

Favelas, barriadas, bidonvilles: the universal morphology of poverty

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Abstract

According to the Global Report on Human Settlements (United Nations, 2005), almost one billion people (1/3 of world urban population) live in favelas or squatter settlements, most of them situated in cities central areas. At least 40% of Caracas and Recife population lives in *barrios* or *favelas*, respectively. In Bogotá and Bombay, 60% of population is sheltered in *barriadas* and *bustees*. In Casablanca, the *bidonvilles* are the only housing option for almost 70% of population. Whatever the terminology around the globe for such low-income and informal urban settlements, all them have in common the feature of being – at least originally – the result of decentralised actions and spontaneous initiative of its inhabitants. These urban phenomena, despite been quite well documented on political, economical and social issues, are still barely known for their morphological features. Their geometrical complexity, spatial irregularity and decentralised urban dynamics tend to a morphological misinterpretation, erroneously associating them to disordered or illogic phenomena. But recent researches related to the morphological features of *favelas* in cities around the world, have revealed an implicit and universal order: a complex and non-linear one. So, contributions presented in this essay deal with such morphological complexity of irregular settlements, which despite cultural and geographical diversities, keep in common universal patterns of spontaneity and self-organisation.

Keywords: favelas, squatter settlements, morphology, complexity, scaling laws

1 Favelas: the logic of diversity.

World population reached more than 6 billion people in 2003 (UN, 2003), from which 4 billion inhabit undeveloped countries. The amount of people living without minimum living conditions is more than 3 billion, which corresponds to more than half the world population. Presently, less than 40% of population in Caracas (Venezuela) and Recife (Brazil) live in barrios and *favelas*, respectively. In Bogotá (Colombia) and Bombay (India), 60% of population is sheltered in *barriadas* and *bustees*. Whatever the terminology around the globe for such low-income and informal urban settlements, all them have in common the feature of being – at least originally – the result of decentralised actions and spontaneous initiative of its inhabitants. These urban phenomena, despite been quite well documented on political, economical and social issues, are still barely known for their morphological features (Figure 1). This kind of spontaneous and informal production of habitation is mostly developed without any kind of urban restriction or central management regarding use and occupation. It is usually a process of continuous upgrading and growth, made by the inhabitants themselves, with their own limited resources. The irregularity and dynamics resulting of this kind of urban growth is usually misunderstood as disorder of illogical phenomena. For decades urban policy applied to squatter settlements and general low income urban occupations has been based on policies of remotion, relocation or simply have been ignored. But the last two decades, specially the last couple of years, have been characterised by a growing effort towards the acknowledgment and understanding of such informal and morphologically irregular, always changing urban structures. Since the Second United Nations Conference on Human Settlements (Habitat II – Istambul, 1996), ideas and actions regarding urbanisation and upgrading of slums and squatter settlements have arisen and being established, instead of the usual and traditional discourses of urban cleaning, or remotion. For example, the well known and widely studied actions of urban cleaning implemented at the Estado Novo, in Brazil (Social League Against Slums). Actually, around the world and along the time, there has been several confliting answers to the same trick question: what to do about slums and squatter settlements? The results are a variety of actions and postures, including those which deal with *favelas* as “cancerous and malign tumors”, to be extracted from urban tissue of cities aiming to be healthy; or distinct perspectives as those which see *favelas* as natural expressions, inevitable and necessary to the equilibrium of a system marked by instability and social inequality (Dwyer, 1981; Drakakis-Smith, 1981; Aldrich & Sandhu, 1995; Barros and Sobreira, 2002).

In practical terms, one could point out four kinds of postures which have been applied to squatter or spontaneous settlements: remotion, relocation, land sharing or *in situ* improvement. Remotion, despite its inefficiency, for facing the issue of *favelas* as a mere legal or administrative question and ignoring social and economic tensions involved in the process, is quite common, mainly in cities and countries with a fragile democracy.

