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MOBILITY, URBAN SPRAWL AND ENVIRONMENTAL RISKS IN BRAZILIAN URBAN AGGLOMERATIONS: CHALLENGES FOR URBAN SUSTAINABILITY[1]

Ricardo OJIMA

Post-doctoral Fellow, State of São Paulo Research Foundation (FAPESP); Collaborating Researcher, Population Studies Center, University of Campinas (Unicamp), Researcher at the João Pinheiro Foundation, Brazil

Daniel Joseph HOGAN

Professor of Demography and Geography, University of Campinas (Unicamp), Brazil

Abstract

Studies of uncontrolled expansion of urban land use mention innumerable social, economic and environmental impacts. Among the principal factors considered in terms of urban sprawl and the consumption of natural resources is the intensive use of individual automobile transportation. While this characteristic may be seen as both cause and consequence, the bottom line is that the greater the distances between different spheres of daily life, such as work, residence, study or shopping, the greater the demand for automobile transportation. A sprawl index was created to identify this process in Brazilian urban agglomerations. The index is constructed with a set of sprawl factors identified in the international

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literature as important measures of sprawl-like situations. Geographic Information Systems (GIS) were also used to create spatial indices, such as urban density and a spatial dissimilarity index. Today's city has a more and more complex structure, above all considering the ramification of urban networks, the interaction of economic flows, the intensification of population mobility and changes in consumption patterns. An agglomeration may therefore take on different forms as it disperses in space and these different forms may have distinct social and environmental impacts.

Key words: *Urban sprawl; Environment; Sustainability.*

1. Introduction

According to United Nations projections, the world's urban population will reach more than 50% in 2008, with the most important change occurring in developing countries. As a major component of modernization, urbanization has long occupied the attention of contemporary social theorists, who have given much consideration to the radical changes at the foundations of modernity. Of central importance in the study of urbanization and environment is that globalization processes are seen both to destroy earlier structures and to offer solutions for certain perplexing paradoxes of contemporary life. The environmental dilemma, as a second major component of modernization is an unequivocal demonstration of this ambiguity in the 21st century because it represents the conflicts of the production-consumption relation. Thus, environmental debates stress the evidence of the 'side-effects' of urban-industrial processes and products. The concomitant occurrence of urbanization and environmental change endangers basic conditions of survival, changes ways of life and puts into question the belief of the superior rationality of experts.

In this sense, global environmental risks express the challenges of such changes through global warming and its impacts on populations. This situation may be better observed in the complexity of urban contexts around the world, including most of the urban agglomerations of developing countries. In Brazil, migration to urban areas occurred rapidly in the nineteen seventies and by late 20th century had begun to present signs of an important transformation. Metropolitan areas that had grown in earlier decades are now losing centrality. New urban agglomerations come to be the preferred destinations of urban-urban migration. In this second "urban transition", urban sprawl is one of the signs of a new spatial relationship of production and consumption.

Brazilian sprawl differs from that of the United States because there is an overlay of social processes that led to these urban forms. In the first urban transition, rural-urban migration was most important and the relationship between urbanization and production was mostly obvious. Today, urban-urban migration reveals new social forces which are leading to new urban forms: consumption of space follows the global urban tendency, in which regions and not cities are the most important scale of everyday life.

The recent tendencies of the world urbanization process in a context of globalized markets point to a situation in which regions (as opposed to specific localities) emerge as economic and political arenas with greater autonomy of action at national and global levels. City-regions constitute nodes which express a new social, economic and political order which, far from dissolution of regional importance resulting from the globalization process, become increasingly central to modern life. Urbanization, then, widens its scope beyond the image of the chaotic city which grows like an amoeba. The image is replaced by one of a polynucleated city, fragmented, with low densities, over wide-ranging territorial extensions, but at the same time more and more integrated.

Studies concerned with this uncontrolled expansion of urban land use mention innumerable social, economic and environmental impacts. Among the principal factors considered in terms of urban sprawl and the consumption of natural resources is the intensive use of individual automobile transportation. While this characteristic may be seen as both cause and consequence, the bottom line is that the greater the distances between different spheres of daily life, such as work, residence, study or shopping, the greater the demand for automobile transportation.

This is part of the growth in demand for fossil fuels as the principal energy matrix of the modern world, a process with many different consequences. In the case of sprawl, the growing use of automobile transportation is also associated with an increase in air pollution. In this context, this paper discusses the recent changes that have occurred in Brazilian urban agglomerations, arguing that population mobility (migration and commuting) play an important role in determining demographic changes, in particular sprawl-like urbanization processes.

Most urban sprawl studies analyze the relationships between urbanization and environmental change in developed countries, but there is a need for efforts to treat these questions in developing countries. This paper will focus on the relations between population mobility and urban form in Brazilian urban agglomerations using demographic data provided by the national Census Bureau (IBGE) to identify the most sprawling areas and the consequences for urban quality of life.

Commuting data has not been commonly used in Brazilian urban studies, probably because it has not seemed to be a relevant phenomenon until recent years. These data began to be used intensively only in the last ten years as commuting increased throughout Brazil. This increase is associated with the expansion of urbanized areas in a new urban morphology associated to the sprawl model. Despite the slowing of urban population growth in recent years, the physical size of urban areas is now increasing in many agglomerations of the country.

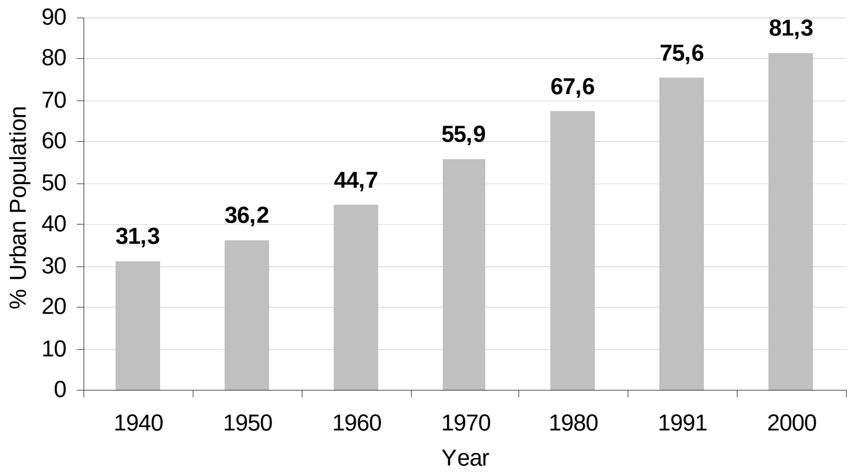
A sprawl index was created to identify this process in each urban agglomeration. The index is constructed with a set of several sprawl factors identified in the international literature as important measures of sprawl-like situations, seeking to adapt it to the Brazilian context. Geographic Information Systems (GIS) were also used to create spatial indices, such as urban density and a spatial fragmentation index. Today's city has an increasingly complex structure, above all considering the ramification of urban networks, the interaction of economic flows, the intensification of population mobility and changes in consumption patterns. An agglomeration may therefore take on different forms as it disperses in space and these different forms may have distinct social and environmental impacts.

2. The Brazilian urban context: commuting and sprawl

In a period of sixty years, Brazil's urban population has increased from 30% to 80% of total population, the urban transition having been made in the mid-sixties. The urban transition, as in other countries of Latin America, occurred in a unique context: **after** developed countries, but **before** most developing countries.

Despite continuous urbanization, social and economic drivers of this process changed in the last years of the 20th century. During the first years of the urban transition, long-distance migration prevailed,

Figure 1 – Urban population (%), Brazil (1940-2000)



Source: IBGE, Demographic censuses 1940-2000.

especially the Northeast-Southeast flow. Today, urban-urban migration has assumed the major role in spatial mobility. Commuting is increasing in metropolitan areas and has become part of individual strategies to reduce social, economic and environmental risk.

Giddens (1991) argues that personal life and the social ties that it involves are deeply interwoven with more far-reaching abstract systems. In late modernity, social rationality is more and more disconnected and fragmented for the individual. And this fragmentation is becoming visible in the morphology of urban areas. Not only as a reflection of economic globalization, but because of new ways of life spreading around the world, including into developing countries.

Brazilian urban studies have long concentrated on such themes as the center-periphery dichotomy, industrial neighborhoods, population densification and rural-urban migration. City planners, sociologists, anthropologists and geographers concentrated on studies of the occupation of intra-urban spaces, seeking to understand the social changes which structured the city. The city – conceived as a center-periphery, wealth-poverty dichotomy – reproduces the marginalization process of the working classes.

Discussions of the relationship between rural and urban persisted for many years as the center of debate. The overarching concern, however, was in relation to growing population concentration in large cities. Inspired in a sociological and geographical tradition that dichotomized the analysis of the social into those two categories, Brazilian studies have emphasized issues such as the relations between urbanization and industrialization; the city as an expression of modernization; real estate speculation; and the establishment of social services. By contrast, the rural was archaic; linked to agriculture, to the simple life, and to smaller populations; and without access to services.

By the 1980s and 1990s, the rural-urban dichotomy no longer dominated urban analyses, especially considering the environmental discourse which introduced new issues for urban studies. Natural resource use and the quality of life changed the meaning of urban for everyone, whether or not they lived in urban areas. The relationships among environmental discourse, quality of life, urban and rural came to be seen as interrelated phenomena.

In Brazil, Metropolitan Areas (MAs) were legally constituted in 1973/74 with the objective of promoting integrated planning and common services of metropolitan interest, under the aegis of the federal government. Nine MAs were created: Belém, Belo Horizonte, Curitiba, Fortaleza, Porto Alegre, Recife, Salvador, São Paulo and Rio de Janeiro. After the Federal Constitution of 1988, the number increased to 26. The significant increase of areas classified as MAs was not necessarily a reflection of metropolitanization processes, but rather reflects a change in the political-administrative process of creating metropolitan areas. The 1988 Constitution (Chapter III, Article 26, Paragraph 3) authorized States to define the number of MAs and the criteria for constituting them. This measure accompanied the process of decentralization of urban administration to the municipal level, and was an incentive to the creation of new MAs.

