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and Léa Cristina Lucas de Souza

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Conference Program and Book of Abstracts

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A METHODOLOGICAL APPROACH IN ORDER TO DEFINE A GEOGRAPHICAL TERRITORIAL STRUCTURE CLASSIFICATION THROUGH AN APPLICATION IN THE SOUTH OF BRAZIL

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Keywords: Sustainable Planning, Geographical Information Systems, Territorial Structure Classification, Kohonen´s Self-Organizing Map (SOM) neural network

Traditionally, the territorial classification is achieved by analysing the land use and spatial statistical information according general classification principles. However, the use of miscellaneous territorial information can be problematic to achieve a good methodological approach. In that context, a methodological approach that makes use of an unsupervised classification of digital information is proposed. A type of classifier is used in order to uncover commonly occurring and distinctive territorial patterns on the assumption that these represent major territorial structures classes. The proposed approach is tested in a case study carried out in the South of Brazil. All the municipalities were classified and grouped within areas according to similar condition of urban preponderance and socioeconomic parameters. The identification of those areas, which constitutes an option to avoid the confrontations that may be derived from the essentially subjective political criteria, can be important to develop common sustainable strategies and advances in municipality partnerships.

Therefore, the main goal of this paper is to test methodologies for defining homogeneous municipalities groups. These methodologies use criteria based on a list of sustainable indicators, searching the delimitation and characterization of these homogeneous zones. Two methodologies are proposed: (a) using a ranking of municipality through an aggregate index; (b) using Kohonen´s Self-Organizing Map (SOM) neural network as an unsupervised classifier. The methodology sequence is structured in four parts: (i) Acquisition of municipality data referred to demographic, socio-economic and environmental indicators; (ii) Selection of indicators to describe the sustainability of the municipalities; (iii) Integration of data bases information in a geographic digital base of study area; (iv) Application of data treatment techniques to identify municipalities groups that configures zones with homogeneous characteristics.

First of all, a group of indicators is selected (Table 1) according the three dimensions of sustainability - demographic, socio-economic and environmental. Hence, the selected indicators became the base to study and classify the municipalities and to identify the homogeneous regions according to urban sustainable characteristics. Then, based on the aggregator index result, the municipalities were ranking in decreasing ordering of values. The municipalities ranking is divided in order to delimitate four groups with similar characteristics based on average and standard

deviation values obtained to the aggregator index. Similar to index aggrega method, the classification process was programmed to result as an output of f classification groups and the first group represents the more sustainable territor and the four the less sustainable.

Table 1: List of Indicators for each sustainable dimension used in the study

Dimensions and Indicators
Demographic: Population Literacy Rate (%); Municipal Human Health Developmen Index (*); Municipal Human Education Development Index (*)
Socio-economic: Percentage of population who lives in domiciles with private car (° Percentage of population who lives in domiciles with public electric energy supply (%); Municipal Human Income Development Index (*)
Environmental: Percentage of people who lives in domiciles with public water suppl (%); Percentage of people who lives in domiciles with waste collection service (%)

* The indexes values were multiplied by 100, for suiting with the percentages. Thus, the scale of 0-1 becomes a scale of 0-1(

The study area is the South Region of Brazil, shaped by the states of *Paraná*, *Sai Catarina* e *Rio Grande do Sul*. The territorial extension of the study area 500.000km^2, occupying 6,8% of Brazilian territory. The total population is 25 millic of habitants, approximately 15% of Brazilian population. The Figure 2 shows t spatial distribution of the four groups as result of the two methods applied.

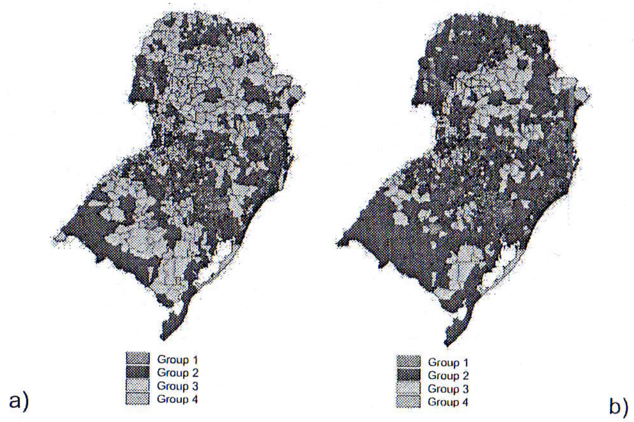

Figure 2 – Municipalities classification - a) Method 1 – aggregator index ranking b) Method 2 – SOM Unsupervised classification

