

ATLAS OF SÃO PAULO: PROPOSAL FOR REPRESENTATION OF SOCIO-SPATIAL DIFFERENCES

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Abstract

This work presents the proposal of the Atlas of the socio-spatial differences of São Paulo city (Brazil). It consists in integrating distinct thematic maps, in several scales, to emphasize the unevenness of the urban occupation of the city. The data, grouped in four levels – region, subprefecture, district and census sector –, were represented by choropleth maps, interpolations, proportional geometric figures and associated, when convenient, with anamorphoses and satellite imagery. Indicators of income, schooling, household characteristics and number of youngsters and elderly people from the demographic censuses of 1991 and 2000 were used.

Keywords: cartographic representation, Thematic Cartography, Atlas of São Paulo, socio-spatial differences.

Introduction

The atlases are used for almost five centuries. In the beginning, this map collection represented, for most of the population, a new view of the terrestrial surface, an original and orthogonal look about the shape, size and location of continents, countries and cities.

The present terrestrial surface representations are incomparably superior to those of the Renaissance and, recently, the media to visualize them have acquired an unimaginable interactivity. Systems like Google Earth, NASA World Wind and Microsoft Virtual Earth are examples of the rapid growth of alternatives for the integrated consultation of maps, satellite imagery and digital elevation models.

Even within this context of extraordinary technological developments, it is believed that the printed atlases have not lost their relevance, because they have preserved their original essence. The characteristics responsible for the initial success of this kind of work, innovation and originality, have become consolidated throughout the years. The shape and location of countries does not surprise their users anymore, like it did by the end of the Middle Ages, but the diversity and the level of detail of the distinct themes represented are able to produce a similar effect in their readers.

These are the attributes that guide the present research, which consists in the proposal of the Atlas of socio-spatial differences of São Paulo city (Brazil). Its two cartographic challenges are: represent the data from the 1991 and 2000 demographic censuses in different scales (region, subprefecture, district and census sector) and integrate the traditional thematic maps – like the choropleth, the proportional geometric figures, interpolations and dot maps – in such a way as to make the main differences in the urban occupation of the city visually stand out.

1 General conception of the atlas

From the structure point of view, the atlas was conceived according to the proposal by Borchert (1999). According to the author, the first decisions that must be taken for the production of an atlas refer to the contents and to its target public, as shows Figure 1.

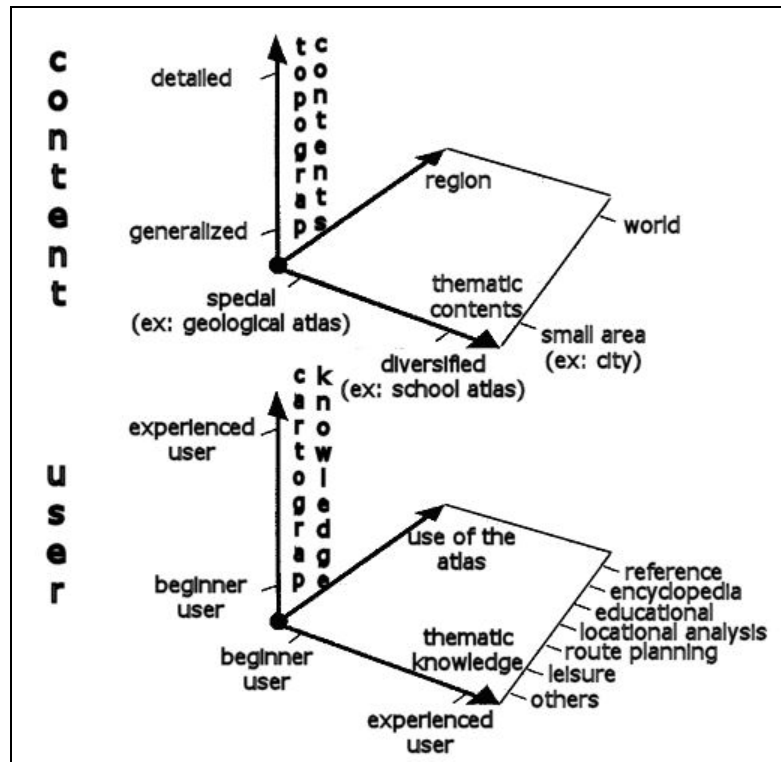


Figure 1: General conception of an atlas
Source: Borchert (1999)

Although it has been originally conceived for an atlas with a digital format, this approach by Borchert has allowed the organization of the central items of the Atlas of socio-spatial differences. In short, it was planned to be a reference work, for beginners, in detail scale and aims the school public from high school on (> 14 years of age).

