Regional Inequalities on Health Services Supply: an analysis for Brazil, 2002*

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ABSTRACT

Since the 1988 Constitution, the Brazilian health sector functions as a unified system. The main alteration was the decentralization of the federative responsibilities, which made the municipalities the principal supplier and administrator of the health services. This occurred as a means to identify the real necessities of the population in order to homogenize the spatial distribution of health services. The objective of this work is to identify and analyze the urban network of health services supply in the Brazilian macro regions with municipal data. The theoretical framework used in the analyses of the health services distribution is based on the Central Place Theory. The basic assumption is that the services supply distribution responds to a spatial network of sub-regional hierarchical urban centers, with prevalence of systems composed of first order central places and other urban centers that are hierarchically inferior. In order to do this we utilized the *Pesquisa de Assistência Médico-Sanitária* (Medical-Sanitary Assistance Survey) database from IBGE (Brazilian Institute of Geography and Statistics), from the year of 2002, which has data about equipments, facilities and human resources in the public and private spheres of the health system. The identification of the urban network of health services was obtained with the use of Cluster Analysis. Subsequently, these results were statistically tested with the Spatial Analysis (LISA) technique and Spatial Econometrics. It was verified that the urban network of health services in Brazil was at the same time not inclusive, overlapped, widely unequal in the regional distribution and concentrated in the South and Southeast Regions of Brazil, beyond what would be expected by economic and population aspects. The obtained results not only describe the hierarchical network of health services supply, but also can aid governmental actions at the planning level for health policies in Brazil.

INTRODUCTION

The provision of health services in developing countries is characterized by large regional disparities. In Brazil, barriers to the use of medical services are frequently observed, despite the fact that the Brazilian 1988 Constitution declares such services as a right that should be equally accessible to all citizens. These barriers are imposed, among other factors, by the lack of availability of basic and specialized health services to the majority of the population.

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The geographical distribution of productive capacity in health is another important constraint in the access to these services, given that the distance between the location of supply and of demand imposes additional difficulties in the use of the services. Understanding all the spatial dimensions involved in the prevention and treatment of illnesses may provide us with adequate planning possibilities on this issue, especially for less developed regions where health costs are relatively higher for a population facing poor living conditions.

This paper intends to analyze the spatial distribution of health services supply in the Brazilian macro-regions in 2002. The remainder of the paper has six sections, besides this introduction. Next section discusses the process of decentralization of health services since the creation of the Unique Health System[4] (SUS); section three provides the theoretical background to understand the question of services supply; section four introduces the database and presents a descriptive analysis of the variables; section five discusses the methodology of multivariate analysis; section six shows the main results and, finally, the last section presents the conclusions of the paper.

DECENTRALIZATION AND REGIONALIZATION OF HEALTH SERVICES IN THE *UNIQUE HEALTH SYSTEM* (SUS)

The Brazilian 1988 Constitution has created the Unique Health System (SUS) aiming to reduce inequalities in the supply of health services, by providing adequate access to these services at no cost to the population[5]. The SUS establishes that the access to health services is to be guaranteed to all citizens, with full coverage of medical needs and equal treatment to people with equal needs. Its organizational principles are decentralization, regionalization and hierarchy of services, as well as community participation. It intends to promote the decentralization of the health system at the local level, both in the management and funding of the services, aiming to adjust the model of assistance to the real medical needs of the population by bringing the solution of the problems to the same regions where they occur (Andrade, 2002).

The process of decentralization and regionalization of health services has gradually developed over time with the implementation of government policies, the so-called

[4] SUS stands for *Sistema Único de Saúde* (Unique Health System), and is the system through which most of the health services are provided by the government.
[5] However, SUS was only regulated two years after its creation, with the Leis Orgânicas da Saúde nº 8.080/90 e nº 8.142/90

NOB/SUS (Basic Operational Norms of SUS), aiming at regulating and defining strategies for the efficient operation of the system. The negotiation of aspects relating to health services are made by the *Bipartite* Management Commission (composed by members from municipalities and states) and *Tripartite* Management Commission (with members from local, state and federal governments). Such commissions are responsible for formulating strategies to consolidate the SUS and integrate all levels of government.

Since the beginning of the 1990s there have been several attempts to transfer duties related to the health system to the municipalities. The norms NOB/SUS 01/91 and NOB/SUS 01/92 had emphasized the importance of decentralizing the actions and services of the health system, but only after norm NOB 01/93 such process of decentralization has actually taken place. Norm NOB 01/93 has defined the conditions under which the municipalities would qualify for the receipt of resources from the National Health Fund (*Fundo Nacional de Saúde*) and has identified criteria according to the various management conditions (incipient, partial, semi-full). Due to difficulties in managing the services, norm NOB/SUS 01/96 has been established in 1996 aiming to define the conditions for managing services at local[6] and state[7] levels. This norm, which is still ruling nowadays, has allowed a rapid expansion of the network of medical services at the local level. In this case, mangers at state and federal levels are co-responsible for the provision of health services.

The Operational Norm of Health Assistance (NOAS/SUS 2001) has been established in 2001 in order to promote regional health care centres and to avoid inefficiencies in the provision of services in each municipality. In this norm, the focus has changed from atomization of services (locally) to optimization of services (regionally). NOAS/SUS 2001 has established a Regionalization Guiding Plan[8] – henceforth PDR – which proposes to organize the health care system at regional level, under the coordination of a state manager. That norm aims to identify the roles of the municipalities in the state health system and to tackle inequalities in the provision of services. In order to do so, it defines a set of actions to be taken by all municipalities regarding basic health care and supports the creation of regional units, able to fulfil the medical needs of a larger population according to its geographical location.

NOAS/SUS 2001 has provided greater flexibility in dealing with regional health care issues, because the PDR has been created in accordance with the epidemiological, sanitary,

[6] *Gestão da Atenção Básica e Gestão Plena do Sistema Municipal de Saúde*
[7] *Gestão Avançada e Gestão Plena do Sistema Estadual*
[8] *Plano Diretor de Regionalização*

geographical and social specificities of each state, as well as the particular conditions regarding the access to health services in each region. However, serious problems in the management and funding of the system still persist, despite the efforts to promote and facilitate the provision of all kinds of health services to the population. As Cordeiro (2001: 324) puts it,

> The atomization of the network of services, due to the increase in the number of small towns (ten to twenty thousand inhabitants) represents a political and administrative difficulty for a regionalized and hierarchical system. The agreement between federal, state, and local governments, which was already complex in the Brazilian federation, has become even more complicated for the implementation of SUS, given that the *Lei Orgânica da Saúde* has defined five administrative levels for the SUS (federal, state, regional, municipal, and district levels), with political and financial autonomy for the management to health subsystems at each level.