It is important emphasize that the case study adopt only data available in WWW, t in futures studies some advance can be achieve with the use of superior da information at refined spatial scale (smaller territorial unit). Thus, if the analysis moc was implemented using a range of historical data and a desegregation level information more detailed, lower than municipality level, the results can provide mo interesting conclusions. Finally, it is highlighted the contribution of mathemati toolbox (statistics and artificial neural networks) applied in a GIS environment in ord to organize and administrate the spatial and multidisciplinary information of tl territory. This shows the potential of news data analysis methods that allows bett perception of urban phenomena in a spatial scale.

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Abstract

Traditionally, the territorial classification is achieved by analysing the land use and spatial statistical information according general classification principles. However, the use of miscellaneous territorial information can be problematic to achieve a good methodological approach. In that context, a methodological approach that makes use of an unsupervised classification of digital information is proposed. A type of classifier is used in order to uncover commonly occurring and distinctive territorial patterns on the assumption that these represent major territorial structures classes. The proposed approach is tested in a case study carried out in the South of Brazil. All the municipalities were classified and grouped within areas according to similar condition of urban preponderance and socioeconomic parameters. The identification of those areas, which constitutes an option to avoid the confrontations that may be derived from the essentially subjective political criteria, can be important to develop common sustainable strategies and advances in municipality partnerships.

Keywords: Sustainable Planning, Geographical Information Systems, Territorial Structure Classification

1. INTRODUCTION

To consolidate the sustainable development in a regional level the municipal administrations give more and more priority to the necessity of characterize the territorial structure in order to improve the public administration to a regional level.

However, this process has difficulties to identify the groups of municipalities to aggregate with similar characteristics and to organize them in function of their socioeconomic features and neighbourhood spatial relationships. Hence, it is important to considerate the fact of these municipalities can be in different levels of development and have different characteristics in function of some sustainable indicators.

For this reason, in last decades, urban and regional studies search to enlarge the application of emergent planning techniques (RAMOS and SILVA, 2002), for example, the use of geoprocessing toolbox, spatial statistics and neural networks in a geographic information system environment. Hence, through these techniques of processing and analysing spatial data in several information layers it is possible to consider multidisciplinary characteristic of decisions in regional and urban planning.

Therefore, the main goal of this paper is to test methodologies for defining homogeneous municipalities groups. These methodologies use criteria based on a list of sustainable indicators, searching the delimitation and characterization of these homogeneous zones. Two methodologies are proposed: (a) using a ranking of municipality through an aggregate index; (b) using Kohonen´s Self-Organizing Map (SOM) neural network as an unsupervised classifier.

The study area is the South Region of Brazil, shaped by the states of *Paraná*, *Santa Catarina* e *Rio Grande do Sul*. The territorial extension of the study area is 500.000km^2, occupying 6,8% of Brazilian territory. The total population is 25 millions of habitants, approximately 15% of Brazilian population.

2. BACKGROUND

Research concerning the municipality classification through a ranking of socio-economic indicators seems to be a simple and efficient form to aggregate several information layers and to achieve municipality data as much as necessary to help the regional and urban planning decisions. Two studies carried out in Portugal shows the applicability of this type of methods: (i) the first study classify the administrative units in predominantly urban areas, median urban areas and predominantly rural areas, according to the population census data (INE; DGOTDU, 1997); (ii) the second study, made in the metropolitan region of Lisbon, analyse a temporal series of socioeconomic and environmental indicators, connected with urban and rural areas defined by the first study, and identify the indicators that delimit and characterize the urban ambient in a better mode (MONTEIRO, 2000)