The principles that guided the making of the thematic maps of the atlas are based on the Semiology of Graphics proposed by Jacques Bertin (1967). The representations are characterized by the following attributes:

- Order and proportion relationships among the represented objects;
- Qualitative representations: choropleth maps and interpolation of the physical aspects and urban infrastructure of the city;
- Quantitative representations: choropleth maps, interpolations, proportional geometric figures and dot maps. Although isarithmic maps (interpolations) are suggested for continuous phenomena, like atmospheric temperature and pressure, its use with data of demographic censuses was adopted as a complement to choropleth maps, since it allows a perception of the distribution of phenomena that goes beyond the administrative limits;

- Relative data (percentage) and, in smaller amounts, the absolute;
- The most used visual variables are: color and, in smaller amounts, size;
- Quartile intervals, of six classes: minimum, percentile 5, 1st quartile, median, 3rd quartile, percentile 95 and maximum. This form of interval definition was regarded the most interesting for the work, since it isolates the data of both extremes. (Waniez, 2008).

The programs used for data manipulations were: ArcMap (ESRI), Philcarto, Excel e Access (Microsoft), Scape Toad and the arcsript Cartogram (anamorphoses).

2 São Paulo and the socio-spatial differences

2.1 Context of the city

The city of *São Paulo de Piratininga* was founded in January 25, 1554, with the construction of a Jesuit college. It was conceived to catechize the Indians of the Piratininga Plateau, and worked in a very simple frame house, made of rammed earth, installed on a hill between the Anhangabaú and Tamanduateí rivers. The origin of the present name of the city is related to the date of foundation of the college, in which the Catholic Church celebrates the conversion of the apostle Paul of Tarsus (Saint Paul).

The geographic factors of the region determined the development of the city (Prado Júnior, 1983). The vegetation cover (prairies), the proximity to the Tietê river and the altitude of the hill represented relevant strategic characteristics, on a first moment, regarding the Indian attacks. Later, it became a very important passage between the coast and the gold mines, during the colonial period. Installed at about 30 kilometers from the Serra do Mar escarpment, was close to the ways that allowed the transposition of this great topographic barrier on the less difficult space (a difference in levels of about 800 meters between the plateau and the coast). For this reason, it performed the role of support site for the travelers and their animals, who were moving between the port and the inlands of the colony.

The sugar cane and coffee culture cycles reassured even more its logistical importance, given the country's export-oriented agricultural talent. The railway built by the British, the São Paulo Railway, that connected the fertile lands of the west of the state with the port of Santos, consolidated this role, in 1867, in the end of the imperial period.

The accumulation of capitals provided by the coffee exportation, the infrastructure and the transportation network existing in the city were the initial inducers of the industrialization of São Paulo (Rattner, 1972). Initially, with the manufacturing of low value products using national raw materials, the industry of São Paulo grew slowly. During World Wars I and II, the number of industries increased significantly, because of the process known as “import substitution industrialization”. The industries grew even more, during the decade of 1960, when the bases for the Brazilian automobile industry were launched (SEMPLA, 2008a).

This rapid industrialization attracted a great number of people, from several parts of the country. To satisfy these labor necessities, the city of São Paulo received millions of workers, mostly from the northeast, who performed a similar role to that of the old

European and Japanese immigrants, who had immigrated during the golden ages of the coffee culture, in the beginning of the republican period.

According to (SEMPA, 2008a), the population of São Paulo passed from a little more than two-million to three-and-a-half-million inhabitants, between 1940 e 1950. The expansion of the economics caused a great increase of population, resulting in an intense urban concentration process. However, this migratory movement was not proportional to the expansion of the infrastructure of the city, necessary to absorb this enormous quantity of new inhabitants. This way, the socio-spatial differences multiplied even more.

In 2000, date of the last demographic census, São Paulo city had 10,434,252 inhabitants (IBGE, 2000). The estimate for 2007 is that 10,886,518 inhabitants are distributed throughout its 1,527km² area. From the administrative point of view, the city is divided into 96 districts, which make up 31 subprefectures and 5 regions, as illustrated in table 1.

Region	Sub-prefectures	Districts	Sectors	Area km ²	Households	Population	Income resp MW	Population density	Household density
Center	1	8	723	26.6612	147975	373914	13.94	14.025	2.53
East	11	33	4937	329.9699	1066932	3835354	5.58	11.623	3.59
North	7	18	2415	299.9327	601784	2092360	6.69	6.976	3.48
West	3	15	1333	129.3223	300414	920806	19.58	7.120	3.07
South	9	22	3870	741.1439	921999	3211818	8.99	4.334	3.48
Totals	31	96	13278	1527	3039104	10434252	6.17	6.833	3.43

Table 1: Synthesis of data from São Paulo city (census of 2000)
Source: IBGE (2000)

Presently, according to SEMPLA (2008b), the city of São Paulo presents great contrasts. It had a GDP of R\$ 282.8 billion, equivalent to US\$ 144 billion, in 2006 (exchange rate of 1 US\$ = 1.964 Reals, in 06/25/2009), which corresponds to 11,94% of the Brazilian GDP. Its GDP per capita was of R\$ 25,674.86, equivalent to US\$ 13,072, in 2006. However, it has 1,602 *favelas* (shanty towns), with 377,066 households, in an approximate area of 30km², that shelter a population of 1,160,590 (data estimated in 2002). Besides, it has 1,902 slum tenements, which shelter approximately 4,234 families.