In addition, according to Souza (2001), the funding of SUS depends to a certain degree on the productive capacity of the health system in each region, which is sometimes not in accordance with the real needs of the population. Therefore, despite the intents to guarantee universal and equal health care to the entire population under the rules guiding the creation of SUS, it is important to check on the spatial distribution of these services in terms of physical and human infrastructure, in order to identify the inequalities that persist between regions in Brazil.

URBAN NETWORK AND CENTRALITY

The provision of health care is composed by basic services, which are used frequently and have lower costs, and by complex services which are subject to economies of scale, because they involve higher technology and lower spatial density of demand. For this reason, the distribution of health services supply is spatially differentiated. As pointed out by Vlahov & Gálea (2002:37),

> (...) social service systems in cities often provide a far wider range of services than are available in smaller cities or in non-urban areas. Although use of these services may be limited by sparse staffing and by difficult, complicated access, their

> availability in cities suggests that resources may already exist in many urban contexts that can contribute to well-being.

Given the existence of such differentiation and such complexity in the supply of health services, it is necessary to search for theoretical elements to interpret this issue. In this case, the Central Place Theory (CPT) and its contemporary developments seem to provide a valuable theoretical benchmark to the analysis of the spatial distribution of health services. Despite the restrictive assumptions of the original model (such as uniform population density, equal transport costs, equal consumer preferences, equal income distribution), its basic concepts of threshold and range can help us in the general understanding of urban networks in the supply of services.

The Central Place Theory, developed by Christäller (1933, 1966), is based on the principle of centrality and considers the space to be organized around a main urban core, called central place. The complementary region, or hinterland, presents a relation of co-dependency with the main core, since this is the *locus* of supply of goods and services that are urban in nature.

The main role of an urban core is to be a centre of services to its immediate hinterland, by providing essential goods and services. These, in turn, have different features, and generate a hierarchy of urban cores according to the services provided. There are two key concepts to understand CPT: i) threshold, defined as the minimum level of demand necessary to promote the supply of a good or service, which reflects the economies of scale in the production of the service as well as the urban agglomeration economies; and ii) range, defined as the maximum distance the consumer is willing to move in order to access a given good or service, and which varies with the complexity of the service.

Therefore, the critical limit may be represented as the smallest concentric circle that justifies the supply of a good or service, and the reach may be described as the largest concentric circle that forms the complementary region of the central place and defines its area of influence. The limits of such area of influence are given by the existence of another area of influence of another centre of similar or higher hierarchy. The size of this exterior circle varies according to the different goods and services that are supplied, and the demand in its interior varies inversely with the distance to the urban core.

The model intends to demonstrate that the sizes of the areas of influence of each central place depend directly to the size and hierarchy of the centres, being the periphery of smaller centres included in the complementary regions of larger ones. The largest the

centrality of a central place, the largest is its hinterland, i.e., the largest the complexity of the services provided, the largest is the area influenced by this centre. According to Regales (1992), the areas of influence of centres of different sizes overlap according to the complexity (hierarchy) of the services supplied, building up urban networks of supply of complementary and interdependent services. Ullman (1970) stresses that the distribution of central places and its areas of influence are not static, and that investment and economic development change the spatial distribution in the supply of services. Richardson (1969) points up that CPT has limits to its applicability due to its extremely restrictive assumption of a uniform distribution of purchasing power, and given that not all areas receive adequate supply of all services demanded.

Despite the limitations of CPT (Berry et al., 1988; Eswaran & Ware, 1986; Gusein-Zade, 1993; Harwitz & Lentnek, 1973; Keane, 1989; Parr, 1978, 1995, 1997; South & Boots, 1999; Thill, 1992), we agree with Richardson (1969:167) when he states that "(…) no other theory emphasizes so much the interdependence between a city and the region where it is located."

In addition, Berry et al. (1988) maintains that in many occasions the services are used very rarely, resulting in a not optimal situation. This argument can be considered given the fact that the supply of health services does not have the same frequency as its utilization. That is to say, emergency services do not present the same spatial frequency as non-emergency services. More than this, there are periodic services that follow identified epidemiologic patterns, but there are also unforeseen and sporadic demands that would justify the supply of complex services without reaching the critical limit that would validate it. From this perspective, a decentralized network of distribution of such demands is extremely necessary in order to optimize the system of provision (Berry et al., 1988).

This argument would be valid for regions in which the distribution of a given service is efficient, i.e., where the services supplied are sufficient for the demands of the region. The complementarities and interdependencies in the supply of complex services, as described by the original model and its extensions, can explain some specific processes regarding services that are public in nature, such as health care, especially in the case of developed countries. In the case of peripheral countries such as Brazil – which has a very unequal income distribution, presents regional imbalances in terms of physical, economic and social infrastructure, shows an erratic pattern of social public spending and has a State that deliberately disregard planning at all levels – the notions of complementarities and interdependence in the supply of services are harder to define and describe. That is to say,

what we usually find are gaps and juxtapositions in the Brazilian urban network – or else redundancies and absences – that are expressed in many aspects, including the health care system.

What one would expect for the case of Brazil is an incomplete urban network, with strong spatial concentration in the main metropolitan centres and their extended surroundings, an incipient capillarity in the South-Southeast region, and a large gap in the Centre-North-Northeast portions of the country. This is the pattern that the paper intends to describe and analyze. Such would be the first step for the identification of unsatisfied needs and for the development of public policies towards provision of adequate and equal health care services in the entire country.

DATABASE AND DESCRIPTION OF VARIABLES

The information in this paper comes from the *Pesquisa de Assistência Médico-Sanitária* (AMS)[9] from 2002. AMS is a national research disaggregated at local level which collects information on physical infrastructure and human resources in health services in Brazil, as well as services supporting diagnosis, treatment and control of diseases. The research includes all health care facilities, both public and private, which provide medical services to individuals and communities.

Using this information, it is possible to analyze the spatial distribution of health services at all levels. The empirical analysis provides information for the formulation of public policies in regard to the health system, aiming at reducing the deficiencies in health care for large parts of the population.

The variables used in this study were grouped in two categories: physical infrastructure and human resources. The former includes equipments, from the simplest to the most complex ones, and health care facilities in general. The latter comprises workers in the health system, with different qualifications – elementary, middle, high schools, and higher education[10]. In this paper we utilized 66 variables of equipments, 34 variables of physical facilities and 36 variables of human resources[11]. Next subsection presents the main socio-demographic features of the Brazilian regions, followed by a preliminary analysis of some of the main variables discussed.

[9] Stands for Research on Medical and Sanitary Care.
[10] However, the number of persons working in all the facilities is not a precise indicator of the amount of workers in a given municipality, since a person can work in more than one facility.
[11] The complete list of variables is on ANEX 1.