Following the same topic about the delimitation of homogeneous zones, researchers are applying emergent planning techniques in integrate and spatial form to analyse several levels of geospatial data. These techniques explore data to identify patterns and hot spots observed in the real world, especially in homogeneous areas studies (MEDEIROS, 1999; TEIXEIRA, 2003; MANZATO, 2007; RAMOS E SILVA, 2007). Between several recent papers in this area, two studies must be highlighted: (i) the delimitation of metropolitan areas in Portugal. The metropolitan region of Oporto and Lisbon were evaluated through census data of 1991 and 2001. Spatial Statistics (Moran local index) and neural networks are applied in order to comprehend the study area profile and to construct a scenario for 2011 (RAMOS and SILVA, 2007); (ii) the study of 21 districts in Western Cape region at South Africa, using a SOM neural networks as spatial classifier to organize demographic data. The goal was to identify homogeneous pattern regions in terms of population, ethnic, income and sex, in order to identify the spatial distribution of social extracts and populations (WINTER e HEWITSON, 1994).

3. METHODOLOGY

The methodology sequence is structured in four parts: (i) Acquisition of municipality data referred to demographic, socio-economic and environmental indicators; (ii) Selection of indicators to describe the sustainability of the municipalities in the environmental, social and economic dimensions; (iii) Integration of data bases information in a geographic digital base of study area; (iv) Application of data treatment techniques to identify municipalities groups that configures zones with homogeneous characteristics.

The data bases and the treatment data techniques adopted will be explained in the next sub-chapters.

4.1 Data base characterization

This research used two data bases: one geographic data base with boundaries of South Region of Brazil municipalities, and another data base with municipalities demographic, socio-economic and environmental indicators.

The geographic data base was obtained from the Territorial Unit Mapping of Brazilian Institute of Geographic and Statistic (IBGE). This product is characterized for representing, based on a topographic map, the Brazilian territory, through thematic maps for each Brazilian territorial spatial unit. In this study, the Municipal Digital Delimitation of 2001 of the States of *Paraná*, *Santa Catarina* and *Rio Grande do Sul* was used (IBGE, 2001), that shows the actual situation of Political-Administrative Division (DPA) of these States and Municipalities referred to Demographic Census of 2000.

Finally, the demographic, socio-economic and environmental indicators for each municipality were extracted from Human Development Atlas of Brazil (PNUD, 2003). This digital data base, based on microdata census of 1991 and 2000, gives digital information on state and municipal level (PNUD, 2006).

4.2 Indicators selection

The selection of indicators to describe the territorial units in order to evaluate the urban sustainable in a simple way, but trustful and suitable with the results extracted from background studies of this paper, was the main objective followed in this work stage. First of all, it is selected a group of indicators easy to integrated, without the necessity of a treatment data, as a normalization process, for example. Hence, data expressed by index (in a scale between 0-1) and by percents (scale between 0-100) was adopted. In the next step, the information that characterizes the three sustainable dimensions – demographic, socio-economic and environmental, was selected. The group of indicators selected according these three dimensions is in Table 1.

Hence, the selected indicators became the base to study and classify the municipalities and to identify the homogeneous regions according to urban sustainable characteristics. To effectuate this step of the study two classification methods are proposed: (i) ranking the municipalities using a aggregator index and the groups are proposed according the municipalities ranking position; (b) carry out an unsupervised classification technique in a GIS environment , using as input data the indicators values associated with each one of the municipalities. Both classification methods will be described in details in next items.

Table 1: List of Indicators for each sustainable dimension used in the study

Dimensions		Indicators
Demographic	D1 -	Population Literacy Rate (%)
	D2 -	Municipal Human Health Development Index (*)
	D3 -	Municipal Human Education Development Index (*)
Socio-economic	SE1 -	Percentage of population who lives in domiciles with private car (%)
	SE2 -	Percentage of population who lives in domiciles with public electric energy supply (%)
	SE2 -	Municipal Human Income Development Index (*)
Environmental	E1 -	Percentage of people who lives in domiciles with public water supply (%)
	E2 -	Percentage of people who lives in domiciles with waste collection service (%)

** The indexes values were multiplied by 100, for suiting with the percentages. Thus, the scale of 0-1 becomes a scale of 0-100.*

4.3 Classification of homogeneous regions through aggregator index ordering

The method is characterized by evaluating each municipality with the indicators used to the study area, without considering the spatial distribution of values in the classification of the groups. Thus, the methodological sequence follows the steps described next. The fundamental hypothesis was to consider that major indicators values signify major contribution to municipality sustainable development. Hence, in this stage, an aggregator index was constructed by total sum of all the eight indicators of Table 1 to each one of all the municipalities.

