). Measuring access to primary medical care: some examples of the use of geographical information systems. Health & Place **4**(2): 183-193.

PENCHANSKY, R. and THOMAS, J.W. (1981), The concept of access : Definition and relationships to consumer satisfaction. Medical Care, 19(2), 127-140.

PINTO M.R. (2000), Metropolitan city governance in India, Sage, 242p.

PUMAIN, D. and T. SAINT-JULIEN (1997), L'analyse spatiale. Localisations dans l'espace. Paris, Armand Colin.

ROUDIER DAVAL C. (2003), Les SIG appliqués à la santé. L'exemple des maladies parasitaires à Mbandjock (Cameroun). Phd dissertation. Université Paris X, Nanterre. France. 392p.

SALEM G. (1998), La santé dans la ville, géographie d'un petit espace dense : Pikine (Sénégal) Karthala-ORSTOM, Coll. Hommes et Sociétés, 360p.

SANDERS L. (1990), L'analyse des données appliquée à la géographie, Alidade, RECLUS, 267p.

SANDERS L. (eds) (2001), Les modèles en Analyse Spatiale, collection IGAT (Information Géographique et Aménagement du Territoire), Paris, Hermès-Lavoisier, 329 p.

THOMAS J.W. and PENCHANSKY R. (1981), The Concept of Access: Definition and Relationship to Consumer Satisfaction. Medical Care 19 (2): 127-40.

VAGUET A. (2004), Healthcare Systems Caught in the Twists and Turns of Globalization, In LANDY F., CHAUDHURI B. (2004). Globalization and Local Development in India. Examining the Spatial Dimension. CSH, Manohar. p.45-62

P. WANIEZ (2002), Les données et le territoire au Brésil, Diplôme d'Habilitation à Diriger des Recherches en Géographie Humaine. Université Paris-X Nanterre, p. 50

WEEKS J.R. (2004), The role of spatial analysis in demographic research. In GOODCHILD F. & JANELLE D.G. (eds) (2004), Spatially integrated social science. Oxford University Press. p381-399

YESUDIAN Y A K (1994), Behaviour of the private sector in the health market of Bombay, Health Policy and Planning, vol. 9, n°1, p.72-80

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ANNEXURE

List of missing towns in the North West India Urban System GIS

State	District	Status	Name	Population (2001)
Rajasthan	Ajmer	M	Vijainagar	27 688
Rajasthan	Ajmer	M	Kekri	34 129
Rajasthan	Alwar	C.T.	Bhander	33 830
Haryana	Ambala	C.T.	Babiyal	21 650
Uttar Pradesh	Baghpat	N.P.	Khekada	40 380
Uttar Pradesh	Bijnor	N.P.	Warhapur	20 863
Rajasthan	Nagaur	C.T.	Basni Belima	21 557
Punjab	Patiala	N.P.	Pattran	22 170
Punjab	Patiala	N.P.	Zirakpur	25 006
Punjab	Rupnagar	C.T.	Karoran	20 351
Himachal Pradesh	Solan	N.P.	Baddi	22592

Source: Census of India (2001)

Discretisation methods

For discretisation of data we use mainly two different methods.

- Q6: Six categories are defined with the following limits: minimum, percentile 5, first quartile, median, third quartile, percentile 95, maximum. This method of discretisation allows us to isolate the 5 % spatial units having the minimal values and the 5 % spatial units having the maximum values. Compared to quartiling the Q6 method has the strong advantage of preserving extreme values.
- Jenks: The number of categories is defined by the user. This discretisation aims at minimising the intra-categories variance and maximising the inter-categories variance. For this reason the limits of each category are not continuous. See JENKS G. (1977) Optimal Data Classification for Choropleth Maps. Occasional Paper 2, Department of Geography, University of Kansas

Spatial autocorrelation coefficients

Moran and Geary coefficients are the two most common spatial autocorrelation coefficients used by geographers. You can find a small table presenting the results on different maps of this paper. The first column gives the neighbourhood order. The second one presents the Moran coefficient. The third column gives this value: 1-Geary coefficient. Both coefficients can be read as followed:

= 0: There is no spatial autocorrelation. The values of neighbouring spatial units are as different from another as the values in the all distribution.

> 0: The spatial autocorrelation is positive. The values of neighbouring spatial units are more similar than the values in the all distribution.

< 0: The spatial autocorrelation is negative. The values of neighbouring spatial units are more different than the values in the all distribution.