Brief socio-demographic characterization of the Brazilian macro-regions

The political-administrative division of Brazil comprises the macro-regions North, Northeast, Southeast, South, and Centre-West. These regions present clear differences regarding socio-economic and demographic aspects. According to Carvalho and Wood (1994: 9):

> The understanding of regional differences is crucial for the study of population and development in Brazil. The division in five macro-regions: North, Northeast, Southeast, South, and Centre-West, provides a broad perspective on the most important features of the Brazilian spatial diversity.

Such differences are based on the history of development of the country, whose regional configuration is characterized by poor linkages among the regions, inherited from the colonial and slavery periods. The concentration of production initially occurred in the Centre-South parts of the country, given the higher development of transportation and communication systems, and the expansion of agriculture in the South region. From the 1970s on, the agricultural frontier expanded towards the Centre-West and North regions and the same process happened in some parts of the Northeast region starting from the late 1980s (Diniz, 1995). This movement of dispersion of production and the expansion in stagnant regions promote demand for other kinds of activities and services, such as health care, education, sewage systems etc in these remote localities.

Table 1 presents the main economic and demographic variables, in order to describe the socio-demographic features of each region.

Table 1: Selected indicators for Brazilian macro-regions - 2000

Socioeconomic	Northeast	North	Centre-West	Southeast	South
Gini coefficient	0.67	0.65	0.63	0.61	0.58
% of total population	28.12	7.60	6.85	42.65	14.79
Urban population (%)	69.07	69.87	86.73	90.52	80.94
Life expectancy at birth	64.83	66.76	69.88	69.85	71.88
Infant Mortality Rate	47.79	34.47	24.55	23.90	18.03
Total Fertility Rate	2.74	3.22	2.28	2.13	2.23
Per capita income	152.16	196.22	366.72	355.69	342.62
% of GDP	4.60	13.09	6.95	57.79	17.57
Illiteracy rate (% persons 25 y.o. and older)	32.48	20.57	12.91	11.13	8.99
Population in homes with toiled and water systems (%)	54.08	45.55	83.97	91.62	90.35
% of the Brazilian territory	18.22	45.27	18.87	10.86	6.77
Demographic density	30.78	3.35	7.24	78.32	43.57

Souce: Human Development Atlas - 2000 and IPEADATA

In can be seen that the Northeast and North regions represent almost thirty-six per cent of the total population and more than sixty per cent of the country's territory, and at the same time present the lowest socioeconomic indicators, such as per capita income, GDP and income distribution. In addition, these are the regions with lower percentage of basic infrastructure, such as sewage and water systems, and with smaller proportions of the population in urban areas as compared to other regions of the country. Regarding educational indicators, illiteracy rates of persons twenty-five or older reach thirty-two per cent in the Northeast, while in the South it is only nine per cent.

Demographic variables are closely related to the socioeconomic indicators, as it can be seen in the case of Infant Mortality Rate that reaches almost forty-eight deaths for 1000 births in the Northeast. This variable in highly sensitive to social policies aimed at improving the living conditions of the population, since it is closely related to infrastructure in the health sector, and to investments in education. This fact can also be verified in the Total Fertility Rate that reaches higher levels in the North region – more than three children per woman – as compared to the Southeast region, with a little over two children.

Looking at area indicators and demographic density, we find that the North region has around three inhabitants per square km, and presents some of the worse economic and social indicators. It is a region with low rates of territorial occupancy, given the fact that it contains almost 100 per cent of the Brazilian Amazon Rain Forest. This causes severe deficiencies in the transportation system, which inhibits the integration among municipalities and, therefore,

the accessibility to health services. In this case, it is important to analyze the distribution of health services, in order to identify the existence of gaps in the supply of these services and, by doing so, provide information for better planning of policies aiming at the basic needs of the population.

Descriptive Analysis

The goal of this section is to describe and analyze some key variables related to the supply of health services. Table 2 presents a preliminary analysis of the indicators of the health services supply in each region. It can be seen that the Southeast, South, and Centre-West regions present higher availability of physical and human infrastructure in health – generally above the country's average.

Table 2: Distribution of health infrastructure per 1000 inhabitants - 2002

Macro-regions	Equipments	Facilities	Human resources
Southeast	7,63	9,83	9,24
South	8,55	11,12	9,21
Centre-West	8,07	10,86	8,89
Northeast	5,32	8,75	7,78
North	5,05	7,58	7,30
Brazil	**6,95**	**9,62**	**8,65**

Source: Authors' calculations from IBGE / AMS, 2002

It is interesting to note that there are also differences among these regions regarding the supply of productive capacity and labour in the health system. For instance, the Centre-West region presents the highest per capita physical capacity, and the lowest indicators regarding human resources. On the other hand, the Southeast region has better human infrastructure than the South, but it has less physical facilities and equipments per capita – given its larger population. Such features of the supply of health services seem to be associated with the fact that the availability of human resources involves a subjective decision of the workers in the health sector, who tend to prefer living in regions with higher concentration of infrastructure and urban diversity.

However, it is important to verify what health services – from the most basic to the most complex ones – are being supplied in the various localities. According to norm NOAS/SUS 2001, there should be created investment lines and agreements between regional managers aiming to close gaps in the provision of health services to the population, in order to avoid inefficiencies in the allocation of resources and to obtain economies of scale.

Therefore, some basic equipment should be supplied in all the Brazilian municipalities so that essential health services could be provided (according to the *Gestão Plena da Atenção Básica Ampliada*). Under the category of basic equipment, we include the electro-cardiograph and the autoclave (equipment for vapour sterilization).

On the other hand, some equipment and facilities – such as clinic pathology laboratories, radiology and obstetric ultra-sound equipments – should be offered in towns with at least 25,000 inhabitants, in order to prioritize investments and stimulate the creation of health care networks. Tables 3, 4 and 5 show the percentage of municipalities in all the Brazilian regions where the listed physical and human infrastructure is not available.

Table 3 shows large disparities between regions in Brazil concerning productive capacity in health, in all levels of complexity. The North and Northeast regions present the highest deficiencies in the supply of health services, which is in accordance with the low levels of economic development in these localities. More than half of the municipalities in these regions lack some basic equipment such as electrocardiograph and autoclave, whereas in the more developed regions – Southeast in particular – less than thirty per cent of the localities lack an electrocardiograph and less than ten per cent lack an autoclave. Although these numbers are small compared to other regions, it is still important than managers of the health system in the most developed regions take actions to fulfil the existing gaps in the supply of health services.