Based on the aggregator index result, the municipalities were ranking in decreasing ordering of values. So, the first ranking positions mean that the municipality reach the best index score to sustainability. In this analysis, a good score in an isolated indicator can compensate poorer values in other indicators to the same municipality.

The municipalities ranking is divided in order to delimitate four groups with similar characteristics based on average and standard deviation values obtained to the aggregator index. The four groups delimitation proposed are:

(i) Group 1: municipalities from maximum aggregator index value to positive index value (average plus standard deviation);

(ii) Group 2: municipalities from positive index value (average plus standard deviation) to average value;

(iii) Group 3: municipalities from average value to negative index value (average minus standard deviation);

(iv) Group 4: municipalities from negative index value (average minus standard deviation) to minimum aggregator index value.

Finally, the group classification for each one of all municipalities was linked to digital geographic base to look at the spatial distribution outcome from the application of this classification method.

4.4 Delimitation of homogeneous regions through SOM unsupervised spatial classification

This method proposes the use of neural networks with in unsupervised classification techniques available in Idrisi GIS software (Idrisi 15.0 – Andes Edition, Clark Labs). The operation chose for testing this method is Kohonen´s Self-Organizing Map (SOM). The Figure 1 shows the software interface to SOM operation.

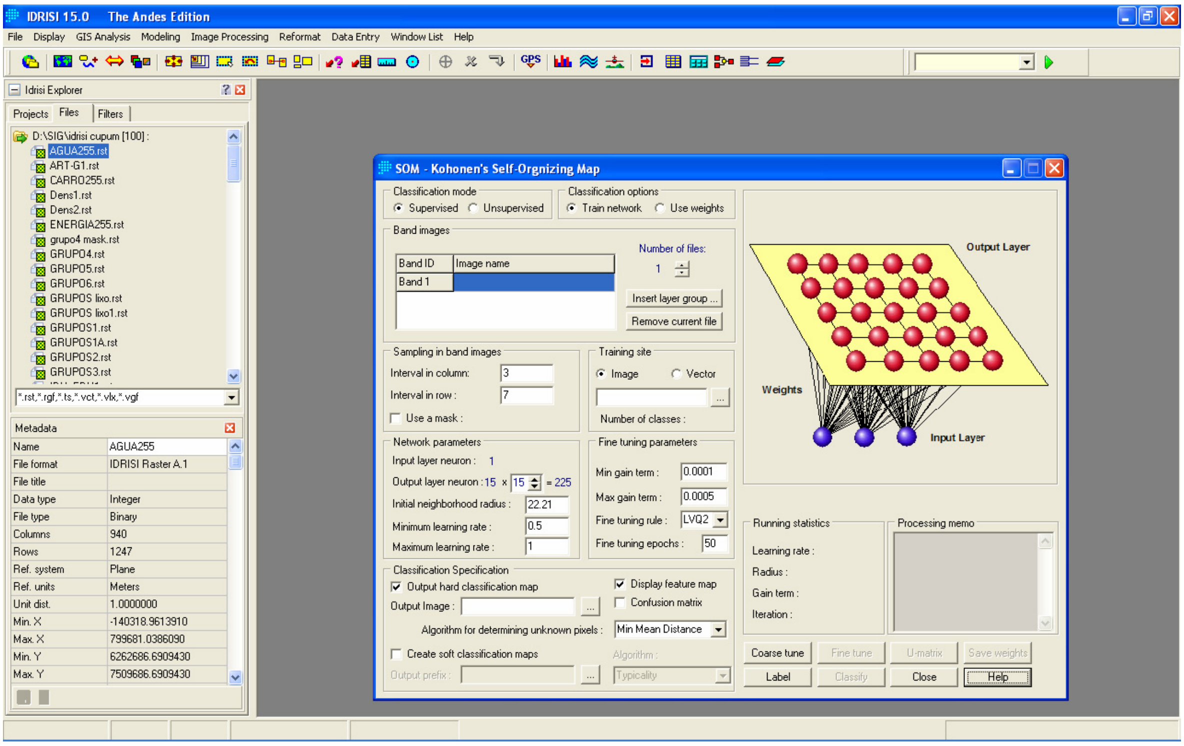


Figure 1 – SOM command interface in Idrisi software.