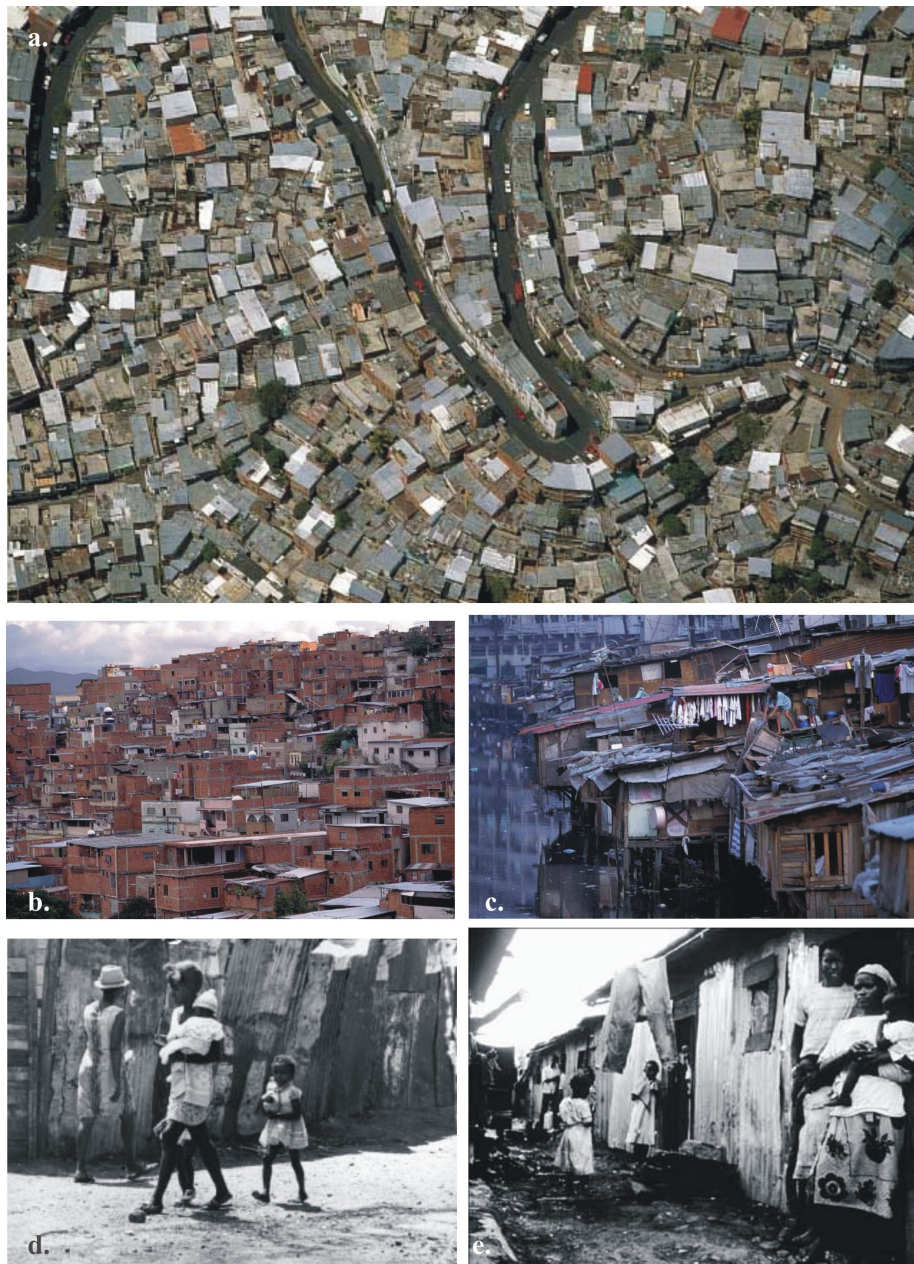


Figure 1 – Favelas around the world **a.** Caracas, Venezuela; **b.** Caracas, Venezuela; **c.** Manila, Philippines; **d.** Jamaica; **e.** Kenya.
 Fonte: www.worldofslums.blogspot.com

Relocation, despite criticisms about its efficiency, is still quite usual in the urban policy of several cities. This kind of action has arisen as an alternative to eviction, and has reached its popularity along the 1970s and 1980s. The basic action of this posture is removing people from squatter settlements and slums situated in highly valued central areas, locating them in long term financed housing estates on peripheral lots of metropolitan areas, usually without services, jobs or infrastructure (Valladares, 1978). A great amount of those new inhabitants sell their apartments and return to new informal areas at the city centre, seeking for jobs and services. Those who manage to stay in those housing estates, change - along the years - the minimalist buildings and landscapes, adapting spaces to their needs and symbolic values. It is a real change from the white and Cartesian modern landscape to a neighbourhood of diversity, colors and multiplicity of uses and typologies (figure 2).