2.2 The socio-spatial differences

The social and spatial differences, manifest in the urban fabric of a large city, have been approached singly by several areas of knowledge for many years and in countless countries. The results of these surveys present a very diversified content, given their nuances, emphases and particularities. In this work, it was chosen to join the terms (socio-spatial), though based on the geographic bias, to make the character of integrated analysis, and in several scales, of the main indicators of urban occupation contrasts stand out.

These terms originates from the notion of geographically unequal development, proposed by David Harvey, in 2004. For the author, the long process of human

occupation of the earth's surface and the evolution of its different social components – as languages, political institutions and religious beliefs –, produced an extraordinary geographic mosaic of socio-ecological environments and ways of life. He considers, still, that the geographic differences are much more than simple historical legacies, because they are being constantly reproduced, sustained and reconfigured by politico-economical and socio-ecological processes. His proposition of unequal geographic development involves the fusion of two components: the change in scale and the production of geographic differences. “We have, therefore, to think in differentiations, interactions and both inter-scalar and intra-scalar relations” (Harvey, 2004, p112).

In this context, the proposal of the atlas of socio-spatial differences of the city of São Paulo aims to answer questions such as: where would the major income, schooling, or urban infrastructure differences be located? Have they increased throughout this decade? Have the areas with extreme conditions had alterations? Does its logic follow the long standing center-suburb relation?

3 Data

The Brazilian Institute of Geography and Statistics (IBGE) is the responsible organ for the realization of demographic censuses, every ten years, in Brazil. It was created in 1938, with the fusion of the National Institute of Statistics and the National Geographic Council, with the mission of organizing the demographic census of 1940, the fourth demographic census of the republican period. Before this, there were the censuses of 1890 (1st), 1900 (2nd), 1910 (3rd, unfinished for political reasons) and 1920 (4th). The 1930 census was not realized due to political instability.

The tenth Brazilian census should have happened in 1990, but because of administrative problems it was only realized in 1991. At that time, the newly elected president was engaged in decreasing the number of public workers in the country and delayed the hiring of the 180 thousand temporary workers of the census. His electoral motto “hunter of maharajas” (a nickname for public workers with high salaries) seems to have been the main responsible for this pitiful delay.

The results of the 1991 census are structured in four axes: occupation (61 variables), chief of the household (29), household (105) and person (115), summing up 310 variables, obtained at the 10,068 census sectors. The results of 2000 are also divided in four groups: households (76 variables), responsible for the household (172), people (177) and educations (102), but sum up 527 variables obtained at the 13,278 census sectors (Table 2).

Type	Variables	
	1991	2000
Census sectors	10068	13278
Occupation condition	61	-
Chief/responsible	29	172
Household	105	76
Person	115	177
Education	-	102
Total	310	527

Table 2: Structure and variables of the 1991 and 2000 censuses
Source: IBGE (1991 and 2000)

Since the 1950 census, the data collecting unit stopped being the city and started being the census sector. According to the IBGE (2000), the census sector is the cadastral control unit formed by a continuous area, which has a single character (urban or rural), with a dimension and number of households that allows the information survey by a single collecting agent (approximately 300 households in an urban area).

As it is possible to see in table 2, the number of census sectors increased in 31,8% (3,210) from 1991 to 2000, a result of the increase in the number of households, which had a greater percent increase than the population growth. The difference in the number of variables is also noteworthy, having grown 70%, passing from 310 to 527. A significant part of this increase in the 2000 census is related to the decomposition of the variables of 1991 and, for this reason, causes no problems when the data of both censuses are compared.

However, there are relevant changes. According to Dedecca; Rosandiski (2003), the methodological advances of the censuses are fundamental and inherent to the process of data survey, since they make the quality better, widen the possibilities of use, reduce the collecting costs and speed up the process of result disclosure. But some methodological changes may make comparisons difficult, such as, for instance, the change of the terms “chief of the household” (1991) for “responsible for the household” (2000). This apparently subtle change may cause a different answer, since the interviewee may interpret the question in a distinct way. The first tends to value more the question of familiar organization, and the second, the financial responsibility of the household.

4 Proposal of the Atlas

4.1 Main characteristics

The atlas shows the socio-spatial differences of the city of São Paulo based on the extreme social indicators obtained by the demographic censuses of 1991 and 2000. These data were complemented, when necessary, with the informations of the Secretaria da Habitação da Prefeitura Municipal de São Paulo - Housing Secretariat of the São Paulo City Hall - and of the Fundação Sistema Estadual de Análise de Dados (SEADE) – Data Analysis State System Foundation, of São Paulo State.