Table 3: Percentage of municipalities without the listed equipment - Brazil, 2002

Regions	Haemodialysis Equipment	Dental X-ray	Echo graphic ultra-sound	Electrocardiograph	Autoclave
Southeast	91.01	58.67	62.53	27.85	7.72
South	92.77	78.07	69.84	49.62	13.51
Centre-West	96.11	80.56	60.04	50.11	19.44
Northeast	97.60	83.42	70.65	63.72	19.42
North	97.33	79.51	72.16	74.16	24.72

Source:Authors' calculation from IBGE / AMS, 2002

More complex equipments such as haemodialysis appliances are available in few localities, as one could expect, given the existence of economies of scale in the provision of such service. Therefore, in all the regions, more than ninety per cent of the municipalities lack this kind of equipment, and the supply is even more limited in the Northeast (ninety-seven comma six per cent), North (ninety-seven comma three per cent) and Centre-West (ninety six comma eleven per cent) regions.

Table 4: Percentage of municipalities without the listed facility - Brazil, 2002

Regions	ITU	Surgery room	Paediatric beds	Dental office	Medical office
Southeast	85.51	36.83	47.47	5.95	1.14
South	90.31	36.36	39.76	5.18	1.95
Centre-West	92.44	31.97	39.09	10.37	3.67
Northeast	95.65	45.42	41.07	10.21	0.95
North	95.10	44.54	42.54	17.81	3.34

Source: Authors' calculation from IBGE / AMS, 2002

The supply of physical facilities shows a similar pattern in terms of the inequalities between regions and between levels of complexity. A reason for concern refers to the existence of dental offices in the North, Northeast and Centre-West regions. A little over ten per cent of the localities in the Centre-West and Northeast do not have any dental offices, and this percentage rises up to almost eighteen per cent in the North region. We can also see that the deficiencies are a lot smaller regarding low complexity facilities such as medical offices, even though its supply is still more deficient in less developed regions. The productive capacity in highly complex facilities such as ITU is not present in more than ninety per cent of the localities, except in the case of the Southeast region.

Table 5: Percentage of localities without the listed health care worker - Brazil, 2002

Regions	Radiologist	Physiotherapist	Dentist	General doctor	Nurse
Southeast	63.25	39.93	6.89	4.74	4.68
South	67.83	56.71	5.43	4.50	5.43
Centre-West	75.16	64.58	9.07	8.21	7.13
Northeast	80.84	75.01	10.76	9.36	4.26
North	84.41	81.29	17.59	12.03	9.35

Source: Authors' calculation from IBGE/AMS, 2002

Table 5 shows the distribution of human resources in health. It is clear that the higher disparities occur with respect to workers in services of medium complexity, such as physiotherapist and dentist. Around forty per cent of the municipalities in the Southeast region lack a physiotherapist, and this percentage increases to over eighty per cent in the North. The difference is also significant between the Southeast and South regions. On the other hand, the lower percentage of localities without a dentist can be seen in the South region (five comma forty-three per cent). Once more, the North region shows great deficiencies as compared with the other regions, since over seventeen per cent of the municipalities lack human resources for dental care.

This preliminary analysis points out to the existence of clear deficiencies in the supply of health services in Brazil, despite the efforts towards the fulfilment of the principles of universality, completeness, and equity, as stated in the legislation. The highest disparities in the supply of services relate to low complexity physical and human infrastructure. That is, large part of the municipalities especially in the North and Northeast regions are not able to fulfil even the most frequent and basic needs of the population, which comprise around eighty-five per cent of all health care needs in the country (Brazil, 1999). This shows that problem solving abilities in the health system are very unequal and highly related with the level of economic and social development of the Brazilian regions. It is clear, therefore, that there is room for intervention by the health system managers especially regarding the basic treatment needs of the population.

Although the principle of regionalization states that health care should be offered at the minimal levels, the demands occur in different levels of assistance. Thus the definition of hierarchies and the regionalization of the health services represent important instruments in verifying the ability of the municipalities to offer health services of reference and counter-reference. Next section presents a multivariate analysis that intends to show how the supply of services is spatially distributed among the municipalities in Brazilian macro-regions.

METHODOLOGICAL FOUNDATIONS: CLUSTERS AND SPATIAL ANALYSIS

This study applies a non-hierarchic cluster*s* analysis (K-means[12]) using the software *S-Plus*, in order to group the sample of municipalities according to the variables discussed here. The method uses the simple Euclidian distance, measured according to the differences between the variables analyzed in each locality, in order to group those with similar configurations of health services supply and to separate in different groups the localities with distinct health care structures, up to the point when the internal variance of each class could no longer be reduced, for a given number of classes.

After classifying the municipalities in specific clusters and viewing the spatial inequalities in the supply of health services in the Brazilian macro-regions, we proceed to the Exploratory Spatial Data Analysis (ESDA), aiming to identify the existence or not of statistically significant spatial patterns at local level (Anselin, 1992, 1995).

[12] On this method, see MacQueen (1967).

One of the most used tests for the detection of global spatial autocorrelation is Moran's *I*. According to Perobelli and Haddad (2003), Moran's *I* statistic provides a formal indication of the linear association between the vector of observed variables and the vector of weighted averages of their neighbouring values, or the spatial lag. Formally:

$$I = \frac{n}{S_0} \frac{\sum_i \sum_j w_{ij} (x_i - \mu)(x_j - \mu)}{\sum_i (x_i - \mu)^2} \qquad (1)$$

where $S_0 = \sum_i \sum_j W_{ij}$, x_i is the observation in region *i*, μ is the average observation of the neighbouring localities, *n* is the number of neighbours, w_{ij} are the elements of the matrix of spatial weights *W*, that defines the degree in which the municipalities are classified as neighbours of each other. The matrix elements indicate how region *i* is connected to region *j*. Different criteria can be used for constructing the matrix of weights, such as adjacency, distance, inverse distance, *k* closest neighbours, among others. The stability or consistency of the results needs to be tested by using different matrices, since the choice of W can affect the value of Moran's *I* statistic. In this study the geographic adjacency is defined by the method *Queen* of first order, which identifies as neighbours of a given individual all the bordering individuals in any direction.

The value of the estimated statistic *I* needs to be compared to the expected theoretical value *E(I)=-1/(n-1)*. If the estimated statistic is significantly higher than its expected value, this suggests the existence of positive spatial autocorrelation in the data. On the other hand, if the estimated statistic is significantly lower than expected, there is an indication of negative autocorrelation.

The structure of local spatial autocorrelation can be understood with the use of specific techniques such as Moran's dispersion maps and graphs and the LISA (Local Indicators of Spatial Association) statistics.