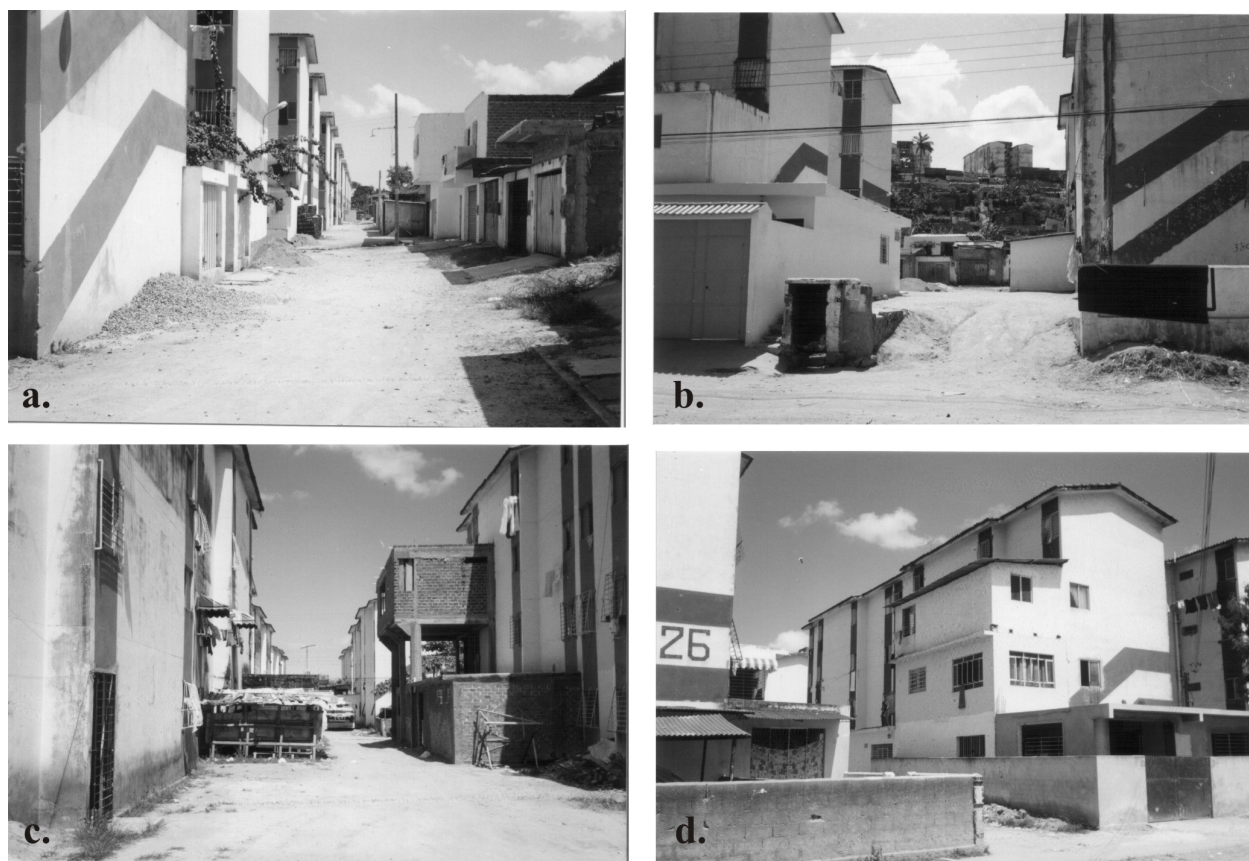


Figure 2 (a,b,c,d) – Changing in Housing Estates – Metropolitan Region of Recife, Brazil. Source: author.