The new dynamics of urban networks in Brazil lead us to question the limits of the metropolis. Terms like city-region, global cities, diffuse city, dispersed urbanization, urban sprawl, peri-urbanization, metapolis or megalopolis are signs of a new spatial-functional organization of the complex system of social, economic and cultural interrelations involved in the globalization process. And it is in these urban contexts that the signs of globalization are felt more clearly; on one hand, a growing need for new interpretations of the urban phenomenon, and on the other, the extreme difficulty in apprehending increasingly complex processes.

The study which updated the concept of urban agglomeration in Brazil, independent of legal definitions, was "Characterization and tendencies of the urban network of Brazil" (IPEA/IBGE/UNICAMP, 2000). This study classified the Brazilian urban network in terms of homogeneous and analytical criteria applicable to the whole country, using uniform data sources. The criteria used for the identification of urban agglomerations in this research were:

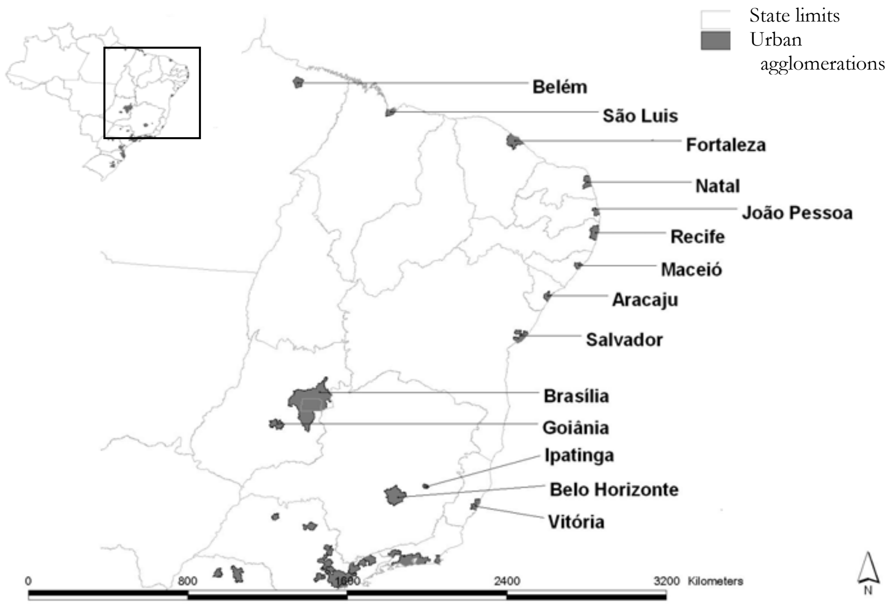
- *Continuous urban spaces (conurbation):* Continuity of the built-up area between the central core and at least one other municipality or the expansion of the built-up area from one municipality to the territory of another;
- *Population size:* For urban agglomerations resulting from the expansion of the central core, municipalities with a 1991 population of 200,000 or more inhabitants were included. When more than one urban core was involved: 150,000 inhabitants for the set of municipalities;
- *Density:* >60 inhabitants per km^2;
- *Economically active population:* 65% of the economically active population in urban activities;
- *Other qualitative indicators of regional importance.*

This methodology produced 49 urban agglomerations, classified into 12 "Metropolitan Areas" (Global, National and Regional), 12 "Regional Urban Centers" and 25 "Sub-regional Centers." According to Baeninger (2004), these results revealed that recent urbanization involved an intense process of interiorization of urban agglomerations, indicating the appearance of new areas of population attraction.

Figures 2 and 3 show the location of these agglomerations. They concentrate approximately 56.4% of total population in 1991, up from 50.8% in 1980. In relation to total *urban* population, however, their share declined from 75.1% in 1980 to 69.4% in 2000. According to UN estimates, Brazil will have 90% of its population living in urban areas by 2050. While total urban population continues to increase, more of this growth is attributable to small and medium-size municipalities, which now absorb an important part of this growth.

Brazil's urban network is increasingly complex and diversified. Traditional migration destinations are now growing more slowly. The growth rates of the global cities of São Paulo and Rio de Janeiro were below the average for urban agglomerations and even for total urban

Figure 2 – Location of urban agglomerations in the North, Northeast and Central-West regions and in the States of Minas Gerais and Espírito Santo

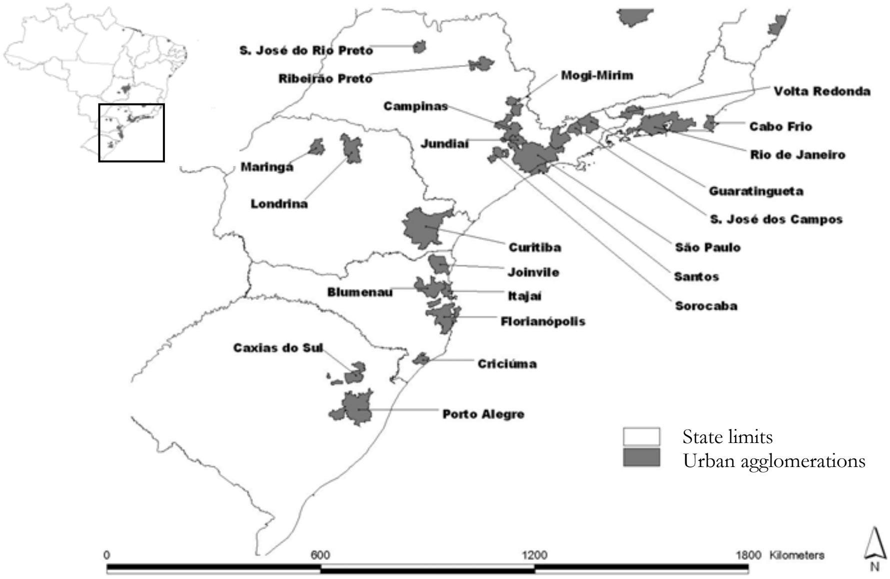


Source: IBGE, Municipal digital shapes, 2000.

population between 1980 and 1991; their share of total urban population declined from 42.8% in 1980 to 37% in 2000. These data require a better understanding of growth processes in this new spatial configuration. Once we recognize decentralization and de-concentration of the urban network, it is important to understand, in a comparative way, whether these processes are equally intense in all parts of the country, and especially whether spatial mobility has different impacts on urban form in different regions.

Given this new configuration of the urban network, we then sought to determine the spatial distribution processes within the 49 agglomerations mentioned earlier. Our hypothesis is that these movements have now become an indispensable criterion for redefining metropolitan and regional limits, and that new intra-urban movements linked to dispersed and fragmented urbanization are especially important. These questions are raised at a moment of new growth tendencies of Brazilian cities. Recent migration is less similar to earlier rural-urban

Figure 3 – Location of urban agglomerations in the South region and in the States of São Paulo and Rio de Janeiro

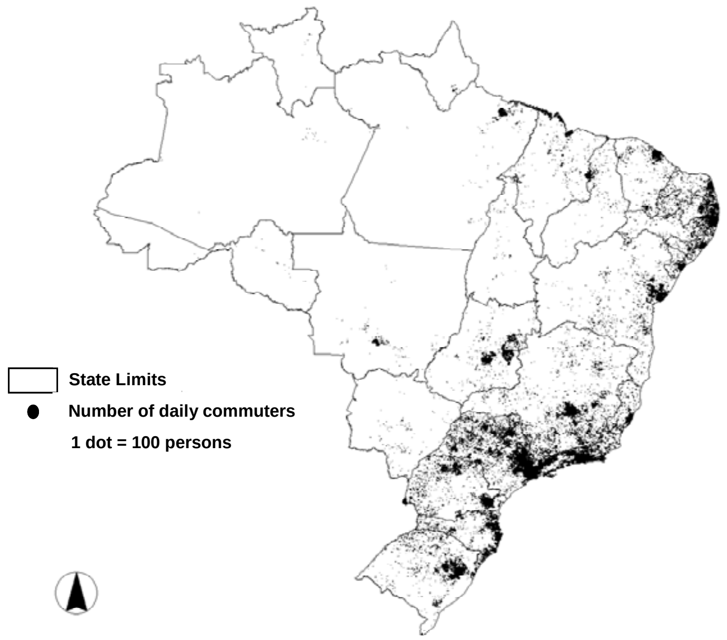


Source: IBGE, Municipal digital shapes, 2000.

and long-distance migration, having shifted to a predominance of short-distance movements. Among the important types of this short-distance movement is the commuting pattern within metropolitan areas, a type of urbanization more similar to sprawl-intense metropolises in other parts of the world. Commuting is an important condition for the consolidation of urban agglomerations.

According to Hogan (1993), commuting plays an important role in sustainable development. While these movements may sometimes redirect the burden of environmental deterioration, favoring some groups and penalizing others, the possibility of carrying out diverse activities (residence, work, study, consumption) in different places serves to conciliate conflicting needs in individual households. On the one hand, there may be a tradeoff between new environmental stresses created by commuting and the attenuation of competing demands of household members. On the other hand, more complex mobility patterns may diminish the vulnerability of households to unemployment, to inadequate educational or health services and to the isolation from family

Figure 4 – Commuters by municipality of residence (2000)



Source: IBGE, Demographic Census 2000.

support which was often a result of earlier migration patterns.

An examination of commuting data for the 49 urban agglomerations shows the relative concentration of this process. According to the 2000 Demographic Census, 7.4 million people worked or studied in municipalities other than that of residence, representing 4.4% of total population. The 49 urban agglomerations considered here account for more than 70% of those movements, 6.4% of the population of these areas.

São Paulo and Rio de Janeiro concentrate 38% of all commuters. When we analyze those volumes in terms of proportion of total population, however, these cities give way to smaller places. In São Paulo and Rio de Janeiro commuters correspond to 6.6% and 7.4% of their total population, respectively, while in agglomerations such as Vitória (ES), Florianópolis (SC) and Jundiaí (SP), commuters represent more than 10% of total population. It is clear, then, that while commuting may be concentrated in some regions, it is not a phenomenon exclusive of traditional metropolises like São Paulo and Rio de Janeiro.