The data used were: population and household densities, percentage of households with piped water, sewerage and waste collection (infrastructure). Percentage of houses, apartments, rooms, of owned households, rented, with 1 dweller and with 10 or more dwellers (households). Percentage of literate inhabitants, illiterate, those responsible for the household with zero to one year of study, zero to three years of study and with fifteen or more years of study, which represents the conclusion of a university course (schooling). Percentage of those responsible without income, average income of those responsible in minimum wages, income of up to half a minimum wage, income of 0 to 3, 3 to 5, 5 to 10, 10 to 20 and of 20 or more minimum wages (income). Percentage of population from 0 to 4 years of age, from 0 to 14 years of age, from 65 or more years of age and from 80 or more years of age (age of population).

Besides being analyzed singly, some of those variables were used for the elaboration of a synthesis map, through the cluster analysis, which allowed the grouping of sectors and

districts that possess characteristics that are more similar, and verify their distribution throughout the city.

From the spatial point of view, the following queries were analyzed: location and distribution, as well as the behavior of the variables in the different spatial outlines - (census sectors, districts, subprefectures and regions) in the decades of 1991 and 2000, besides having the percent increase/decrease evaluated in this period.

The simple representation and the plurality of scales were the two most important premises for the making of the atlas. The anamorphoses and the satellite imagery (Ikonos) were also analyzed to complement the thematic maps, when pertinent, to make their comprehension even easier.

The integration of these distinct representations was not a simple task, because of the character of the data of São Paulo city. Table 3 relates the data grouping scales with the graphic representation forms and qualify them, attributing to each line/column crossing the concepts weak, medium and good.

Scale	Choropleth			Geometric figures			Interpolations			Anamorphoses			Satellite imagery		
	W	M	G	W	M	G	W	M	G	W	M	G	W	M	G
Sector			X	X			-			X					X
District			X			X			X		X		X		
Subprefecture			X			X			X		X		X		
Region	X				X			X		X			X		

Table 3: Relation between the kinds of graphic representations and data grouping scales

The choropleth maps, which express the relative data, were well evaluated in all of the scales, except region, because it is visually little representative due to the size of the areas. This kind of zonal e ordered representation, associated with a hot color gradient, is well established and of a relatively simple interpretation.

The proportional geometric figure maps, which represent the absolute data, received the concept good at the intermediate scales, subprefecture and district, but medium for region, because it expresses little variation among the five units. The concept weak, for the census sectors, is due to the high number and small size of the units of collection of the census. Its elaboration made the map unreadable because the more than 10,000 overlapping circles would not allow any visual interpretation of the numeric variable.

Although recommended for continuous data, the interpolations (isarithmic maps) presented a good evaluation in the district and subprefecture scales. Generated from the polygon centroids, the interpolations complemented interestingly the choropleth maps, because they allowed the apprehension of gradients between the extremes of the variables. They have the advantage of representing the data without the fragmentation imposed by the limits of administrative units, in case there are significant differences among the values (not recommended for water and sewerage, for instance). They showed themselves averagely expressive in region scale and could not be evaluated in detail scale, because the program could not perform the kriging calculations for the quantity of sectors (10,068 e 13,278).

The anamorphoses, representations that deform the limits of the map according to a numeric variable, were averagely evaluated in the intermediate scales. It received a weak concept in the sector and region scales, because the results are difficult to interpret, since the form variations are not perceptible with the high number of sectors and of little significance for the region scale. In the district and subprefecture scales they may present interesting results, complementing the choropleth maps, in case the numeric difference among the data is significant. If not, the anamorphosis is similar to the original map, losing its most relevant character.

The use of Ikonos satellite imagery had the inverted concept of the choropleth maps, because its detail richness and file size allows a good visualization of small areas, compatible with that of the sectors. The overlaying of sectors to the images revealed an interesting composition, although the vectors do not adjust perfectly to the image pixels. Its use showed itself efficient only in a large scale, to view from 5 to 20 census sectors.

4.2 Contents

The contents of the atlas were grouped in three main parts: physical aspects, urban infrastructure and the socio-spatial differentiation indicators. Their complete description can be observed next:

- Introduction (objective, proposal and context);
- History of the city;
- Urbanization elements of the city;
- Physical aspects of São Paulo: terrain, hydrography, geomorphology, climatology;
- Urban infrastructure: main road network, transportation system, schools, hospitals, green areas and parks;
- Socio-spatial differentiation indicators: population and household densities, piped water, sewerage and waste collection. Number of houses, apartments, rooms, owned households, rented, with 1 dweller and with 10 or more dwellers. Literate and illiterate inhabitants, those responsible for the household with zero to one year of study, with zero to three years of study, and with fifteen or more years of study. Those responsible without income, average income of those responsible in minimum wages, income of up to half a minimum wage, income of 0 to 3, 3 to 5, 5 to 10, 10 to 20 and of 20 or more minimum wages. Population of 0 to 4 years of age, of 0 to 14 years of age, of 65 or more years of age and of 80 or more years of age.
- Final considerations (synthesis maps).