Land sharing is one of the most recent and sometimes successfully alternatives for squatter settlements situated in central areas (Angel & Boonyabancha, 1988; Boonyabancha, 1988). This method is based in an intervention process which results from the agreement between the shelters and potential public or private entrepreneurs interested on that piece or urban land. Usually, government or non-government agencies intermediate the negotiation.

In situ improvement is presently the most usual posture for inner city squatter settlements intervention, and apparently the most economic and efficacious one (Bapat, 1987; Nostrand & Cornelius, 1982). The process includes necessarily a series of procedures, as (1) legalising the land property; (2) area protection – through urban legislation - against speculation, as the creation of Social Interest Special Zones (Marinho, 1999); e finally (3) the project of intervention itself, keeping the general morphological features of settlements, but improving it on water supply, pavements, public spaces, services and general infrastructure. In some cases of *in situ* improvement, planners try – through new urban legislation to those settlements - to impose a rigid plan, restricting growth, occupation and usual adaptations made in time. They use to forget symbolic particularities of these informal areas and try to impose the urban and aesthetic patterns of formal city, ignoring its dynamics and cultural diversity. The result is a contradiction process, in which the natural dynamics arises in a tension against the formal rules and the original intervention plan is never properly applied (Van Horen, 1999).

Regarding this issue, even considering the intentions in favour to legitimate squatter settlements, it is clear that public administration has not been effective in action. Most of the difficulties faced by urban planners and public managers are related to lacking data about use, occupation and urban dynamics at the local scale of informal areas and the absence of appropriate

tools that would permit them to catalogue, handle and publish spatial information with urban management purposes. Availability and precision of maps, and its interrelation to statistical and spatial data are key elements to a proper action towards settlements upgrading. But this kind of information is not available in most countries and municipalities that face the decentralised urban growth associated to poverty.

The researches, findings and experiments presented in this paper refers to the discussion of new analytical methods and tools that could permit a new understanding of inner city squatter settlements, based on spatial and morphological aspects of such complex and intriguing phenomena. Conjectures and finds of these analyses are based on the assumption that it is needed to, in parallel to political and social discussions, to look towards squatter settlements from the spatial perspective, including static and dynamic features.

Metaphorically speaking, watching these urban informal phenomena from the morphological perspective, comparing them to historic processes of urban occupation, one could say that *favelas*, as inner city informal settlements, are the contemporary “citadels”, the historical strongholds into which people could go for shelter during a battle. So, under a symbolic point of view, *favelas* are the new citadels. But the contemporary walls are not necessarily built of massive stones; sometime the barriers are discrete, but the social gap separating these new citadels from the formal city are even deeper (figure 3). But the metaphor which relates slums to citadels also distinguishes them. Socially, whereas the medieval citadels are the official place for the “chosen ones”, the contemporary ones are the place for the excluded. Politically, whereas the first is the symbol of the official control in medieval times, the latter is the result, in some sense, of the lack of control of the contemporary world. In the historical case, the official city is inside, whereas at the contemporary one, the official city is outside. In the contemporary citadels, the boundaries which separate the distinct social structures also distinguish morphological differences: the formal city, outside, and the informal one, inside. Some of these boundaries are attractive to the growth of *favelas* (attractive barriers), and connect them to the formal city: avenues and streets usually the original points or lines from which the *favelas* grow – growth attractors. The non-attractive barriers are property limits and railway lines.

The inner city settlements grow inside limited urban voids, starting from attractors (streets, avenues...) on the margin. They tend to consolidate as highly dense structures, resulting from physical, economical, geographical and social tensions and restrictions, as their spreading is limited by the surrounding physical barriers. On the other hand, settlements which grow relatively free from the urban tension tend to develop in such a disperse way, as less dense structures. The combination of these two morphologies of squatter settlements characterise the hybrid settlements, which are born as semi-rural settlements and turn into urban ones, because the growth and extension of the formal city grid, that along time involves the previously unoccupied areas or scarcely occupied lots.