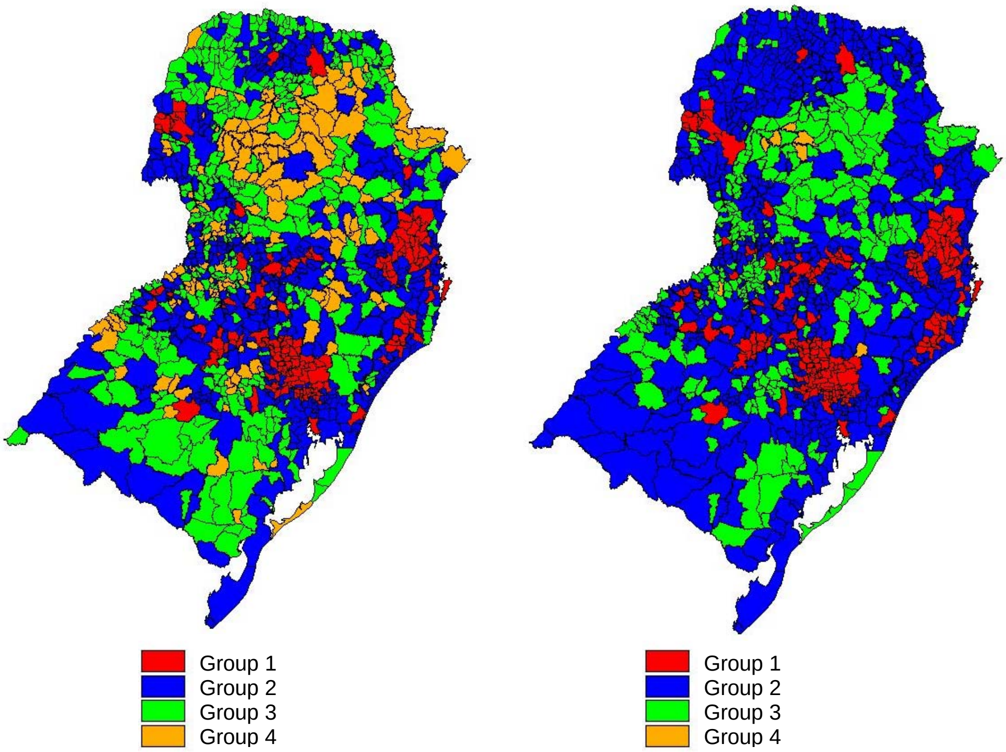
The SOM was developed by Prof. Teuvo Kohonen in the early 1980s and it is a neurospatial classifier with a powerful neural process based on parts of brain that operates in a similar form. The SOM is widely used as a data mining and visualization method for complex data sets. Application areas include, for instance, image processing and speech recognition, process control, economical analysis, and diagnostics in industry and in medicine. In the following, four particular views of the SOM are given: (1) The SOM is a model of specific aspects of biological neural networks; (2) The SOM constitutes a representative of a new paradigm in artificial intelligence and cognitive modelling; (3) The SOM is a tool for statistical analysis and visualization; (4) The SOM is a tool for the development of complex applications. A summary of SOM algorithm, operation and applications is given in several recent literatures (KOHONEN, 2001; LI and EASTMAN, 2006; LI, 2006)

Therefore, as input for classification processing it was apply the images with the same indicators data base of the first method. However, this data was connected to a raster geographic image to be adjusted to Idrisi software specifications.

Similar to index aggregator method, the classification process was programmed to result as an output of four classification groups and the first group represents the more sustainable territories and the four the less sustainable. Due to the fact of the Idrisi unsupervised classification produces as final result a raster map with the output information, it have been necessary to change the pixel scale analysis to vector entity scale analysis to compare the results with the first method.