According to Gallo and Ertur (2000), the local version of Moran's *I* statistic for each region *i* is given by:

$$I_i = \frac{(x_i - \mu)}{m_0} \sum_j w_{ij} (x_j - \mu) \qquad \text{where} \qquad m_0 = \sum_i (x_i - \mu)^2 \Big/ n \qquad (2)$$

The local statistics allow the identification of significant agglomerations of (dis)similar values. In addition, these statistics are useful for the detection of spatial outliers and influent observations.

The final stage of the spatial analysis consists on the visualization of Moran Maps, which are divided in four quadrants representing the different types of association:

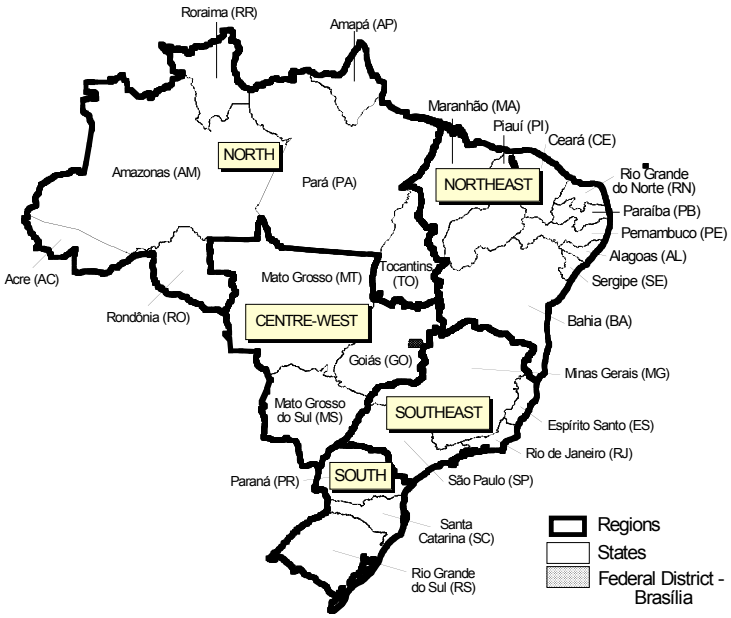
1. High-High: region presents high value of the variable under analysis, and is surrounded by a neighbourhood that also has on average a high value of the same variable;
2. Low-Low: region with low values with a neighbourhood that also presents low values;
3. Low-High: region with low values, surrounded by regions with high values on average;
4. High-low: region has high value and its neighbours have low value on average.

RESULTS AND DISCUSSION

Cluster Analysis

This section intends to analyze the clusters of health services supply in Brazil as a whole. The study presents two separate analysis for clusters of human resources (Chart 1) and cluster*s* of equipment and facilities (Chart 2). The Brazilian map, with indication of Brazilian States and its abbreviations is above.

Figure 1. Brazilian Administrative Map



The analysis of the supply of health services in general shows that cities of São Paulo and Rio de Janeiro present clusters hierarchically superior, both in terms of human resources and equipment/facilities. Such municipalities concentrate the largest productive capacity in health in Brazil, and are reference points concerning the treatment of certain diseases, as it is the case of cardiovascular illnesses in São Paulo.

The differentiation of groups begins after cluster three since certain large cities – such as Fortaleza and Porto Alegre – are not included in cluster three in case of human resources, but they are included in this same cluster in terms of physical infrastructure. These two cities are reference points for large geographical areas. In the Northeast region, only two municipalities are hierarchically superior to Fortaleza in the supply of human resources in health: Salvador and Recife. Since this region has large territorial extension and over 1790 municipalities, this creates an excess demand in these localities, especially for more complex services.

Therefore, Fortaleza fulfils part of this deficiency and represents a core of absorption of demands for specialized health services in the northern parts of the Northeast region, despite being in a cluster that is hierarchically inferior to Salvador and Recife.

Chart 1

Clusters of human resources by localities - Brazil, 2002

Cluster 1	**Cluster 5**	
São Paulo (SP - SE)	*North*	*South-East*
	Manacapuru (AM)	Bauru (SP)
Cluster 2	Belém (PA)	Campinas (SP)
Rio de Janeiro (RJ - SE)		Guarulhos (SP)
	North-East	Juiz de Fora (MG)
Cluster 3	Aracaju (SE)	Jundiaí (SP)
Belo Horizonte (MG - SE)	João Pessoa (PB)	Niterói (RJ)
Salvador (BA - NE)	Maceió (AL)	Osasco (SP)
Recife (PE - NE)	Natal (RN)	Ribeirão Preto (SP)
	Teresina (PI)	Santo André (SP)
Cluster 4	São Luiz (MA)	Santos (SP)
Brasília (DF - CW)		São Bernardo do Campo (SP)
Curitiba (PR - S)	*Centre-West*	São Gonçalo (RJ)
Fortaleza (CE - NE)	Campo Grande (MS)	São José do Rio Preto (SP)
Porto Alegre (RS - S)	Cuiabá (MT)	São José dos Campos (SP)
	Goiânia (GO)	Sorocaba (SP)
Cluster 6		Vitória (ES)
All other		
	South	
	Florianópolis (SC)	
	Londrina (PR)	

Source: Authors' elaboration from IBGE / AMS - 2002

Another important result appears when we compare cluster five in both charts. It can be seen that there is a significant difference in the quantity of municipalities in this cluster. The human resources cluster has a smaller number of towns, and some towns are included in chart 1 but not in chart 2. This is the case of the North region, for instance. Manacapuru and Belém are included in the human resources cluster, but not in the physical infrastructure cluster. On the other hand, Manaus, Porto Velho and Rio Branco appear in cluster five in the case of equipment/facilities but not in case of human resources. This difference depends in part of the planning strategies of the various state secretaries of health. The Secretary of Health in the state of Amazonas, for instance, prioritizes the formation of human resources, aiming at the development and quality improvement of the Family Health Program[13]. This depends on coordinated efforts from health managers and research institutions for the creation of training centres for workers in the health system, such as *Oficinas de Educação* (Education workshops). One of the three *Oficinas de Educação* in the state of Amazonas is located in Manacapuru, a town with around 80,000 inhabitants. It is also remarkable the large number of medium size municipalities in cluster five in the Southeast region – particularly in

[13] *Programa de Saúde da Família*

upstate São Paulo – with a higher relative centrality as compared to other towns of similar size. This aspect is going to become more evident in the next section when we will test the statistical significance of the results.