Figure 3 – Top left: Aigues-Mortes, medieval citadel founded as a basis from which were sent expeditions to the “Holy Land” (image edited from Kostof, 1999). Right: contemporary citadels. Inner city squatter settlement in central Manila, Philippines, developed in an urban void, surrounded by train lanes, commercial avenues and by natural barriers, as rivers and canals (Source: Payne, 1977). Bottom left: diagrams show tension of occupation and development of squatter settlements around attractive borders, related to commercially attractive streets, infrastructure and transportation lanes. These barriers are attractors of development and define the morphology of informal settlements.

As a consequence of these urban tensions, a transformation occurs in the spatial patterns of low density settlements: because the boundaries development (as streets and property limits), the settlement – originally disperse and with low density – turns into an inner city, fragmented and highly dense slum.

Usually, one observes these spontaneous settlements as expressions of informality, spreading through the urban grid, in cyclic process of urban growth and consolidation: settlements which (de)form cities, which form new settlements, and so on... In this cycle of transformation, one question last: how to plan any kind of urban intervention to settlements characterised by informality and urban dynamics, without accept and recognise its growth logic and unusual morphological patterns? In fact, it is necessary to find what happens inside these urban fragments called favelas, in an attempt to extract data and build analytical tools which could support the making of global urban policies and local projects of improvement. But before talking about analytical tools, the analysis and experiments related to the morphological aspects of such informality, it is important to discuss some theoretical issues which are the basis of the new scientific perspective over the production of urban informality.

2. Dualities between planned and spontaneous

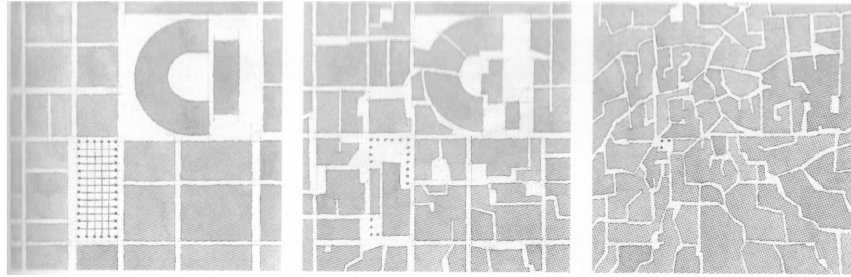
Classifying the urban system in planned or spontaneous, ordered or disordered, static or dynamic, is not quite appropriate to describe the multiplicity and superposition of elements which make the real city. The idea of a strictly planned city and free of decentralised or spontaneous actions belongs only to the utopical universe. At the same time, the natural and spontaneous movement of cities is not completely free from centralising initiatives, on several scales (whether legislation laws or informal neighbourhood codes). The real city escapes from patterns and rules intended by planners of the conceptual city, and at the same time it is beyond the localised decision of individuals. Cities are multiple, and result from the simultaneous combination of apparently opposite and excluding movements, but that actually complement themselves: the planned and the spontaneous.

In fact, distinctions between natural and planned are, sometimes, confusing, because the natural continuity between what is natural and planned inside the urban tissue. But some distinctions could be considered. The natural (spontaneous) parts of the cities grow slowly, comparing to the planned ones. These naturally grown parts of the cities are the result of a myriad of individual decisions at the local scale. The planned ones result from centralised decisions at the global scale, and they are usually conceived to be built rapidly. These planned parts of the cities are usually monumental and regular, expressions of political forces which use it as symbolic elements of triumph and power. The natural ones, generally, are the result of a series of superpositions of influences and changes made along time, and use patterns mix in the urban grid. The planned ones were designed as permanent objects, not to be changed, divided into specific zones of occupation, use and services. But reality has shown that keeping the planned process untouchable is quite impossible along time, because it confront the natural force of growth for any city (Batty and Longley, 1994). All these distinctions are visually clear, and translate into really distinct patterns: irregular and fragmented (natural ones), and regular or Euclidean (planned ones).