4.3 Atlas layout

The atlas was planned for the A4 size, with landscape orientation, and Couché Reflex (150g/m²). Although the A3 size was more appropriate, the costs for a 3,000 copy edition made its choice prohibitive, even with the contribution of research support agencies.

After countless tests and the making of 676 maps, a layout pattern was chosen for the chapter of socio-spatial differentiation indicators: choropleth, interpolations, scales and hybrids, with the prevalence of the district representation.

In this sequence, each of the themes (income, schooling, etc.) shall be illustrated by four pages of maps. The population density example is illustrated in the next figures, except for the text that will go with the representations. With this layout, the left and right pages will be used always in pairs, so that the reader may compare them visually.

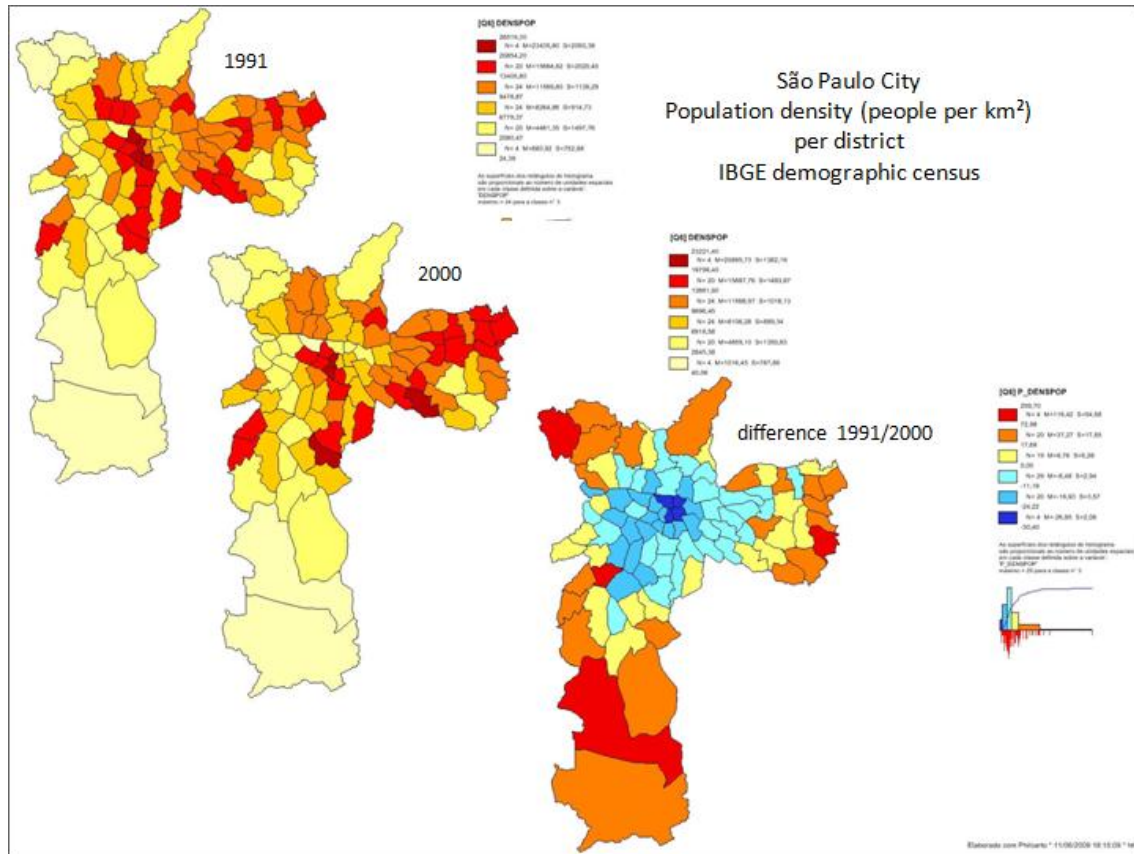


Figure 2: Choropleth maps of population density in 1991, 2000 and of the difference 1991/2000, per district (left page).