Chart 2

Clusters of equipment / facilities by locality - Brazil, 2002

Cluster 1	**Cluster 5**		
São Paulo (SP - SE)	*North*	*South-East*	
	Manaus (AM)	Araras (SP)	Niterói (RJ)
Cluster 2	Porto Velho (RO)	Barbacena (MG)	Nova Iguaçu (RJ)
Rio de Janeiro (RJ - SE)	Rio Branco (AC)	Bauru (SP)	Osasco (SP)
		Botucatu (SP)	Paracambi (RJ)
Cluster 3	*North-East*	Cachoeira do Itapemerim (ES)	Petrópolis (RJ)
Belo Horizonte (MG - SE)	Aracaju (SE)	Caieiras (SP)	Piracicaba (SP)
Fortaleza (CE - NE)	Camaragibe (PE)	Campos do Jordão (SP)	Presidente Prudente (SP)
Porto Alegre (RS - S)	Campina Grande (PE)	Campos dos Goytacazes (RJ)	Ribeirão Preto (SP)
Salvador (BA - NE)	Crato (CE)	Duque de Caxias (RJ)	Santo André (SP)
Recife (PE - NE)	Feira de Santana (BA)	Guarulhos (SP)	Santos (SP)
	Imperatriz (MA)	Itaboaí (SP)	São Bernardo do Campo (SP)
Cluster 4	Itabuna (BA)	Itapira (SP)	São Gonçalo (RJ)
Brasília (DF - CW)	João Pessoa (PB)	Itu (SP)	São José do Rio Preto (SP)
Campinas (SP - SE)	Juazeiro (BA)	Jaú (SP)	São José dos Campos (SP)
Curitiba (PR - S)	Maceió (AL)	Juiz de Fora (MG)	Sorocaba (SP)
Belém (PA - N)	Mossoró (RN)	Jundiaí (SP)	Tupã (SP)
Goiânia (GO - CW)	Natal (RN)	Marília (SP)	Uberaba (MG)
	Sobral (CE)	Moji das Cruzes (SP)	Uberlândia (MG)
Cluster 6	São Luis (MA)	Montes Claros (MG)	Vitória (ES)
All other	Teresina (PI)		Volta Redonda (RJ)
	Vitória da Conquista (BA)		
	Centre-West	*South*	
	Anápolis (GO)	Blumenau (SC)	Passo Fundo (RS)
	Campo Grande (MS)	Cascavel (PR)	Pelotas (RS)
	Cuiabá (MT)	Caxias do Sul (RS)	Ponta Grossa (RS)
		Florianópolis (SC)	Santa Maria (RS)
		Joinville (SC)	São José (SC)
		Londrina (PR)	São José dos Pinhais (PR)
		Maringá (PR)	

Source: Authors' calculation from IBGE / AMS - 2002

Therefore, the fact that some municipalities are hierarchically superior in terms of the supply of physical infrastructure in health but not in terms of human resources can be explained by the way in which the health system is organized. The investments made for purchasing medical equipment and building up facilities are not always combined with appropriate quantity of workers in health. This happens because the supply of human resources in a given locality depends basically on two factors. The first one relates to the individual decision of migrating to certain municipalities, particularly to the ones located in less developed regions. Several health care workers prefer to stay in their hometown or closer

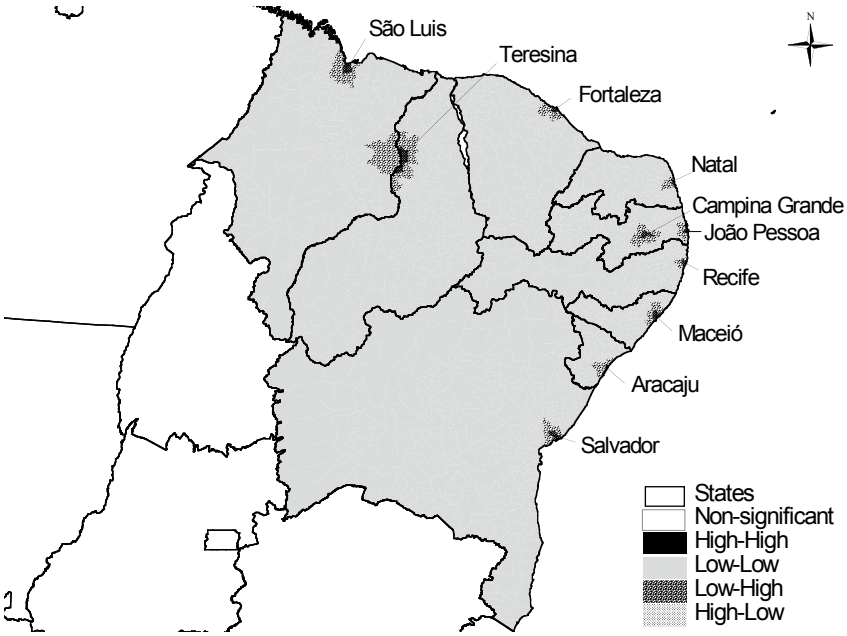
to the major urban centres of the country, even at lower wages, than to move to distant localities where the supply of other kinds of services such as education, leisure, transportation, among others, is deficient[14]. Another factor relates to the very availability of public resources to fund the hiring of human resources, particularly of certain types of specialists that receive higher wages.

In this sense, the complementarities between the supply of equipment/facilities and human resources in health care are essential for adequate planning and resource allocation in the health system, in order to provide good quality services to the population and to use public funds efficiently.

Exploratory Spatial Data Analysis

This section presents an exploratory data analysis of each of the Brazilian macro-regions separately, in order not to overlook the regional specificities of the country. Only the North and Centre-West regions are grouped together due to their similarities regarding health services supply.

Figure 2. Spatial correlation in the supply of health services – Northeast



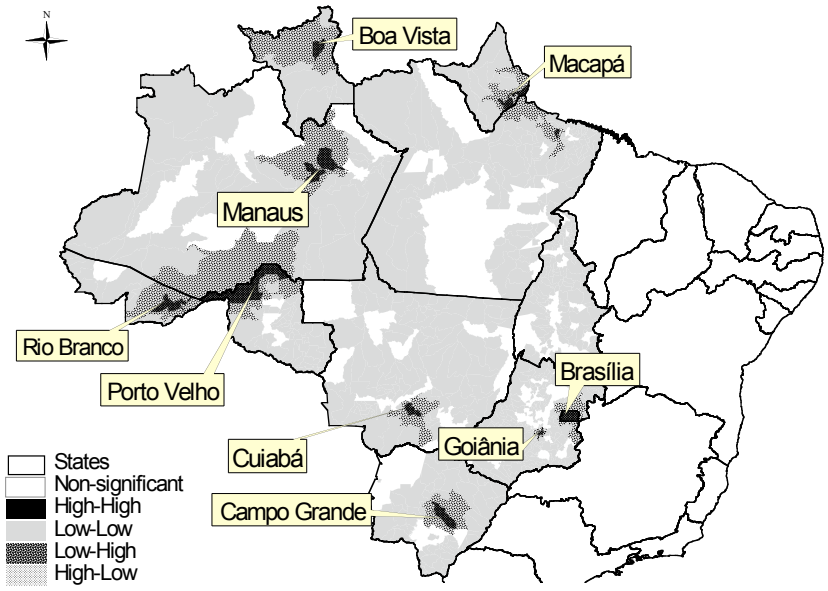
Source: Author's elaboration from IBGE/AMS (2002)

[14] However, one of the factors that can explain the decision to move to smaller and more isolated localities is the increasing concern with quality of life, due to security problems and other issues common to large cities.