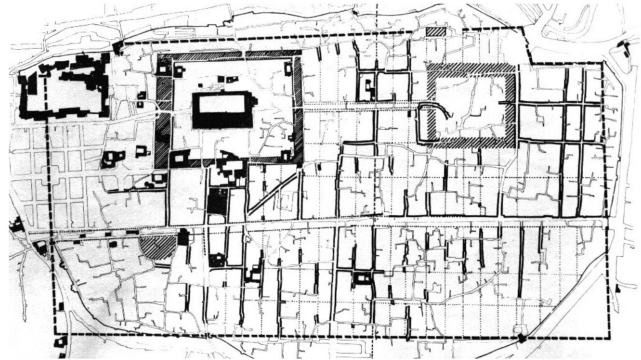
Any planning process is based on concepts and principles. But there has been a tension between theory and reality. Conceptualisation about cities from the beginning of 20th century usually contradicted the real ones. They used to describe and theorise the city “as it should be”, instead of understanding how it really is. So, facing the absence of the necessary duality to properly understand its complexity, the consequence has been a growing gap between real and conceptual: utopia.

In most ‘real cities’, the resulting morphological structure is a mixture of these two kinds of movement: planned and natural. It is hard to find cities that along their history have been kept purely planned or strictly spontaneous. The contemporary city, as mentioned before, is a mosaic of interventions, sometimes centralised ones, sometimes decentralised. Just like a palimpsest, in which the present symbols are written over the past ones, in such a way that readings and interpretations are always inducted by the superposition of images of distinct ages. It is usual, for example, to find urban structures which were originally planned and have been adapted for years along by localised actions, promoting a natural growth over an originally regular structure. At the same time, it is also easy to find urban structures that were originally ‘organic’, but that were target of successive centralised and planned actions.

a.



b.



c.

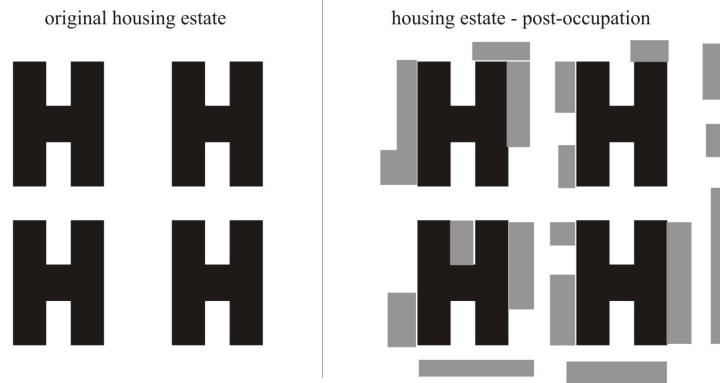


Figure 4 – a. Transformation of the urban tissue after the Islamic occupation over a Roman grid (Source: edited from Kostof, S., 1999); b. superposition of urban languages in the centre of Damasco (Source: edited from Benevolo, L.); c. sketch describing typical changes in low income housing estates analysed in Brazil, particularly at the Metropolitan Region of Recife (Source: author).

At figure 4a, one can notice the gradual transformation of a Roman grid into an Islamic city. At the left, the regularity of the Roman grid, defined by the streets, open air market and the amphitheatre. At the centre, it is the first transformations resulting from the Arab occupation. Population appropriate of public monuments to private uses, forming alleys, tortuous streets and the general urban fragmentation, changing the original regular grid. Finally, at the right, one can observe the complete transformation, where the void spaces are minimum, lasting a few elements and signs of the original city. In figure 4b, representing the centre of Damascus, city occupied by Arabs by the VII century. The ‘organic’ urban tissue spread over the Hellenistic city, destroying its regularity or, to be more exact, building a new and more complex, non-linear regularity. The figure 4c illustrates a contemporary example of spatial transformation. It refers to the gradual and decentralised change of low income housing estates. The original, Modernist buildings and its orthogonal distribution are gradually changed by a self-organised process of public spaces

occupation, buildings upgrading, individualising access and services, adding colors and symbolic elements. Fragmentation is the key aspect of this transformation.