Table 1 – Commuters by urban agglomeration and type of movement
(Intra: within the same UA; Inter: between UAs; Extra: to places outside an UA)

Urban agglomeration	Intra UA		Inter UA		Extra UA		Total	
	N	%	N	%	N	%	N	%
São Paulo	1,012,422	91.4	33,713	3.0	61,779	5.6	1,107,914	100.0
Rio de Janeiro	723,353	92.1	11,397	1.5	50,396	6.4	785,146	100.0
Salvador	59,213	81.1	2,987	4.1	10,855	14.9	73,055	100.0
Belo Horizonte	345,180	92.3	5,582	1.5	23,219	6.2	373,982	100.0
Fortaleza	70,397	86.8	1,656	2.0	9,065	11.2	81,119	100.0
Brasília	121,728	93.1	2,201	1.7	6,880	5.3	130,809	100.0
Curitiba	178,581	92.0	4,793	2.5	10,801	5.6	194,175	100.0
Recife	262,550	92.1	4,316	1.5	18,201	6.4	285,067	100.0
Porto Alegre	314,031	94.0	3,567	1.1	16,423	4.9	334,021	100.0
Belém	106,297	88.4	1,327	1.1	12,607	10.5	120,231	100.0
Goiânia	91,046	84.1	5,722	5.3	11,431	10.6	108,199	100.0
Campinas	128,802	78.6	22,690	13.8	12,394	7.6	163,886	100.0
São Luis	30,078	86.7	977	2.8	3,654	10.5	34,710	100.0
Maceió	8,460	58.6	955	6.6	5,015	34.8	14,430	100.0
Natal	40,454	86.0	1,388	3.0	5,213	11.1	47,055	100.0
Teresina	15,236	77.3	1,204	6.1	3,267	16.6	19,707	100.0
João Pessoa	27,655	79.1	2,135	6.1	5,185	14.8	34,975	100.0
São José dos Campos	33,523	67.2	11,385	22.8	4,949	9.9	49,857	100.0
Ribeirão Preto	15,936	64.0	2,979	12.0	5,993	24.1	24,908	100.0
Cuiabá	22,281	82.6	251	0.9	4,459	16.5	26,991	100.0
Sorocaba	29,826	63.3	11,610	24.6	5,699	12.1	47,135	100.0
Aracaju	42,555	84.5	1,315	2.6	6,503	12.9	50,373	100.0
Londrina	24,856	75.8	3,364	10.3	4,559	13.9	32,779	100.0
Santos	101,484	80.1	19,338	15.3	5,873	4.6	126,695	100.0
Joinvile	14,428	65.6	3,896	17.7	3,672	16.7	21,995	100.0
São José do Rio Preto	5,386	50.2	1,948	18.2	3,393	31.6	10,726	100.0
Caxias do Sul	7,055	60.6	3,105	26.7	1,485	12.8	11,645	100.0
Pelotas	1,441	29.8	1,194	24.7	2,202	45.5	4,837	100.0
Jundiaí	32,812	62.2	17,371	32.9	2,537	4.8	52,720	100.0
Florianópolis	74,817	90.7	4,205	5.1	3,497	4.2	82,519	100.0
Maringá	23,982	81.1	2,323	7.9	3,258	11.0	29,563	100.0
Vitória	142,544	90.2	3,165	2.0	12,324	7.8	158,033	100.0
Ilhéus	1,690	34.5	984	20.1	2,223	45.4	4,897	100.0
Volta Redonda	21,980	61.0	5,846	16.2	8,204	22.8	36,030	100.0
Blumenau	14,979	79.7	2,715	14.5	1,095	5.8	18,789	100.0
Limeira	4,555	26.7	6,975	40.9	5,529	32.4	17,059	100.0
Cascavel	508	10.6	1,487	31.2	2,774	58.2	4,769	100.0
Caruaru	569	24.3	541	23.2	1,227	52.5	2,337	100.0
Ipatinga	11,314	60.0	3,119	16.5	4,418	23.4	18,851	100.0
Petrolina	4,455	58.3	750	9.8	2,433	31.9	7,637	100.0
Juazeiro do Norte	3,452	50.4	1,309	19.1	2,088	30.5	6,850	100.0
Araraquara	1,089	14.2	3,051	39.7	3,538	46.1	7,678	100.0
Araçatuba	1,750	28.9	1,386	22.9	2,916	48.2	6,052	100.0
Criciúma	10,249	62.3	1,784	10.8	4,418	26.9	16,452	100.0
Itajaí	16,291	72.8	4,001	17.9	2,093	9.3	22,384	100.0
Cabo Frio	11,800	62.0	4,593	24.2	2,625	13.8	19,017	100.0
Mogi-Mirim	5,925	45.8	4,446	34.4	2,568	19.8	12,939	100.0
Guaratingueta	7,527	51.8	4,566	31.4	2,440	16.8	14,534	100.0
Itabira	1,160	22.2	2,384	45.5	1,692	32.3	5,236	100.0
Total	4,227,705	87.0	243,997	5.0	389,069	8.0	4,860,770	100.0

Source: FIBGE, Demographic Census 2000.

As a result of the increase of commuting in Brazil, urban areas look more and more like classic sprawl. While the term "urban sprawl" emerged around 1960 as a pejorative designation to express the uncontrolled expansion of North American urban areas, above all in reference to the suburban pattern of urbanization (Kiefer, 2003), it refers basically to a pattern of low density. Although the definition of the term is still controversial, there is a considerable body of research which shows the importance of the phenomenon in other areas of the world, mostly on the basis of case studies.

Los Angeles is one of the most cited cases. Between 1970 and 1990, the population of the Los Angeles area grew by 45%, while the physical area occupied by this population grew by 300% (Meadows, 1999); in other words, there was a significant reduction in urban density. Outlying areas grew at the expense of the consolidated urban center.

In general, the consensus on the sprawl debate is this gap between population growth and the physical expansion of the city, which explains the tendency toward low urban densities in most metropolitan areas of the world. In this sense, several studies show the same urban distortion of Los Angeles occurring in several areas of the United States and in other areas of the world. Even in European cities, traditionally associated with a compact urban form (Richardson and Chang-Hee, 2004), there are signs that sprawl is increasing.

Urban sprawl research leans heavily on case studies. They demonstrate the historical processes of urban occupation and how urban limits changed over time. However, from an historical point of view, urban growth associated to physical expansion is not a new concern; to a certain extent, growth has always meant territorial expansion. What is new today is the fact that new urban forms have appeared over the second half of the 20^{th} century. According to Richardson and Chang-Hee (2004:1), there seems to be a convergence in urban settlement patterns in the United States and Western Europe.

This transition can be observed in lifestyles which are disseminated through large urban centers, propelled by the globalization of consumption patterns, which produce increasing homogeneity in different areas of the world. Dependence on individual transportation plays an important role in the compression of space and time in postmodern cities. As part of this process, both medium and long-distance commuting is becoming much more evident.

But what is sprawl in the context of developing countries? It is clear that the drivers of sprawl are not the same in different social contexts, even considering the homogenization of consumption patterns in the world's cities. In Brazil, mega-cities like São Paulo and Rio de Janeiro reveal a certain ambiguity in this regard, and new social behaviors are not so directly reflected in these cities' consolidated urban form. In the case of newer metropolitan areas like Brasilia or Campinas, the morphological consequences of new behaviors can be more easily observed. It is important to keep in mind, then, that Brazilian urbanization is not explained only by the experience of São Paulo or Rio de Janeiro, in spite of their population concentration. Urbanization is increasingly characterized by a complex network of urban areas in the country as a whole.

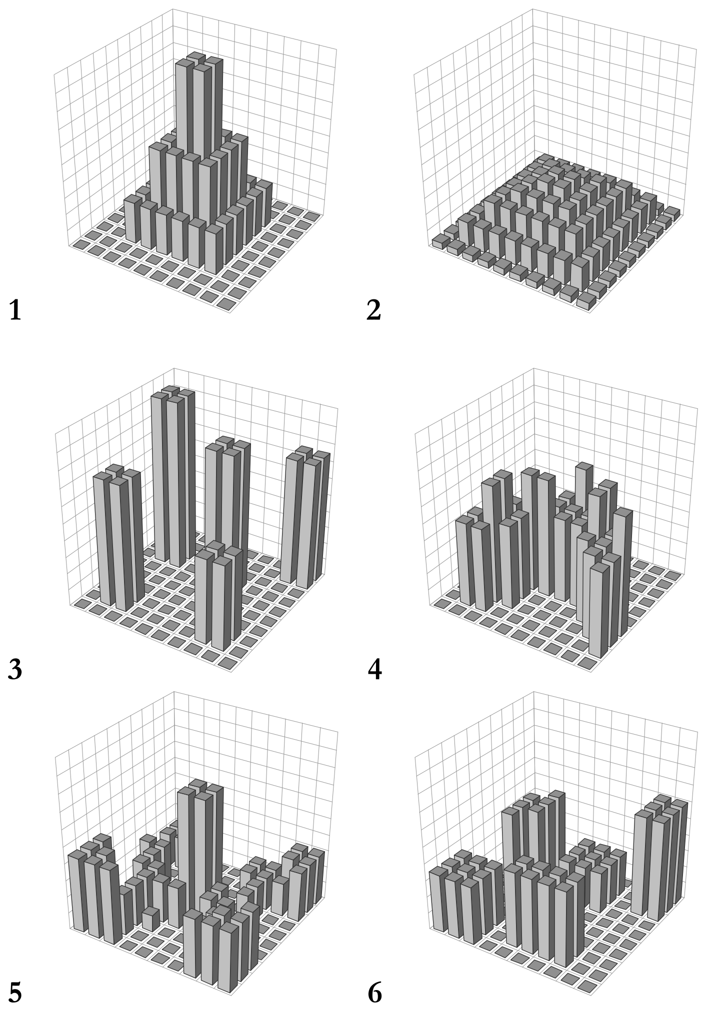
3. Data and method: measuring sprawl in Brazil

The challenge of studying the dimensions of urban sprawl may be summarized as the task of measuring the urban expansion which extrapolates the limits of a conurbation. The urban sprawl literature seeks to identify empirically observable factors in metropolitan areas, in order to compare a country's overall situation. In the present study, then, urban sprawl is understood as a process and not as a phenomenon in itself, since the empirical phenomenon can only be apprehended in comparative terms.