The most intriguing result from the analysis is on the Northeast region. All the municipalities in this region show significant values of spatial correlation, at ten per cent significance level. This finding does not change even if we consider five per cent significance level. The result is intriguing but it is also disturbing. Almost all localities in the Northeast region present spatial correlation of Low-Low type, i.e., these are municipalities with deficient supply of health services, surrounded by neighbours with similar features. The results are essentially the same for human resources and for equipment/facilities. Only the state capitals in the region show correlations of High-Low type in human resources and, in addition, Campina Grande (PB) presents High-Low correlations in equipment/facilities. It means that only a little part of the municipalities aims to show up as a high hierarchical health services supplier. For this reason, these cities form isolated bubbles regarding the supply of health services in the region. This fact is a serious problem, mostly when we realize that the inhabitants of these low-low municipalities represent more than 77% of the Northeast population and nearly and nearly one quarter of the Brazilian population. This lack on health services supply just reinforce the fact that Northeast region has the worse general health indicators in Brazil as seen on TAB1.

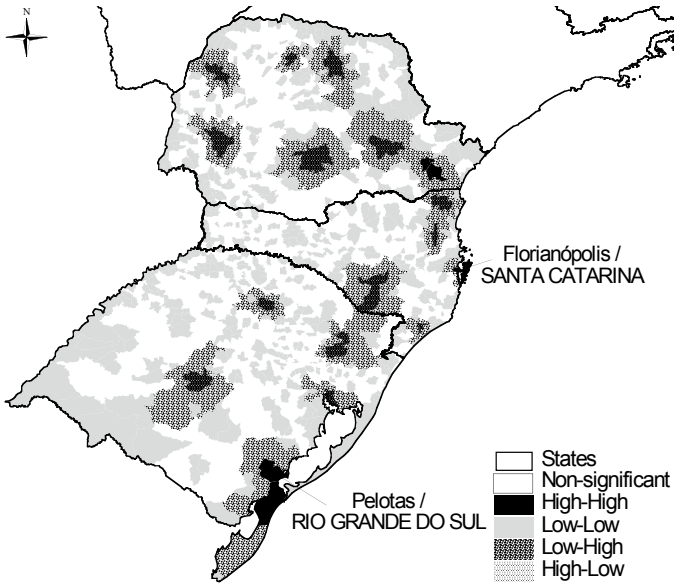
A similar spatial pattern of agglomeration also appears in the North and Centre-West regions, where the supply of services concentrates in the state capitals and their hinterland. In the case of these regions it is important to consider the deficient inter-city and inter-state transportation network, along with the large dimension of their territories that together represent over sixty per cent of Brazil's total area. Some localities in the North region are usually reached by boat and it can take a few days to go from one place to another. The difficulty of access reduces considerably the reach of the health services and this means that spatial concentration implies the non fulfillment of the needs of large portions of the population. This problem, in addition to a low demographic density, makes the issue of health services supply much more complicated and the use of the concepts of threshold and range a lot more complex in the case of these regions.

Figure 3. Spatial correlation in the supply of health services – North e Centre-West



Source: Author's elaboration from IBGE/AMS (2002)

Figure 4. Spatial correlation in the supply of health services – South Region

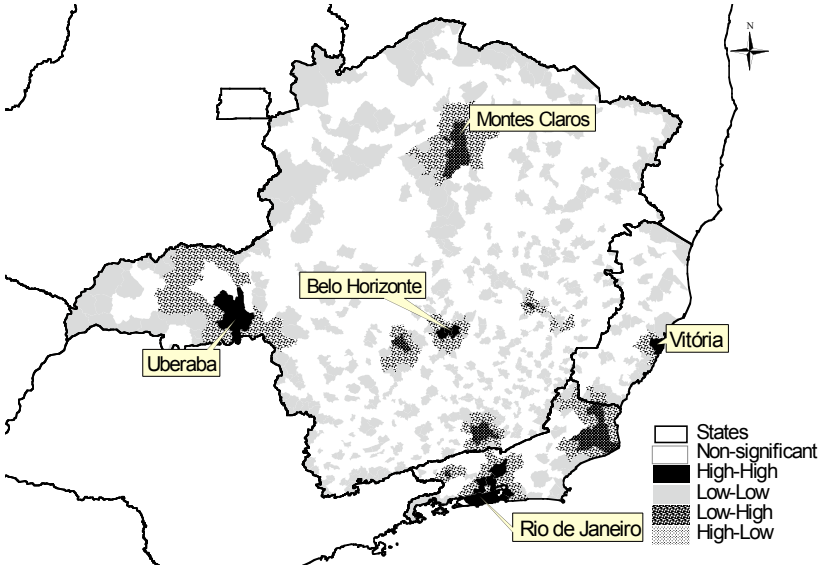


Source: Author's elaboration from IBGE/AMS (2002)

The South region, in turn, presents a totally different configuration of spatial distribution of health services. The existence of sparse spots High-Low and some disperse Low-Low localities around the map suggests the presence of an integrated and spatially

distributed network of health services supply. The occurrence of High-High localities in the metropolitan areas of Curitiba and Florianópolis, as well as in Pelotas-Rio Grande, shows the concentration of more complex services around the large cities, which are also benefited in statistical terms by the small number of neighbouring municipalities. Nevertheless, the existence of many Low-Low municipalities shows that, even in the South (one of the more developed regions in the country) the more complexes health services network is inefficient in the point of view of geographical accessibility.