From the morphological perspective, the planned urban form could be translated as the result of the linear and repetitive disposition of elements or 'islands', all at the same scale, in a Cartesian order (Barcelona, Manhattan, Brasília). On the other hand, a few words have been dedicated to analyse the geometric properties of the spontaneous or fragmented urban form. As a result of this lack of a proper objective analysis, last the metaphors: natural, organic, chaotic, and disordered. If on one hand the planned city has been described, geometrically, as the literal expression of Euclidean and Cartesian principles (determinism, linearity, precision), there would be geometrical expressions that could characterise such structures described as organic or spontaneous? Are the spontaneous settlements simply the results of tortuous streets and deformed grids, squares and alleys, all disorderly connected? Or there would be any kind of hidden order behind the apparent morphological disorder?

Regarding the variable time, the planned urban form has traditionally represented what is static and definitive, while the spontaneous urban form represents what is dynamic and unstable. Regarding space, the scale and the regularity are the key elements to understand the geometrical differences between these two forms and processes: planned and spontaneous. The planned one is characterised by objects which belongs to the same scale and are distributed in a regular grid. As a consequence of the centralised process of creation and control, the planned object is marked by a "symmetry of repetition" (relation of equality among the elements, at the same scale) and "scale unity" (the object is composed by elements with the same size). These are the two geometrical properties of the planned city, in which the whole object can be easily assimilated from the observation of its parts (the basic principle of centralised planning).

But in reference to the spontaneous urban form, from the spatial and geometric perspective, one can observe two basic properties, clearly in opposition to the previous one: "symmetry of dilatation" (relation of similarity between elements of distinct scales) and "scale multiplicity" (an object is composed by elements with several sizes, that is to say, all scales are present). An typical example of an urban systems in which we find the planned and the spontaneous side by side is Barcelona, where the regular grid (characterized by the scale unity, regularity) involves the informal structure of the medieval centre (scale multiplicity, fragmentation).

Spontaneity, after all, is an essential part in the morphological palimpsest that characterises the cities along their history. Regular and spontaneous are not specific of cultures or ages; they are spatial expressions of local needs. They are both historic and contemporary processes of urban growth and consolidation. Space, in this case, is the main tool to be used with the purpose of better understanding the varied and complex symbols of these processes. But to talk about a hidden order in irregular structures it is needed some sort of ideological and conceptual rupture in relation to deterministic principles. This rupture has marked the recent discussions not only in Morphology, but in Physics, Biology, Economics and Philosophy, and is essential to the making of new analytical methods to understand the spatial expression of informality.

3. Acknowledging Complexity

While in the conception of Modern Science the whole is the predicted result from the linear sum of its parts, in Complexity Theories the whole is more than the mere addition of behaviours, characteristics or dimensions of its elements, and it is directly related to non-linearity. In this whole-part relationship, “complexologists” affirm that complex systems express an apparent disorder at the global level, but hide intrinsic logic of order based on simple rules and individual elements at the local one. Another peculiarity of these systems is that the level of apparent irregularity remains constant in distinct scales, that is to say, the complex world shows a “regular irregularity” across scales. That is why Complexity has been a strange and seductive attractor to where several disciplines, saturated by traditional conceptions of Science, have converged from the last 15 years. After all, Complexity gathers objects, systems and characteristics which, so far, had been ignored or extremely simplified.

The idea of an adaptive complex system as an apparently disordered set, composed by diversified elements interacting to each other and in permanent changing seems to fit to society and humanity itself. Language, social relations, international affairs, cities, all these are part of an intricate social network characterised by a deep complexity (Holland, 1998). But is there any the practical correlation between Complexity and Urban Morphology?

It has been difficult, along the history of Urban Sciences, interrelate social and spatial issues, in such a way that the spatial approaches, based on the idea of cities as objects, have not been ideally connected to the theories of cities as social, political and economical systems. There is a conceptual gap and an intricate paradox: on one hand, there is no doubt that the morphology of cities is the physical expression of social and political tensions; on the other hand, there is no agreement on how form, space and geometry translate it. This paradox reveals the need for a new look over the Urban Science, which could permit the understanding of spatial fragmentation, acknowledging its complexity, instead of simply ignoring it.