To elucidate this relationship, in an effort to generalize, we can hypothesize different forms of urban settlement and assess their impact on urban life. Figure 5 shows how a population's distribution in the intra-urban space can assume different expressions in spite of the same average density.

Models 1 and 2 represent typical monocentric cities, but with different spatial distributions, the first being more compact. Model 3 is clearly more fragmented and, as is also the case of Model 2, can be classified as more dispersed than Model 1. While Models 4, 5 and 6 seem to be more similar, Model 4 possesses more pronounced continuity than Models 5 and 6. If those models represent urban areas or urban agglomerations, what could be said in this respect? Do people who live in two different areas, for example, in Models 1 and 5, have similar daily activities? The hypothesis is that urban space – socially built and reflecting different interests and social actions – has differentiated consequences in urban life, according to their formal characteristics. In terms of environmental conditions, the impacts of urban expansion seem to be more evident. Intuitively, Model 3 (more dispersed) will have smaller continuous urban areas, fragmented green areas and greater demand for automotive transport, among other environmentally relevant factors.

Figure 5 – Schematic models of different urban shapes



Of course it is not possible to summarize the complexity of urbanization with such simplified schematic models, using a classification based on single-factor categories, but it is unquestionable that Brazilian urban agglomerations take on very different formal dimensions. In terms of the perception of the person who travels from one city to another, it is common to hear comparisons between origin and destination city to the effect that distances between one activity and another are greater, that spatial organization is different, or that traffic jams and access to services are worse.

The objective of this section, then, is to identify, from the sprawl literature, the principal indicators for classifying an urban area in terms of urban dispersion. These dimensions are then applied to 37 selected urban agglomerations to obtain a ranking of urban sprawl and to map sprawling situations in the country. The selection of 37 of the 49 urban agglomerations was based on the results presented in Table 1, considering those agglomerations with predominantly intra-UA commuters. Additionally, we excluded urban agglomerations composed of only two municipalities (UA of Teresina, Cuiabá and Petrolina/Juazeiro) even when they show important intra-UA commuting.

The index is presented in the next section in Table 6, which summarizes the dimensions considered for the Brazilian sprawl index. Finally, the section seeks to verify the existence, or not, of a "pattern" in contemporary Brazilian urbanization and whether this "pattern" can be apprehended in spatial terms in a comparative way, in a diversity of economic, social, political and demographic contexts.

3.1. Density

The works of Galster *et al.* (2001), Batty *et al.* (1999), Chin (2002), Torrens and Alberti (2000), Cutsinger *et al.* (2005), Roca *et al.* (2004), Angel *et al.* (2005), among others, used satellite images to evaluate urban expansion in several parts of the world. Angel *et al.* present a worldwide study considering a group of approximately 4 thousand cities with population greater than 100 thousand inhabitants. In this study, the densities of developing country cities tend to be greater than in the developed countries; however, in both groups the tendency over time has been toward lower density.

The Global Rural-Urban Mapping Project (GRUMP) developed at the Center for International Earth Science Information Network (CI-

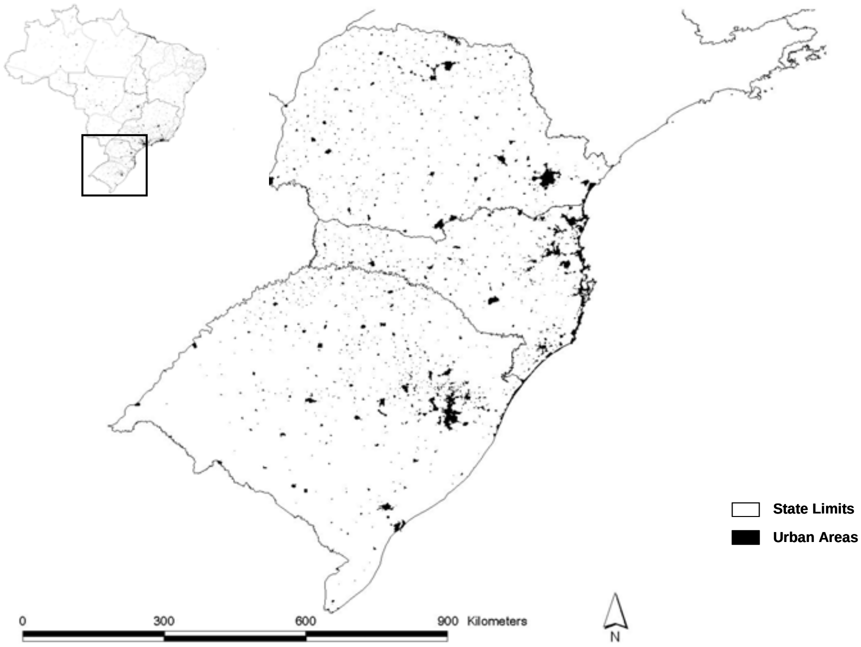
ESIN), Columbia University, used satellite images and nighttime lights emitted by urban agglomerations to estimate urbanized areas. And in Brazil, Kampel (2003) has carried out similar work in the Amazonian State of Pará.

But the systematic use of these instruments still has operational limitations. Among them is the high cost of acquiring the images and the subsequent processing and analysis, above all when more detailed spatial units are needed, as in the case of urban agglomerations which are not part of institutionalized metropolitan areas in Brazil.

For these reasons, official IBGE data on urban and rural census tracts were used; these are public access data, available in digital format. Garcia and Matos (2005) also used these data and discussed their under-utilization in Brazilian urban studies. These data are organized in a Geographical Information System and classify census tracts into urban/rural categories, detailing each situation according to function. For example, it distinguishes areas with rural villages from those areas of agricultural use only.

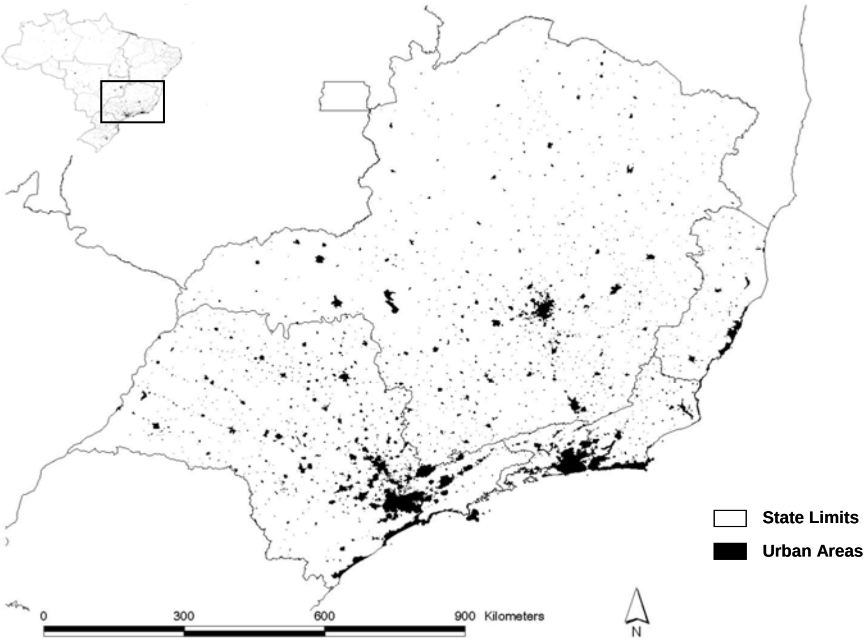
The total urban area in Brazil, according to this criterion, is approximately 95 thousand km^2, which represents 1.12% of Brazilian territory, holding 140 million people – 81.8% of total population in 2000. This reduced share of national territory occupied by cities is visualized in Figures 6 to 10; Southeast and South regions have the largest urban areas. The national population density is approximately 20 inhabitants per km^2; when only the urban area is considered, density is 1,400 inhabitants per km^2. The selected 37 urban agglomerations represent about 1/3 of the total urban area (30.5 thousand km^2) and concentrate 71.6 million people. Population density in these agglomerations is 2,353 inhabitants per km^2. The region with the highest urban density has 8,300 inhabitants per km^2 and the lowest density is 600 inhabitants per km^2. Very different situations exist, then, in terms of urban density. São Paulo, for example, in spite of holding second place in terms of territorial size (with 4,000 km^2), has one of the highest urban densities (4.3 thousand inhabitants per km^2).

Figure 6 – Urban areas, South region



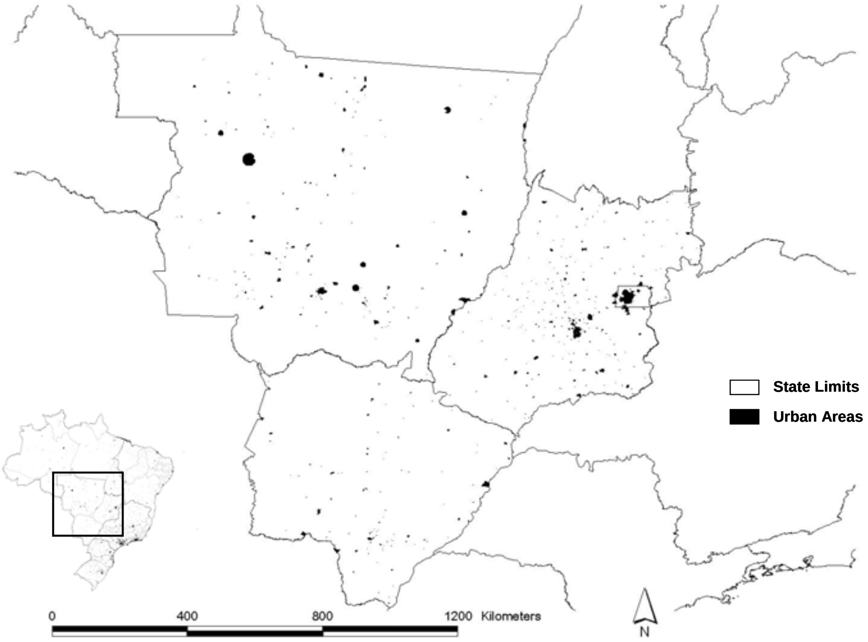
Source: IBGE, Municipal digital shapes, 2000.