Figure 5. Spatial correlation in the supply of health services – Southeast Region (except São Paulo)

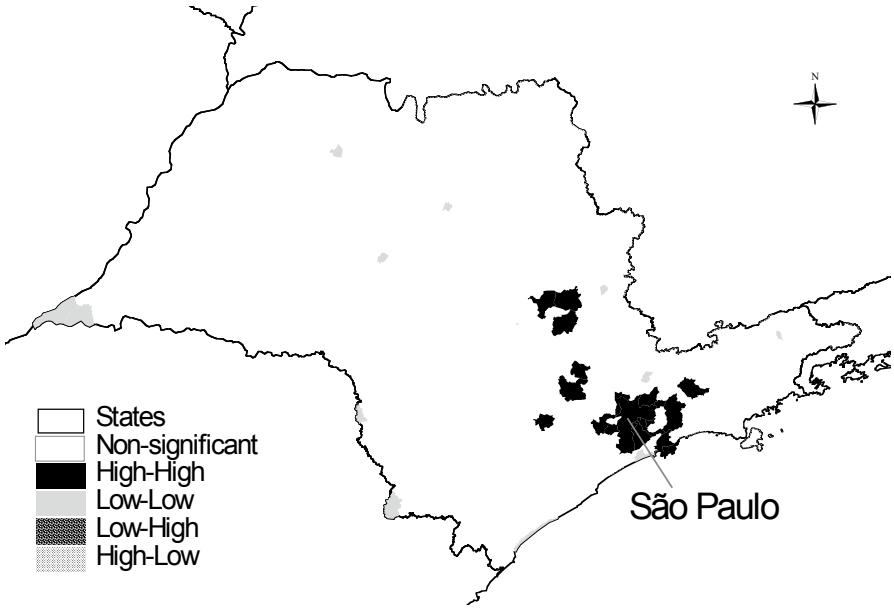


Source: Author´s elaboration from IBGE/AMS (2002)

In the Southeast region it can be clearly seen the strong network of health services in São Paulo and Rio de Janeiro. The concentration of High-High municipalities in these states suggests the existence of health services supply networks that provide services at all levels of complexity, in addition to intermediary centres (High-Low) that are consistently distributed in the majority of the region. These features indicate a well structured urban network that is superior to its counterparts in the other regions of the country. The São Paulo (SP) urban health network is almost desirable, because the existence of High-Low structure on heatlh supply. This characteristic improves the efficiency of the system because minimize the

transportation costs and maximize the accessibility to all kind of health services. More than this, it reduces the demand overpressure on a few localities.

Figure 6. Spatial correlation in the supply of health services – São Paulo



Source: Author´s elaboration from IBGE/AMS (2002)

However, it should be noted that the northern part of Minas Gerais shows a concerning situation. The absence of High-High and High-Low localities – except for the city of Montes Claros, which is a true socio-economic enclave in the region – suggests that this region present severe deficiencies in the supply of health services even at low levels of complexity. Montes Claros City concentrates all the supply on medium and complex health services in the north part of Minas Gerais State[15].

FINAL REMARKS

The issue of health service accessibility is very important in any study regarding the living conditions of the population, since barriers or difficulties in the fulfilment of medical needs may affect the quality of live and even put at risk the survival of the individual.

[15] On this region is localized The Jequitinhonha River Valley, one of the poorest Brazilian regions and one of the lowest levels of Human Development in South America.

In this context, the availability of physical and human infrastructure in the health system is extremely relevant. The current study shows the existence of large gaps in the supply of health services, including the total absence of certain types of equipment, facilities and human resources, necessary for basic medical procedures, in several localities in Brazil. These gaps in the supply of services point to deficiencies in the inter-cities assistance networks, which are one of the pillars of the proposals for regionalization of the health system. Such results may obstruct the implementation of adequate policies for the health system in the country, and may hamper the access of the population to health services at all levels.

Despite the advances in the health system in the last few years, the spatial inequalities in the supply of health services reflect primarily the disparities in the levels of social and economic development among the Brazilian regions. They also point to deficiencies in the planning of public policies and in the priorities regarding the allocation of public resources in strategic areas for the population.

The managers of the health system at the three levels of government should act in a coordinated way in order to provide not only basic medical services – which represent most of the demands of the population – but also to allow the access to more complex medical procedures. This is an important challenge to be faced, aiming to provide comprehensive and good quality health care to all the Brazilian population, and allowing an improvement in the health indicators in the country.

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ANEX 1

Chart I: List of selected variables

Equipments		
Gamma Camera	Temporary Pace-maker	Blood gas analysis equipment
Mammography	EKG monitor	Haemodialysis equipment
Stereo-Tax	Invasive pressure monitor	Dental equipment
Fluoroscopy X ray	Non-invasive pressure monitor	Bier heater
X Ray 100 to 500 Ma	Oximeter	Brachterapy
X Ray 100 Ma	Mechanical Ventilator	Radioimmunoassay
X Ray 00Ma	Adult mechanical ventilator	Linear accelerator
Dental X-ray	Paediatric mechanical ventilator	Cobalt pump
Bone densitometry	Electrocardiograph	Autoclave
Catheterization X Ray	Electroencephalograph	Adult scale
Magnetic resonance	Fiteroptic bronchoscope	Paediatric scale
Computer tomography (CT Scan)	Fiteroptic urinary	Centrifuge
Colour Doppler	Digestive endoscope	Blood cell counter
Echo graphic ultra-sound	Optometry equipment	Catheterization equipment
Central air conditioner	Laparoscopy	Adult sphygmomanometer
Power Generator	Surgical microscope	Paediatric sphygmomanometer
O_2 Power plant	Diathermy equipment	Spectrophotometer
Defibrillator	Electrical stimulation	Foetal Doppler-Pinard
Phototherapy equipment	Infusion pump	Stove
Incubator	Aphaeresis equipment	Microscopy
Audiometric equipment	Extra-corporal circulation pump	Nebuliser
Vaccine refrigerator	Otoscope	Ophthalmoscope

Facilities		
Ambulatory surgery's room	Childbirth room	Beds of medical clinic
Rehydration room	Daily pay room childbirth	Beds of gyneco-obstetrics
Rest/comment room	Surgical recovery room	Beds of other specialities
Dental office	Cradle in joint accommodation	Paediatric beds
Nursing office	Cradle for just born	Psychiatry beds
Nursing room	Adult ITU	Total of beds
Immunization room	Coronary ITU	Sickroom with two beds
Curative room	Infant ITU	Sickroom with three beds
Medical office	Neonatal ITU	Sickroom with more than six

		Beds
Warm cradle	Burnt ITU	Rooms and apartments
Surgery room	Intermediate Unit of Internment	ITC/ITU
Curettage room	Beds of surgical clinic	

Human Resources		
Communitarian agent of health	Zoonosis control agent	Sanitarist
Agent of public health	Midwife	Sanitary inspector
General doctor	Anaesthetist	Nursing technician
General surgeon	Social assistant	Pharmacian technician and assistant
Gynaecologist / Obstetrics	Biochemist	Oral health technician and assistant
Dentist	Nurse	Physiotherapy and whitewashing technician and assistant
Radiologist	Voice Therapist	Haematology technician and assistant
Psychiatrist	Family doctor	Histology technician and assistant
Laboratory technician	Nutritionist	Nutrition technician and assistant
Physiotherapist	Paediatrics	Sanitary and ambient monitoring technician and assistant
Nurse aid	Psychologist	Cytology technician
Diverse services assistant	Resident	Health care equipment technician

Source: IBGE / AMS - 2002