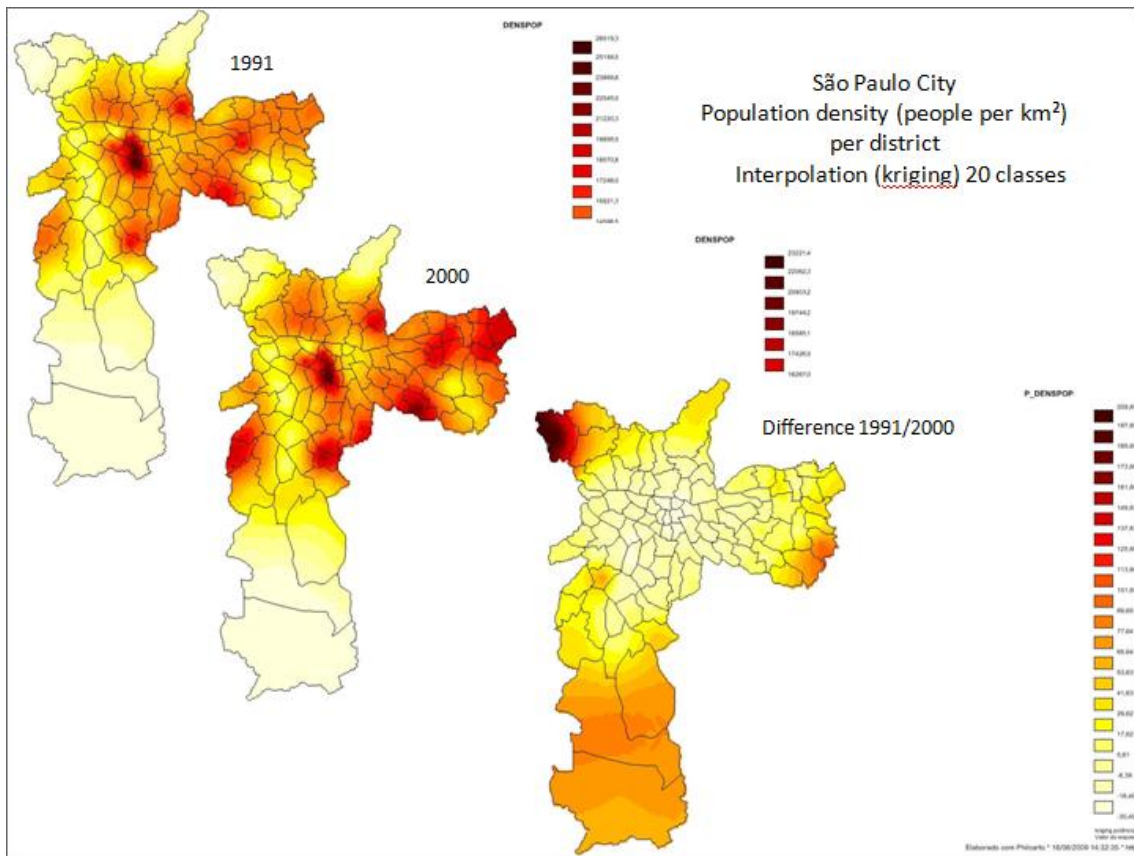


Figure 3: Isarithmic maps (interpolations) of population density in 1991, 2000 and of the difference 1991/2000, per district (right page).