4.5 Comparing analysis of results

The Figure 2 shows the spatial distribution of the four groups as result of the two methods applied. In the figure 2.b the pixel information result from the second method was transferred to municipality delimitation, allowing the result comparison between the two methods. In the final of the paper, the Appendices 1 shows all indicators value summary for each group from each classification method.



a) Method 1 – aggregator index ranking b) Method 2 – SOM Unsupervised classification

Figure 2 – Municipalities classification

The delimitation proposed by both methods to defined the Group 1 in similar and coherent. The municipalities of the Group 1 have the maximum indexes value of urban sustainable and are located in metropolitan and industrial regions of the South of Brazil. This group concentrate the municipalities with major values of per capita income and municipal human development index.

In other way, the delimitation of Groups 2 and 3 seems contradictory in the two methods: while the aggregate index ranking method shows a better balance municipal distribution between groups 2 and 3, the SOM method shows more municipalities classified in group 2 than in group 3. The both groups have values of human development indexes and per capita income at an intermediate level, characterizing a transition space between group 1 and 4.

In the same way, the Group 4 have the most different solution between the two methods: the aggregate index ranking method classifies 169 municipalities in group 4, against only 9 municipalities in the SOM method. The Group 4 is characterized by minor sustainable urban score and low values of per capita income.

Never the less, it is possible to conclude that, based on criteria defined by indicators in two methods applied, the municipalities with best urban sustainable index (Group 1) showing the best per capita income. This result indicate that, in this specific case, the urban sustainable is conditioned by municipal per capital income and not only by demographic density and socio-economic factors.

Comparing the two methods proposed through a qualitative and empiric evaluation the SOM method indicates a result more coherent with observed reality than the ranking method. The main reason for this conclusion is the fact of object study shows strong socio-economic contrasts between areas closely to metropolitan regions and municipalities located in rural areas, distant from administrative centres or employment areas. This situation highlights an unbalanced situation between financial and social resources distribution among the territorial extension.

4. CONCLUSION

The study has achieved with success the objective proposed but some affirmations defended previously, in result analysis, require complementary investigation. The indicators selection, especially in social and environmental aspects, must be an important aspect to futures studies. The suggestion is to search indicators that could represent in better way environmental and social conditions and looking for relationships between them and urban sustainability, besides the per capita income correlation.

Also, it is important emphasize that the case study adopt only data available in WWW, but in futures studies some advance can be achieve with the use of superior data information at refined spatial scale (smaller territorial unit). Thus, if the analysis model was implemented using a range of historical data and a desegregation level of information more detailed, lower than municipality level, the results can provide more interesting conclusions.

Finally, it is highlighted the contribution of mathematics toolbox (statistics and artificial neural networks) applied in a GIS environment in order to organize and administrate the spatial and multidisciplinary information of the territory. This shows the potential of news data analysis methods that allows better perception of urban phenomena in a spatial scale.

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Appendices 01 – Data from SOM method (superior tables) and from ranking method (inferior tables). The values highlighted show an increase in standard deviation value.

SOM classification method

Number of municipalities			INDEX (Z-score)				Water supply			
			mIn	media	Std.Dev.	max	min	media	Std.Dev.	max
GROUP1	206	17.8%	0.19	1.23	0.29	1.88	78.19	97.54	2.66	99.76
GROUP2	657	56.7%	-1.62	0.18	0.50	1.02	79.14	94.65	3.67	100.00
GROUP3	287	24.8%	-3.23	-1.17	0.67	0.26	56.67	82.17	7.99	100.00
GROUP4	9	0.8%	-4.37	-3.74	0.39	-3.23	53.14	64.12	7.30	79.79
	1159	100.0%							21.62	

Ranking classification method

Number of municipalities			INDEX (Z-score)				Water supply			
			mIn	media	Std.Dev	max	min	media	Std.Dev	max
GROUP1	172	14.84%	1.00	1.32	0.22	1.88	90.62	98.15	1.54	99.76
GROUP2	453	39.09%	0.01	0.51	0.28	1.00	78.19	95.53	3.21	100.00
GROUP3	365	31.49%	-1.01	-0.44	0.30	0.01	68.56	90.43	5.85	100.00
GROUP4	169	14.58%	-4.37	-1.74	0.71	-1.01	53.14	78.55	8.97	96.13
	1159	100.00%							19.57	