Figure 7 – Urban areas, Southeast region



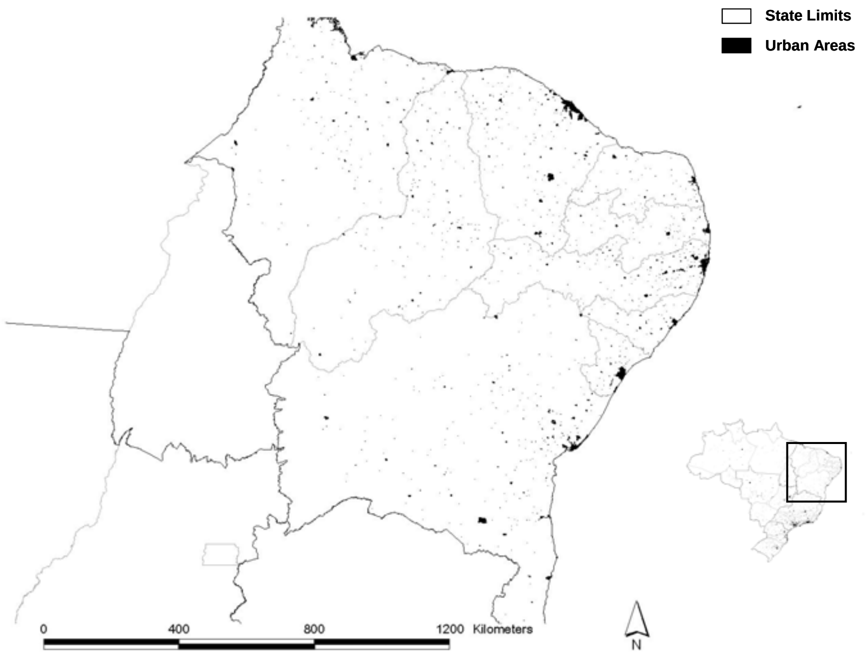
Source: IBGE, Municipal digital shapes, 2000.

Figure 8 – Urban areas, Center-West region



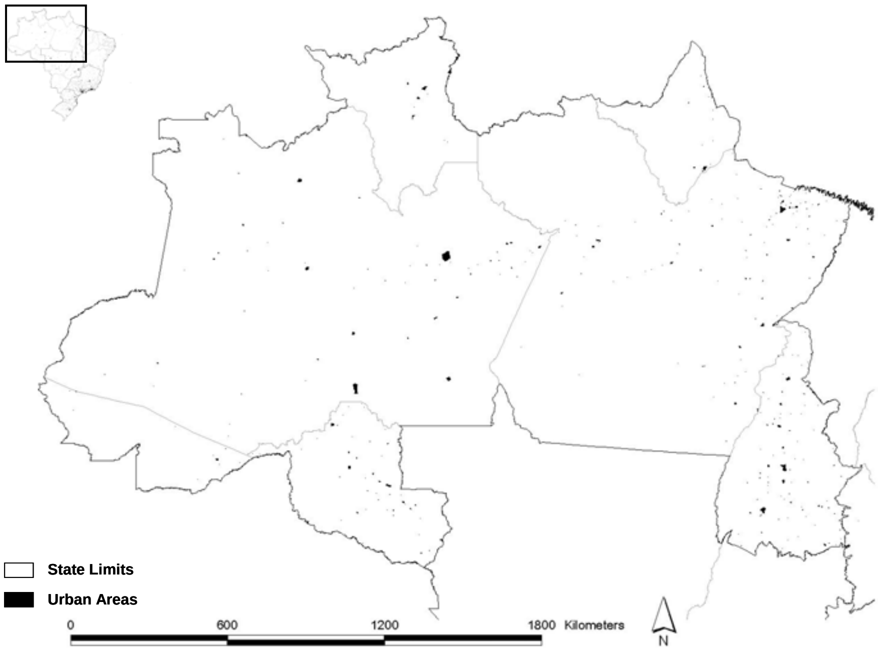
Source: IBGE, Municipal digital shapes, 2000.

Figure 9 – Urban areas, Northeast region



Source: IBGE, Municipal digital shapes, 2000.

Figure 10 – Urban areas, North region



Source: IBGE, Municipal digital shapes, 2000.

Table 2 – Population, households, urban area, demographic density, household density and average number of inhabitants per household by urban agglomeration, 2000

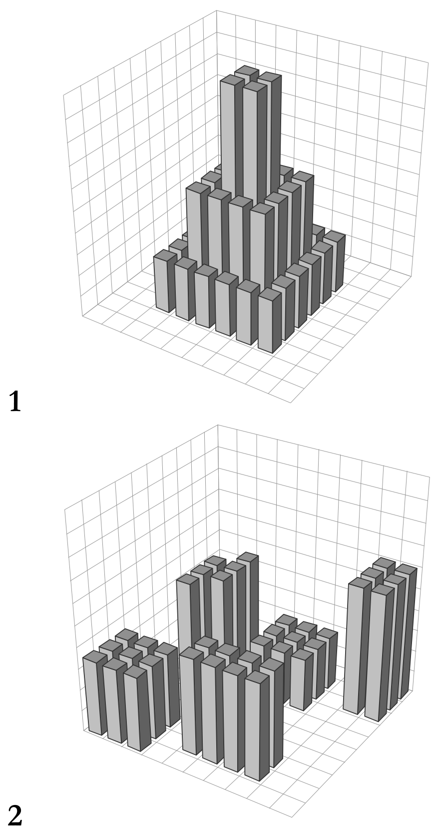
Urban agglomeration	Population	Households	Urban area (km²)	Demogr. density (inhab./ km²)	Household density (household/ km²)	Average No. of inhab. per household
São Paulo	17,596,957	5,000,541	4,033.50	4,362.7	1,239.8	3.5
Rio de Janeiro	10,870,155	3,295,702	5,128.16	2,119.7	642.7	3.3
Salvador	2,959,434	791,007	696.14	4,251.2	1,136.3	3.7
Belo Horizonte	4,210,662	1,151,418	1,666.49	2,526.7	690.9	3.7
Fortaleza	2,821,761	692,926	1,278.83	2,206.5	541.8	4.1
Brasília	2,623,303	701,028	2,083.55	1,259.1	336.5	3.7
Curitiba	2,502,129	728,859	1,184.91	2,111.7	615.1	3.4
Recife	3,238,736	849,458	973.43	3,327.1	872.6	3.8
Porto Alegre	3,436,431	1,065,320	1,566.11	2,194.2	680.2	3.2
Belém	1,965,794	412,634	404.53	4,859.5	1,020.0	4.8
Goiânia	1,560,625	447,284	724.37	2,154.5	617.5	3.5
Campinas	2,119,322	610,616	1,167.06	1,815.9	523.2	3.5
São Luis	945,280	221,409	332.56	2,842.4	665.8	4.3
Maceió	865,717	220,414	244.90	3,535.0	900.0	3.9
Natal	961,638	241,998	248.07	3,876.5	975.5	4.0
João Pessoa	828,712	212,388	315.22	2,629.0	673.8	3.9
São José dos Campos	1,172,423	319,772	869.79	1,347.9	367.6	3.7
Ribeirão Preto	603,452	173,083	309.48	1,949.9	559.3	3.5
Sorocaba	873,329	242,659	505.68	1,727.0	479.9	3.6
Aracaju	703,983	178,052	711.11	990.0	250.4	4.0
Londrina	564,768	162,867	311.64	1,812.2	522.6	3.5
Santos	1,350,446	395,757	716.33	1,885.2	552.5	3.4
Joinvile	566,106	160,270	606.87	932.8	264.1	3.5
São José do Rio Preto	395,379	120,894	121.81	3,245.9	992.5	3.3
Caxias do Sul	518,069	158,949	271.36	1,909.2	585.7	3.3
Jundiaí	496,413	140,029	275.01	1,805.1	509.2	3.5
Florianópolis	698,447	207,661	647.42	1,078.8	320.8	3.4
Maringá	399,356	116,631	47.82	8,351.2	2,439.0	3.4
Vitória	1,327,342	373,646	845.91	1,569.1	441.7	3.6
Volta Redonda	530,317	153,483	313.64	1,690.8	489.4	3.5
Blumenau	380,273	112,126	512.30	742.3	218.9	3.4
Ipatinga	341,608	90,418	196.05	1,742.5	461.2	3.8
Criciúma	238,867	67,556	275.80	866.1	244.9	3.5
Itajaí	326,236	95,286	287.29	1,135.6	331.7	3.4
Cabo Frio	204,939	59,885	346.57	591.3	172.8	3.4
Mogi-Mirim	196,551	55,382	92.02	2,136.0	601.8	3.5
Guaratingueta	213,180	58,742	114.15	1,867.5	514.6	3.6
Total	71,608,152	20,086,149	30,425.80	2,353.5	660.2	3.6

Source: FIBGE, Demographic Census 2000.

3.2. Fragmentation

But low urban densities do not necessarily guarantee more dispersed urbanization. The spatial pattern of settlement within each region contributes differently to the extent of dispersion. When two hypothetical urban areas possess the same density, they may have very different patterns of distribution (as shown by Figure 11). Diagram 1 presents a monocentric form of settlement while Diagram 2 is constituted by several spatially separated nuclei. It is the situation which the sprawl literature calls leapfrog development. Such urbanization is characterized by the fragmentation of urban spaces and it is associated with the physical separation of nuclei of urban development.