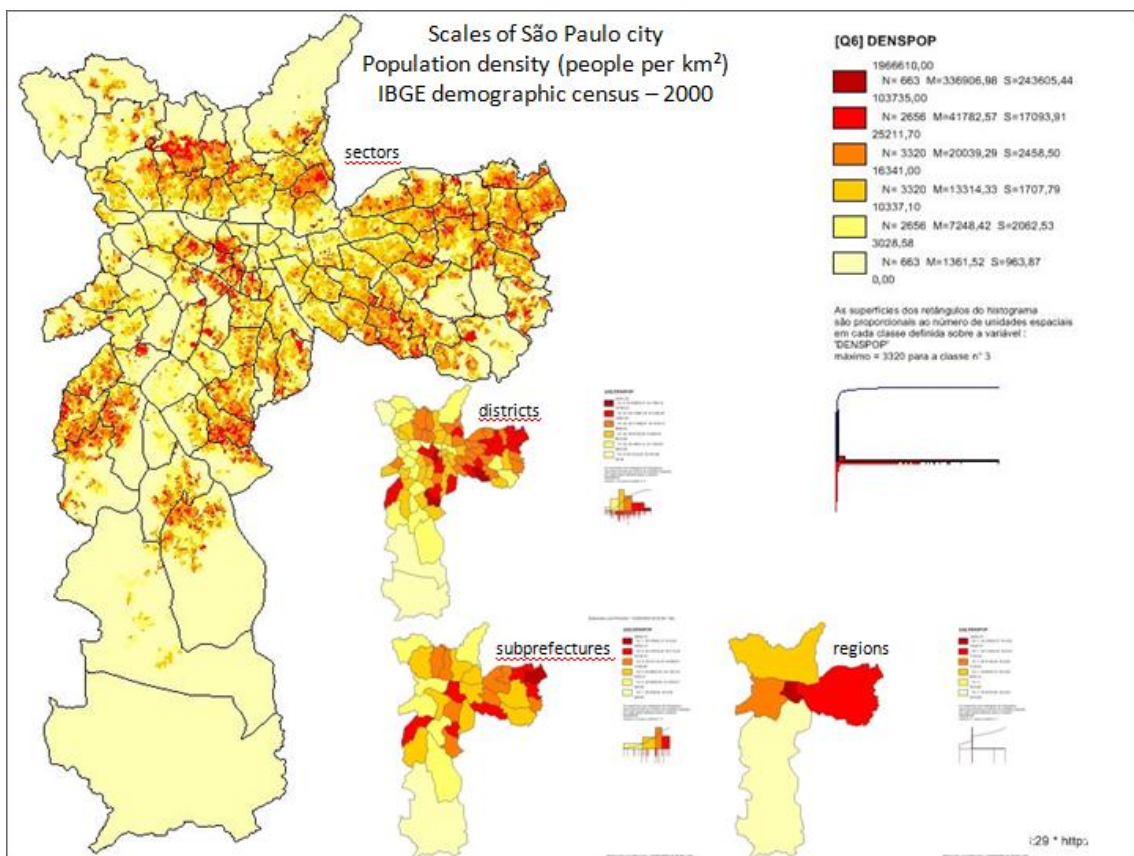


Figure 4: Maps of population density in 2000 in the four data grouping units (left page).

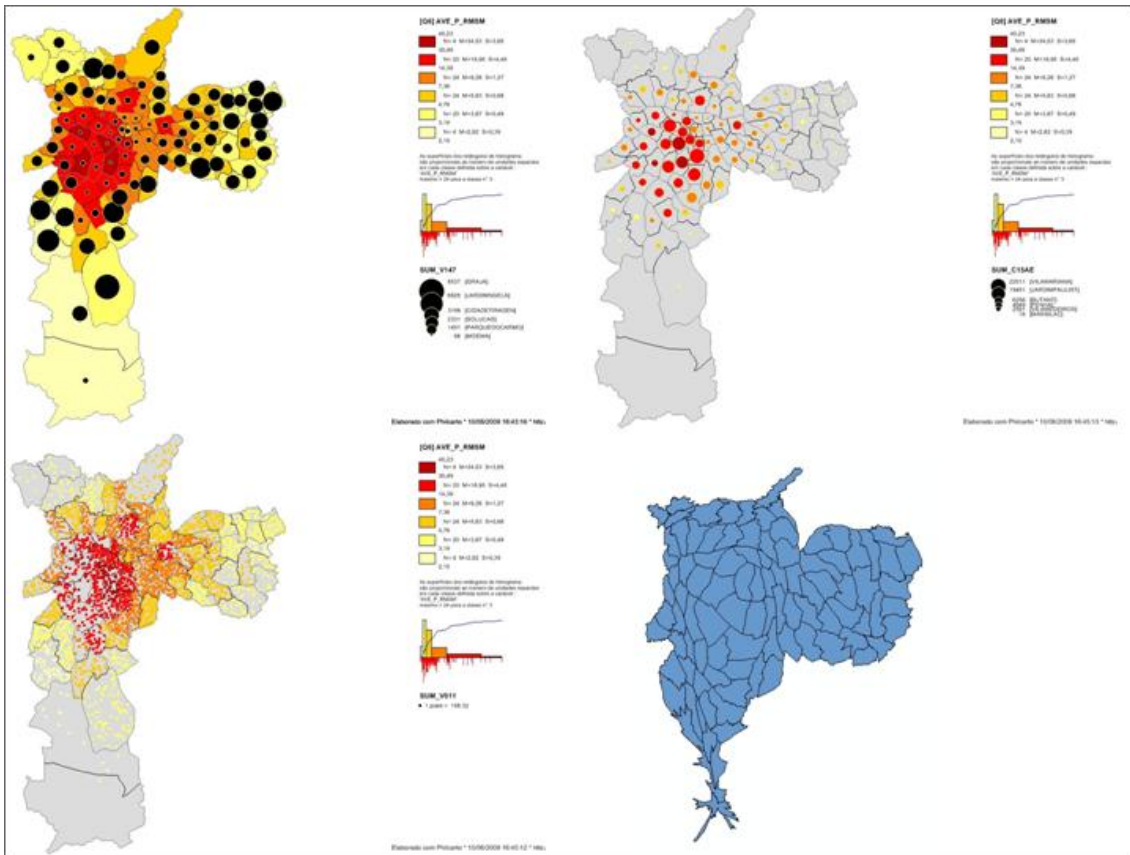


Figure 5: Composed thematic maps and anamorphosis (right page).

In figures 2 and 3, it was intended to represent the spatial distribution and the temporal dynamics (1991, 2000 and 1991/2000), in the district scale. It is expected that the setting of the choropleth maps, on the left page, and of the interpolations, on the right page, against each other will provide the reader with an interesting visual comparison, because in the first the colors are restricted to the district limits, and in the second, they transcend them, giving the idea, though hypothetical, of a gradient between the extremes.

In figure 4, with the illustration of the variable in the four representation scales, with a privilege for the sectors, it is intended that the reader notices the representation differences in each one of them. The text that will go with them shall have a fundamental role to guide this perception.

In figure 5, the concern was to insert thematic representations made up of two variables and, when convenient, anamorphoses and/or satellite imagery so that the reader relates the various data. In this case, it was included a map of the income of the one responsible and of the number of those responsible with up to 1 year of study, a map with the income of the one responsible and the number of those responsible with 15 or more years of study (colored geometric figures) and the map of income and number of rented properties (dot maps). The population density anamorphosis of 2000 shows the population concentration in the central region and the low density in the south region of the city.