Private car				Electric energy supply				Waste collection service			
min	media	StdDev	max	min	media	StdDev	max	min	media	StdDev	max
45.84	59.94	6.87	79.56	96.83	99.50	0.52	100.00	50.88	96.00	4.69	99.80
17.64	42.41	7.68	63.74	87.71	98.11	1.80	100.00	67.92	94.96	4.00	99.91
6.99	32.13	6.52	56.80	57.19	88.90	7.87	99.71	20.00	86.01	13.45	99.20
14.51	21.09	6.01	33.33	43.35	54.62	9.25	69.65	20.00	61.60	20.58	81.48
		27.08				19.43				42.72	

Private car				Electric energy supply				Waste collection service			
min	media	StdDev	max	min	media	DesvPadr	máximo	min	media	StdDev	max
46.47	60.96	6.87	79.56	97.92	99.62	2.59	100.00	90.06	96.99	2.15	99.80
27.67	46.79	6.43	63.74	89.76	98.62	3.97	100.00	50.88	95.38	4.24	99.91
17.64	35.89	4.99	50.55	82.26	95.62	4.40	99.95	72.21	92.64	5.27	99.37
6.99	28.65	6.58	56.80	43.35	84.32	5.58	99.68	20.00	81.05	17.10	97.37
		24.86				16.55				28.76	

Literacy				Health				Education			
min	media	StdDev	max	min	media	StdDev	max	min	media	StdDev	max
89.27	94.77	1.76	98.41	0.74	0.83	0.03	0.88	0.87	0.91	0.02	0.98
75.73	89.03	4.26	99.09	0.63	0.77	0.05	0.88	0.75	0.86	0.03	0.95
71.03	84.64	4.36	94.39	0.61	0.75	0.05	0.86	0.69	0.82	0.04	0.90
74.93	79.70	3.63	85.18	0.59	0.68	0.05	0.76	0.73	0.78	0.03	0.81
		14.02				0.18				0.12	

Literacy				Health				Education			
min	media	StdDev	max	min	media	StdDev	max	min	media	StdDev	max
89.27	94.88	1.77	98.41	0.75	0.83	0.03	0.88	0.87	0.91	0.02	0.98
82.22	91.23	2.87	99.09	0.69	0.80	0.04	0.88	0.81	0.88	0.03	0.95
76.85	85.97	3.82	94.39	0.65	0.75	0.04	0.87	0.77	0.84	0.03	0.92
71.03	82.81	4.62	94.07	0.59	0.73	0.06	0.86	0.69	0.80	0.04	0.89
		13.09				0.17				0.11	

Income				Per capita Income				Demographic Density			
min	media	StdDev	max	min	media	StdDev	max	min	media	StdDev	max
0.66	0.74	0.04	0.87	205.06	337.50	78.11	709.88	3.30	148.95	412.61	3682.80
0.57	0.68	0.03	0.78	116.09	233.33	47.58	406.43	2.60	69.57	221.28	2516.10
0.52	0.62	0.03	0.71	86.00	163.90	29.13	270.86	2.20	20.07	11.07	97.70
0.54	0.56	0.02	0.58	96.63	110.20	10.70	125.54	5.50	15.64	8.09	28.50
		0.12				165.52				653.05	

Income				Per capita Income				Demographic Density			
min	media	StdDev	max	min	media	StdDev	max	min	media	StdDev	max
0.68	0.75	0.03	0.87	223.77	348.86	78.53	709.88	3.30	164.53	447.28	3682.80
0.62	0.70	0.03	0.78	156.35	256.60	42.75	406.43	4.30	91.48	264.81	2516.10
0.58	0.65	0.02	0.73	126.73	190.79	28.29	307.90	2.20	25.80	26.46	330.60
0.52	0.60	0.03	0.71	86.00	147.75	27.23	265.70	2.40	18.53	9.44	63.80
		0.12				176.79				747.99	