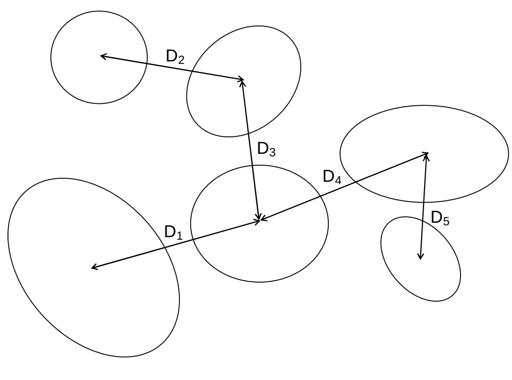
Figure 11 - Schematic models of different urban forms, fragmentation dimension



Leapfrog development can be understood as part of an *unconnectedness* of daily life spaces within the urban agglomeration and it is clearly associated to changes in the spatial displacements of population, given that the continuity of the urban area is no longer necessary for its integration. This aspect of urban development is, after density, the most characteristic factor of urban sprawl, because it provides spatial evidence of the pattern of population distribution of urban areas. In operational terms, the fragmentation of urban spaces can be apprehended in different ways. As we can observe in an intuitive way from Figure 11, distance between urbanized areas is a measure of dispersion. In other words, two areas with the same population, distributed in an equivalent urban area, may have similar densities; but one may have a compact form of concentric circles while the other may be polycentric, with urban branches going in different directions.

Urbanization by leaps may compromise agricultural uses in outlying areas and also require expansion of the network of infrastructure services – water supply and sewage collection (Angel *et al.,* 2005). Environment is an important aspect for this dimension, because both causes and effects may be identified. On the one hand, there is a growing demand for environmental amenities in residential areas. On the other hand, as urban growth reaches these areas, such amenities are compromised. The trend, then, is the creation of urban spaces more and more disconnected from each other. To measure this dimension, the Average Nearest Neighbor Index was used, using the software ArcGis (version 9.0).

Figure 12 – Illustrative model of the method of calculation of the Average Nearest Neighbor Index



This index measures the distances between polygons defined by their contiguous urban census tracts and their respective standard deviations for each study area. The ratio between the average of those distances and the average of the distances in a hypothetical area with random distribution is an indicator that allows us to measure the degree of dispersion of the urbanized areas in each of the agglomerations. That indicator was later adjusted so that values varied between zero and one. Values closer to zero represent more compact patterns while values closer to one, the most dispersed patterns. The same procedure was carried out for each of the 37 selected areas. Also using the proportion of non-urbanized areas[2] of the agglomerations, an arithmetic average was calculated of both indices to compose a Fragmentation Index, as shown in Table 3.

3.3. Orientation/Linearity

The geographic orientation of cities also plays an important role in urban expansion and in the amount of sprawl. The growth of some urban agglomerations is conditioned by physical constraints such as mountains, rivers, oceans or other natural barriers. They may also have a direct relationship with other elements such as highways, railroads and regional economic poles.

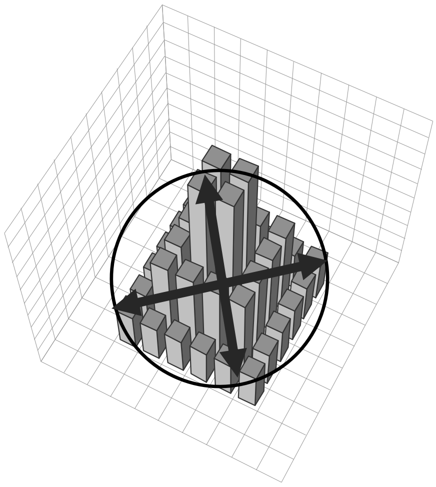
Under such conditions, urban areas grow in different ways, which should be taken into account when urban form is analyzed. An urban agglomeration that grows on the basis of concentric circles potentially has a greater capacity to optimize the distribution of service infrastructure compared to a region that develops following a highway, for instance. It is important to differentiate areas in terms of the orientation of their expansion; in other words, whether the form is more circular or more ellipsoidal. Referring again to the diagrams of hypothetical areas (Figure 13), we can observe two areas with the same density and little fragmentation. However, the pattern of urban development in Model 2 is linear and tends toward more sprawl, as we can see intuitively in Diagrams 1 and 2.

2. Defined by the Census Bureau as non-urbanized areas inside the urban perimeter.

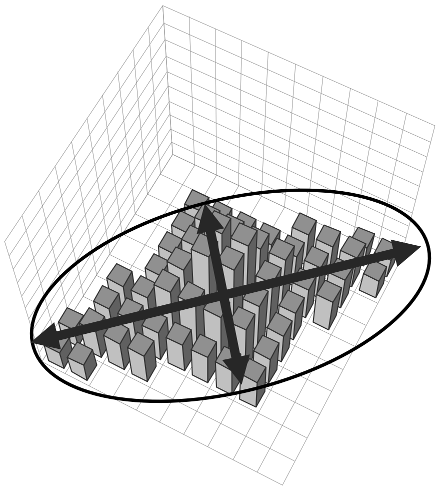
Table 3 – Average Nearest Neighbor Index, Non-Urbanized Urban Area Index and Fragmentation Index by urban agglomerations

Urban agglomeration	Average Nearest Neighbor Index	Non-Urbanized Urban Area Index	Fragmentaion Index
São Paulo	0.507474	0.596288	0.551881
Rio de Janeiro	0.510043	0.561902	0.535972
Salvador	0.506744	0.867612	0.687178
Belo Horizonte	0.509927	0.799578	0.654753
Fortaleza	0.508427	0.732650	0.620538
Brasília	0.521121	0.999861	0.760491
Curitiba	0.513419	0.993102	0.753261
Recife	0.507797	0.704222	0.606010
Porto Alegre	0.511222	0.859887	0.685555
Belém	0.506698	0.878143	0.692421
Goiânia	0.506272	0.749456	0.627864
Campinas	0.504337	0.670152	0.587244
São Luis	0.502090	0.845094	0.673592
Maceió	0.502942	0.824971	0.663956
Natal	0.504136	0.987652	0.745894
João Pessoa	0.504052	0.775588	0.639820
São José dos Campos	0.511492	0.841248	0.676370
Ribeirão Preto	0.509455	0.902392	0.705924
Sorocaba	0.506870	0.834627	0.670749
Aracaju	0.509277	0.575437	0.542357
Londrina	0.509281	0.992914	0.751097
Santos	0.510989	0.641895	0.576442
Joinvile	0.507831	0.847868	0.677849
São José do Rio Preto	0.506213	0.965161	0.735687
Caxias do Sul	0.509768	0.999941	0.754854
Jundiaí	0.503368	0.738709	0.621039
Florianópolis	0.512588	0.969475	0.741031
Maringá	0.508136	1.000000	0.754068
Vitória	0.506384	0.639759	0.573072
Volta Redonda	0.506874	0.953118	0.729996
Blumenau	0.509180	0.904173	0.706676
Ipatinga	0.506088	0.913666	0.709877
Criciúma	0.504895	0.761600	0.633247
Itajaí	0.510802	0.729249	0.620026
Cabo Frio	0.505387	0.690380	0.597883
Mogi-Mirim	0.505431	0.999999	0.752715
Guaratingueta	0.507099	0.999998	0.753548

Figure 13 – Schematic models of different urban forms,
orientation/linearity dimension



1



2

Orientation is considered as a dimension of sprawl because even if urbanization could grow limited by geographic barriers or close to roads and highways, these conditions figure impacts on daily activities. Figure 13 shows an example of a situation where people living in a more flattened urban area (Diagram 2) need to cover longer distances. With the Directional Distribution tool of the software ArcGis (version

9.0), it is possible to measure whether a distribution of a polygon follows a certain directional tendency. A polygon is generated in elliptic format, and axes (represented by the arrows at Figure 13) are obtained by the standard deviation of the centroids of the polygons in relation to the rotation axis.

The difference between the axes allows us to compare urban areas in terms of the orientation of urban development. In Diagrams 1 and 2 of the illustration, the difference between the axes indicates the degree of "flattening" of the ellipse. In the same way, when the difference between the axes is close to zero, as in Diagram 1, the tendency is for the ellipse to be closer to a circle. In terms of the analysis of sprawl, more circular forms are considered more compact. With standardized data, varying from zero to one, numbers closest to zero are more circular, and those closer to one more linear. Table 4 synthesizes the information obtained by this procedure and presents the Orientation/Linearity Index.

3.4. Integration/Commuting

In spite of all of the dimensions considered here, it is important to remember that if there is no integration among the urbanized areas, form does not matter. A much sprawled area in spatial terms, but where in practice commuting flows are minor, can be considered less sprawled because there is no real impact of a fragmented area. For this reason we added an indicator of commuting to measure the integration dimension of the urban agglomeration.

Two integration indicators were used: the proportion of commuters within an urban agglomeration with non-polarized destinations and the proportion of commuters to total population. The first refers to the pattern and direction of movements because urban agglomerations that have commuting patterns with multiple destinations or more than one destination can be understood as more sprawled than one with a single destination. The proportion of commuters in relation to total population serves as a standardization parameter, which weighs commuter flows by the importance of this kind of movement. The Integration Index was calculated for each of the 37 urban agglomerations and is summarized in Table 5.