4.4 Main problems

The problems faced in the initial stage of elaboration of the atlas were divided in three groups: cartographic, data and software. The most important cartographic problems were:

- The lack of proportion in the sizes of the census sectors made their representation more complex and made the use of proportional geometric figures impracticable. The smallest one has 0.0003 km^2 , the largest one, 77.973 km^2 , the average $0,115 \text{ km}^2$ and standard deviation 0.931 km^2 .
- The lack of proportion was also repeated in the districts, minimum size of 2.196 km^2 , maximum of 209.777 km^2 , average 15.906 km^2 , and standard deviation 26.898 km^2 . In the choropleth maps, the larger areas, which are located at the suburbs, stand out much more than the smaller ones, more central;
- The choropleth representation of more than thirteen thousand census sectors loses part of its nuances, particularly when small and neighboring polygons belong to distinct intervals.

As to the data of the IBGE demographic censuses, the following events stand out:

- A considerable number of census sectors that have no data, that is, all of the variables are equal to zero. In 1991 are 154 sectors, and in 2000, 53 sectors¹.
- The codes of the census sectors are different on both censuses (1991 e 2000) and their correlation is not trivial, because many disaggregations of different natures occurred and, in a smaller number, aggregations;
- The lack of the number of illiterate in 1991. To allow the comparison with 2000, it was calculated the following way: total population minus the literate population added to the population of 0 to 4 years of age. Since the intervals of the census data are from 0 to 4 years of age, from 5 to 9 years of age, and from 10 to 14 years of age, this may be a problem, because not all 5 year-old children go to school, and this is no reason for them to be considered illiterate. According to the new Brazilian law, the child who turns 6 years old until June 30 will have the right for a place at school;
- The difference of size of the areas of the sectors. The sum of sectors in 1991 was of 1527.445022 km^2 and, in 2000, 1527.030052 km^2 . This means a small percentage difference, -0.02716759% , but it represents 0.41497 km^2 in the city, that is, $414,970 \text{ m}^2$. The one of 2000 was used, for being considered more up-to-date and, therefore, probably more precise.
- The difference in the number of households of the sectors. Although, in 2000, an average number of 300 households per sector is foreseen, the largest one has 1,493 households, the smallest has 1, the average 224.8 and standard deviation 90.09;
- Insecurity as to the date of disclosure of the data of the 2010 census. Those of the 2000 census took two and a half years, but, since computers have had a much greater use, it may be available from mid 2011. If the atlas is published without the data of 2010, it may become outdated in less than one year (possible issuing in 2010). The novelty and completeness of the data is a stimulus to wait for the new data, but the project of which this work comes from ends in March 2011.

The main problems that occurred with the manipulation of software were:

¹ To preserve the privacy of the interviewee, IBGE does not disclose the data when the sectors have 5 or less households.

- The data of the IBGE demographic censuses are supplied in the shape (shp) format. Microsoft Access 2007 did not recognize the data bank extension (dbf) of these files;
- Microsoft Excel 2007, which had its column limit expanded from 256 to 16,384, reads the dbf format, but does not import anything beyond 256 columns, less than half of the 527 variables of the census;
- Arcmap did not succeed in exporting data in text (txt) format. The program delivered an error message when processed the 527 column and 13,278 line file;
- Some census sectors are made of two (disconnected) polygons, contrary to what their definition foresees, or are islands. This way, it was not possible to treat these issues during the data import stage of the Philcarto software. The referred polygons were computed, but ended up without their respective centroid;
- Philcarto did not succeed in calculating the interpolation (kriging) of the census sector files, given the amount of data and complexity of the algorithm;
- Scape Toad, used to generate the anamorphosis, did not allow the use of the density function. To make the data uniform, only the mass statistic function was used.

5 Final considerations

The proposal of the Atlas of socio-spatial differences of São Paulo city was presented. It was sought to represent the data of the 1991 and 2000 demographic censuses, in different scales, and integrate the distinct thematic maps to make the urban occupation unevennesses stand out.

Its contents were grouped in three main parts: physical aspects, urban infrastructure and socio-spatial differentiation indicators. It was planned for the A4 size, with landscape orientation and Couché Reflex (150g/m²) paper.

To visually point out the unevennesses of the urban occupation, the layout has foreseen the use of the following maps: choropleth, interpolations, in 4 scales and hybrids, with a prevalence of the district representation. To make the visual comparison and the perception of the extremes easier, it was adopted only one kind of interval, the quartiles, with six classes.

Each of the themes should have to be illustrated by four pages of maps, intercalated with the respective explanatory texts. In this layout, the left and right pages are used in pairs, so that the reader can visualize: choropleth maps in the left page, interpolations in the left page, different scales in the left page and hybrid maps in the right one.

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