Table 4 – Calculation of the Orientation/Linearity Index, axes and difference between axes

Urban agglomeration	Axis 1	Axis 2	Difference between axes	Orientation Linearity Index
São Paulo	0.441176	0.194153	0.247023	0.597555
Rio de Janeiro	0.199811	0.897000	0.697189	0.757158
Salvador	0.231182	0.134745	0.096437	0.538413
Belo Horizonte	0.368077	0.459865	0.091788	0.536567
Fortaleza	0.324692	0.228447	0.096245	0.538337
Brasília	0.549457	0.754262	0.204805	0.581138
Curitiba	0.381371	0.495693	0.114322	0.545509
Recife	0.186138	0.385728	0.199590	0.579099
Porto Alegre	0.373645	0.621580	0.247935	0.597908
Belém	0.213778	0.110328	0.103450	0.541197
Goiânia	0.255034	0.101435	0.153599	0.561037
Campinas	0.321116	0.236737	0.084379	0.533622
São Luis	0.085513	0.049549	0.035964	0.514344
Maceió	0.106719	0.064356	0.042363	0.516895
Natal	0.218222	0.097758	0.120464	0.547942
João Pessoa	0.031081	0.133998	0.102917	0.540986
São José dos Campos	0.204088	0.470597	0.266509	0.605076
Ribeirão Preto	0.400174	0.139164	0.261010	0.602958
Sorocaba	0.241025	0.195505	0.045520	0.518154
Aracaju	0.101968	0.196912	0.094944	0.537820
Londrina	0.213863	0.353992	0.140129	0.555721
Santos	0.084895	0.426765	0.341870	0.633776
Joinvile	0.263922	0.175317	0.088605	0.535302
São José do Rio Preto	0.096826	0.202400	0.105574	0.542040
Caxias do Sul	0.184828	0.445323	0.260495	0.602759
Jundiaí	0.243963	0.103869	0.140094	0.555707
Florianópolis	0.531899	0.316013	0.215886	0.585462
Maringá	0.150571	0.237719	0.087148	0.534723
Vitória	0.128774	0.357987	0.229213	0.590648
Volta Redonda	0.324912	0.195729	0.129183	0.551394
Blumenau	0.512855	0.197006	0.315849	0.623941
Ipatinga	0.100394	0.205147	0.104753	0.541714
Criciúma	0.137581	0.195778	0.058197	0.523204
Itajaí	0.217323	0.034300	0.183023	0.572610
Cabo Frio	0.103695	0.184237	0.080542	0.532097
Mogi-Mirim	0.242095	0.171656	0.070439	0.528078
Guaratingueta	0.177504	0.200793	0.023289	0.509290

Table 5 – Population, proportion of commuters to the agglomeration core, proportion of commuters and Integration/Commuting Index

Urban agglomeration	Population	Commuters to the agglomeration core		Commuters		Integration/ Commuting Index
		N	%	N	%	
São Paulo	17,829,352	585,650	58.3	1,003,764	5.6	0.83598
Rio de Janeiro	10,943,847	487,767	68.3	714,649	6.5	0.88946
Salvador	3,012,837	25,327	45.6	55,548	1.8	0.69942
Belo Horizonte	4,273,274	245,625	71.8	341,888	8.0	0.91607
Fortaleza	2,899,231	54,076	79.0	68,418	2.4	0.82831
Brasília	2,747,993	112,165	95.0	118,114	4.3	0.91875
Curitiba	2,669,472	142,694	80.4	177,440	6.6	0.92679
Recife	3,323,422	197,892	77.4	255,767	7.7	0.92922
Porto Alegre	3,557,772	186,556	60.2	309,861	8.7	0.88029
Belém	1,795,536	91,262	87.1	104,746	5.8	0.93129
Goiânia	1,582,680	86,138	95.7	89,983	5.7	0.94655
Campinas	2,156,235	61,663	48.8	126,365	5.9	0.79780
São Luis	1,053,600	28,083	93.4	30,078	2.9	0.87997
Maceió	884,346	6,869	83.7	8,202	0.9	0.81674
Natal	1,043,321	34,900	86.3	40,454	3.9	0.88723
João Pessoa	844,171	22,967	83.0	27,655	3.3	0.86267
São José dos Campos	1,211,748	14,804	44.2	33,523	2.8	0.70908
Ribeirão Preto	609,363	9,622	84.9	11,338	1.9	0.83504
Sorocaba	908,217	17,053	64.7	26,362	2.9	0.79331
Aracaju	714,681	38,026	89.4	42,555	6.0	0.93799
Londrina	588,731	16,665	85.1	19,583	3.3	0.86980
Santos	1,353,374	64,717	65.0	99,504	7.4	0.88851
Joinvile	596,343	3,816	41.7	9,142	1.5	0.67992
São José do Rio Preto	418,400	4,675	86.8	5,386	1.3	0.83047
Caxias do Sul	586,791	2,463	38.1	6,467	1.1	0.66083
Jundiaí	529,990	25,117	76.6	32,811	6.2	0.91008
Florianópolis	749,067	52,122	71.6	72,793	9.7	0.92203
Maringá	410,507	20,247	94.8	21,355	5.2	0.93690
Vitória	1,337,187	94,144	66.0	142,544	10.7	0.90597
Volta Redonda	542,918	16,199	73.4	22,082	4.1	0.85365
Blumenau	427,709	5,657	57.8	9,782	2.3	0.75448
Ipatinga	347,618	7,748	81.7	9,487	2.7	0.84486
Criciúma	265,679	6,372	70.9	8,988	3.4	0.82726
Itajaí	338,284	6,626	40.7	16,291	4.8	0.73618
Cabo Frio	223,348	4,861	55.3	8,791	3.9	0.78283
Mogi-Mirim	214,551	2,236	42.8	5,224	2.4	0.69733
Guaratingueta	228,228	2,322	44.3	5,242	2.3	0.70123
Total	73,219,823	2,785,126	68.2	4,082,182	5.6	-

Source: FIBGE, Demographic Census 2000.

4. Results and discussions: a sprawl index for Brazilian urban agglomerations

On the basis of the dimensions of sprawl considered above, a sprawl index was calculated from the average of these dimensions. According to Lopez and Hynes (2003:331), a sprawl index should not be influenced by the size of population or territory, because the index must consider different characteristics in terms of form, shape and integration. Table 6 summarizes the four dimensions and the Sprawl Index. Values near zero represent less sprawl and values near one, more sprawl. Alongside the numeric index, the rank of each urban agglom-

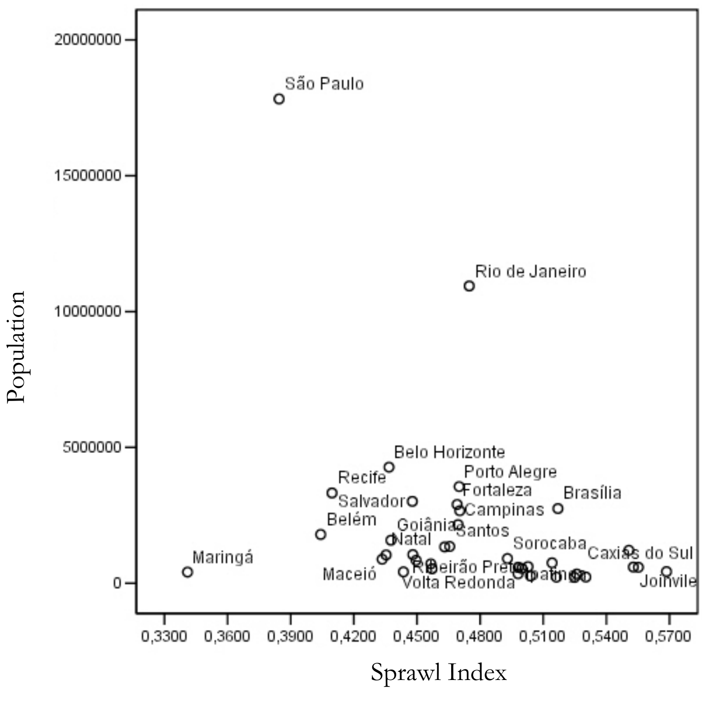
Table 6 – Dimensions of sprawl and Sprawl Index

Urban agglomeration	Density		Fragmentation		Orientation		Intergration		Sprawl Index	
	Indicator	Rank	Indicator	Rank	Indicator	Rank	Indicator	Rank	Indicator	Rank
Blumenau	0.69802	2	0.70668	13	0.62394	3	0.24552	8	0.56854	1
Caxias do Sul	0.52397	21	0.75485	2	0.60276	6	0.33917	1	0.55519	2
Joinvile	0.67803	5	0.67785	18	0.53530	28	0.32008	2	0.55282	3
S. J. dos Campos	0.63034	9	0.67637	19	0.60508	4	0.29092	6	0.55068	4
Guaratingueta	0.55924	15	0.75355	4	0.50929	37	0.29877	5	0.53021	5
Itajaí	0.64718	7	0.62003	29	0.57261	13	0.26382	7	0.52591	6
Mogi-Mirim	0.51595	22	0.75271	6	0.52808	32	0.30267	3	0.52485	7
Brasília	0.64495	8	0.76049	1	0.58114	11	0.08125	30	0.51696	8
Cabo Frio	0.71780	1	0.59788	31	0.53210	31	0.21717	9	0.51624	9
Florianópolis	0.65224	6	0.74103	9	0.58546	10	0.07797	31	0.51418	10
Criciúma	0.68656	3	0.63325	25	0.52320	33	0.17274	13	0.50394	11
Ribeirão Preto	0.53713	20	0.70592	14	0.60296	5	0.16496	16	0.50274	12
Volta Redonda	0.57166	13	0.73000	11	0.55139	17	0.14635	19	0.49985	13
Londrina	0.55529	16	0.75110	7	0.55572	15	0.13020	21	0.49808	14
Ipatinga	0.58543	11	0.70988	12	0.54171	21	0.15514	18	0.49804	15
Sorocaba	0.57631	12	0.67075	21	0.51815	34	0.20669	10	0.49298	16
Rio de Janeiro	0.49560	25	0.53597	37	0.75716	1	0.11054	26	0.47482	17
Curitiba	0.50934	23	0.75326	5	0.54551	19	0.07321	32	0.47033	18
Porto Alegre	0.47688	28	0.68555	17	0.59791	7	0.11971	23	0.47001	19
Campinas	0.55500	17	0.58724	32	0.53362	30	0.20220	11	0.46952	20
Fortaleza	0.54578	18	0.62054	28	0.53834	25	0.17169	14	0.46909	21
Santos	0.54050	19	0.57644	33	0.63378	2	0.11149	25	0.46555	22
Vitória	0.59490	10	0.57307	34	0.59065	9	0.09403	27	0.46316	23
Jundiaí	0.56192	14	0.62104	27	0.55571	16	0.08992	28	0.45715	24
Aracaju	0.68414	4	0.54236	36	0.53782	26	0.06201	36	0.45658	25
João Pessoa	0.48009	27	0.63982	24	0.54099	23	0.13733	20	0.44956	26
São Luis	0.48408	26	0.67359	20	0.51434	36	0.12003	22	0.44801	27
Salvador	0.26499	35	0.68718	16	0.53841	24	0.30058	4	0.44779	28
S. J. do Rio Preto	0.32697	33	0.73569	10	0.54204	20	0.16953	15	0.44356	29
Goiânia	0.50816	24	0.62786	26	0.56104	14	0.05345	37	0.43763	30
Belo Horizonte	0.47156	29	0.65475	23	0.53657	27	0.08393	29	0.43670	31
Natal	0.33465	32	0.74589	8	0.54794	18	0.11277	24	0.43532	32
Maceió	0.36967	31	0.66396	22	0.51690	35	0.18326	12	0.43345	33
Recife	0.38266	30	0.60601	30	0.57910	12	0.07078	33	0.40964	34
Belém	0.31464	34	0.69242	15	0.54120	22	0.06871	34	0.40424	35
São Paulo	0.22441	36	0.55188	35	0.59755	8	0.16402	17	0.38447	36
Maringá	0.01202	37	0.75407	3	0.53472	29	0.06310	35	0.34098	37

eration shows the results in a comparative perspective, with Blumenau the most sprawled area and Maringá the most compact. São Paulo also ranks as one of the most compact agglomerations, despite its position as the largest city of Brazil in terms of population and territorial size.

The index respects the criterion of not being influenced by the region's size, as Figure 14 shows. Although the urban Sprawl Index does not contemplate all of the possible dimensions for the analysis of urban expansion, it includes the principal dimensions mentioned in the literature. The relatively precarious data is compensated by its completeness and uniformity, allowing us to build a set of indicators for the whole country.

Figure 14 – Sprawl Index *versus* Population



As we have seen, the indicator captured the dimensions of dispersion and permitted us to classify regions on the basis of general criteria without taking into account peculiar or historical characteristics. Population size, contradicting some expectations, is not positively correlated with the degree of sprawl. The most dispersed areas are found in the South-Southeast portion of the country, except for Brasília; that is, the most developed region of the country, with a dense network of highways. Urban agglomerations located in the North and Northeast are all among the most compact, except for Fortaleza, which is in the intermediate group. This can probably be explained by regional characteristics of economic integration, expansion of transportation technology or even by overarching globalization processes. Independently of the answer in each case, it is a finding which merits further investigation, following this first effort of comparative analysis.

A statistical correlation was found with the proportion of homes with at least one automobile. In other words, the higher the sprawl, the larger the proportion of homes with at least one automobile. That result was expected, since the literature already pointed to that tendency, which, indeed, seems obvious. If an area has greater urban dispersion, the need for transportation should also be greater. Especially in a developing country, household income has an important role in this regard, although the same negative correlation is found in all classes of *per capita* income. From households with lower *per capita* income up to those with more than 2 minimum wages per person, the correlation is statistically significant. More dispersed urban agglomerations have a larger proportion of automobiles, independently of income.

These results raise important challenges for the future of sustainable urbanization in post-transitional countries, considering that urbanization is now at a turning point. Urban areas are increasingly complex, with fragmentation, integration and intensification of commuting. New migration flows are becoming more evident and probably will have a very marked impact on urban structures, especially in terms of access to public services by the poor. Many social problems typical of developing countries become worse with sprawl.

If we all expect to live in urban areas by the end of this century, what would be the best urban form for a sustainable world? What are the specific impacts of this kind of urbanization in developing countries? An analysis of the world's most well-known cities rarely considers the diversity of urban realities, a diversity which becomes more and more relevant in developing countries. Results appear to tell us that urban agglomerations in Brazil have an important commuting element related to sprawling urbanization. These sprawling regions are transforming land use, reducing green and open spaces around cities and increasing automobile dependence, air pollution and costs of public services. New challenges are posed for urbanization in developing countries and if we are unable to understand this process and its consequences in the near future, we can expect to see these countries face old problems (poverty) and new problems (sprawl) simultaneously.

5. Policy recommendations: conceptualization, data collection/ management and policy response

The questions raised in this discussion suggest the need for action at several levels. In the urban century which awaits us, it will not only be the **population** of cities but their **form** which will determine sustainability. Morphology matters. It matters for the quality of life of city-dwellers and it matters for the quality and integrity of the natural world. More attention, therefore, must be paid to describing, measuring and comparing the spatial distribution of urban populations. This requires, in the first place, that researchers seek greater conceptual and methodological clarity. Many different expressions are in use to denote more dispersed population patterns. While some of these may be imprecise or reflect different research traditions without reflecting substantive differences, several expressions reflect empirically different phenomena. There is little clarity in the literature about what these might be. More intense efforts to sort out the different concepts will be needed to direct data collection which includes urban form. The availability of standardized data in existent data bases, necessary though it may be, will be possible only when there is more agreement on the most useful concepts and measurements.

One thing is clear: there is considerable consensus on the environmental and social benefits of urban morphologies which maximize access to services while minimizing environmental impact. It will be necessary, however, to go beyond such generalizations to arrive at policies which effectively direct city growth. Comparative work is essential. In highly urbanized regions (USA, Europe, Latin America), there is urban infrastructure already in place which will require adaptation in the light of new technologies and new values. In those areas which still expect considerable demographic growth of cities (Asia, Africa), the planning needs are even greater, though potentially more viable and rewarding: not exactly learning from the mistakes of others, but not making the mistake of adopting 20th century approaches to solving 21st century challenges.

Goals and **values** must be clear. Considering the diversity of urban forms in the contemporary world, it seems evident that quality of life is not irrevocably tied to a single pattern. If greater urban densities have been found compatible with quality of life in some places, and if such densities promote a more sustainable and resilient relationship with the natural world, then it is not unthinkable that they be replicated in other settings. Reordering priorities in favor of sustainable urbanization involves value changes which cannot be taken for granted. Governments, international organizations, NGOs and researchers have their mutually reinforcing roles. The techniques of urban planning will have to evolve in parallel with the evolution of the values appropriate to sustainability.

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References

Angel, S, Sheppard, S C, and Civco, D L (2005) *The Dynamics of Global Urban Expansion*, Transport and Urban Development Department, The World Bank, Washington DC.

ARCGIS 9.0. Environmental Systems Research Institute, Inc. (ESRI).

Baeninger, R A (2004) "Interiorização da migração em São Paulo: novas territorialidades e novos desafios teóricos", in *Anais do XIV Encontro Nacional de Estudos Populacionais, 20-24 de setembro de 2004*, Caxambu-MG, ABEP.

Batty, M, Xie, Y, and Sun, Z (1999) *The Dynamics of Urban Sprawl*, Center for Advanced Spatial Analysis (CASA), Paper 15, University College London, London.

Chin, N (2002) *Unearthing the Roots of Urban Sprawl: A Critical Analysis of Form, Function and Methodology*, Center for Advanced Spatial Analysis (CASA), Paper 47, University College London, London.

Cutsinger, J, Galster, G, Wolman, H, Hanson, R, and Towns, D (2005) "Verifying the Multi-dimensional Nature of Metropolitan Land Use: Advancing the Understanding and Measurement of Sprawl", *Journal of Urban Affairs*, 27(3): 235-259.

Galster, G, Hanson, R, Wolman, H, Coleman, S, and Freihage, J (2001) "Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept", *Housing Policy Debate*, 12(4): 681-717.

Garcia, R A, and Matos, R (2005) "Densidade populacional urbana e fluxos migratórios: um modelo de estimação da área urbana dos municípios brasileiros", *IV Encontro Nacional sobre Migração*, ABEP, Rio de Janeiro.

Giddens, A (1991) *The Consequences of Modernity*, Polity Press, Basil-Blackwell.

Hogan, D J (1993) "População, pobreza e poluição em Cubatão, São Paulo", in G. Martine (org.) *População, Meio Ambiente e Desenvolvimento*, Ed. Unicamp, Campinas, 101-131.

IPEA/IBGE/UNICAMP (2000) *Características e Tendências da Rede Urbana no Brasil,* Instituto de Economia, UNICAMP, Campinas.

Kampel, S A (2003) *Geoinformação para estudos demográficos: representação espacial de dados de população na Amazônia brasileira*, PhD dissertation, Universidade de São Paulo.

Kiefer, M J (2003) "Suburbia and its Discontents", *Harvard Design Magazine*, 19: 1-5.

Lopez, R, and Hynes, H P (2003) "Sprawl in the 1990s: Measurement, Distribution and Trends", *Urban Affairs Review*, 38(3): 325-355.

Meadows, D H (1999) "So what can we do – really do – about sprawl", in *Sprawl Articles, Sierra Club*, http://www.sierraclub.org/sprawl/articles/meadows3.asp.

Ojima, R (2007) *Análise comparativa da dispersão urbana nas aglomerações urbanas brasileiras: elementos teóricos e metodológicos para o planejamento urbano e ambiental*, PhD dissertation, Campinas.

Richardson, H W, and Chang-Hee, C B (eds) (2004), *Urban Sprawl in Western Europe and the United States*, Ashgate Publishing Limited, England.

Roca, J, Burns, M C, and Carreras, J M (2004) "Monitoring Urban Sprawl Around Barcelona's Metropolitan Area with the Aid of Satellite Imagery", *XXth ISPRS Congress, 12-23 July, Istanbul, Turkey.*

Torrens, P M, and Alberti, M (2000) *Measuring Sprawl*, Center for Advanced Spatial Analysis (CASA), Paper 27, University College London, London.