A new look has been established on Urban Sciences from the last 15 years (Batty and Longley, 1994), partly influenced by the diffusion of Complexity theories, whose concepts have somehow affected the way some urban theorists and analysts see the urban phenomena. They now believe that the irregularity and apparent confusion identified in contemporary city morphologies are only superficial expressions of a deeper and more complex order. In this sense, Complexity theories and its mathematical and physical concepts, as Fractals, have been fundamental tools in this conceptual review. Generally, all systems, objects or geometric patterns which reveal a richness of details through scales, have fractal properties and cannot be described using Euclidean Geometry. Nowadays, several studies affirm that cities are systems with fractal features, and that is not a simple expression of rethoric. Such studies confirm that the urban form of unplanned cities is the result of a non-linear logic, whose patterns cannot be measured by usual concepts and tools from classic geometry (Batty and Longley, 1994; Frankhauser, 1997; Sobreira and Gomes, 2000).

The logic behind Fractals is derived by observing an object through successive scales. A circle, a square or a triangle (classic examples of Euclidean Geometry) can be described according to a

linear geometry, that is based upon integer dimensions as new details will not be noticed as one observe the object closer. But, if one observes a city, as an example, one will find that the closer the view, more details will be noticed, more roughness, protrusions, complexity. The fractal dimension quantifies the degree of irregularity or fragmentation of an object of spatial pattern (Moreira, 1999).

But, what is, after all, the connection between Complexity, Fractals, and the studies on spontaneous settlements? The answer is that *Favelas* are complex systems and from the morphological perspective, they present the same universal spatial properties around the world: urban fragmentation and morphological diversity (Sobreira & Gomes, 2000; Sobreira, 2002). The implicit order of social codes, economical needs and spatial restrictions all result in its dynamic and universal morphological structure. So, if *Favelas* are Complex Systems, one could use the same set of analytical tools used to describe these systems in an attempt to describe the urban complexity of such settlements.

On the following sections, one presents a synthetic review of recent findings regarding the morphology of informal and spontaneous inner city settlements, using mathematical concepts as Scaling Laws, Fractals and Lacunarity. The section 4 (The Geometry of Slums) refers to the morphological fragmentation of the built environments using fractal analysis and scaling laws. The section 5 (Favelas via Satellite), analyses the multiplicity of scales of non-built areas (void spaces), from the perspective of satellite images and multi scaling spatial analysis (lacunarity).

4. The Geometry of Slums

In recent studies (Sobreira, 2002; Sobreira & Gomes, 2000) it has been shown that slums and squatter settlements are not merely disordered. Actually, they can be defined as complex structures, and such complexity can be quantified considering patterns of irregularity on the configuration. Particularly, it is made by analyzing the frequency of units (built spaces) according to their sizes, i.e., by using scaling-laws. In recent years a great deal of effort in pure and applied science has been devoted to the study of nontrivial spatial and temporal scaling laws which are robust, i.e. independent of the details of particular systems. These studies at present involve a multitude of complex systems formed by a large number of small units communicating via short-range interactions and submitted to both deterministic rules and random influences. As examples of particular interest we can cite the study of the geometry of railway networks (Benguigui, 1995), as well as the study of the dynamics of traffic jams (, and the modeling of urban growth patterns (Makse et al, 1998), among many others, all them exhibiting several types of scaling laws or power-law behavior. On the other hand, in the last few decades, the idea of disorder associated to the spatiotemporal configurations of cities has been replaced by the concept of complexity. In this section we report some results of this study on the geometry of squatter settlements. This analysis focuses and quantifies in particular the fragmentation occurring in the built space of these urban structures. Firstly, the authors analysed an ensemble of nine *favelas* distributed in different areas of the Metropolitan Region of Recife, on the northeastern coast of Brazil. Later, these results were compared to squatter settlements in Bangkok (Thailand) and Nairobi (Kenya).

In order to give a general view of the kind of urban structure we are dealing with, we show in figure 5 an image of the nine settlements originally examined by Sobreira and Gomes (2000). Each small cell of irregular shape in this figure represents an actual single habitation, and more precisely the space limited by roofs. As can be seen from these images, the settlements exhibit a

seemingly disordered or spontaneous fragmented structure, characterized – among other things - by the diversity of size of islands and the irregularity of their distribution and shape. These islands present a variable number s of habitations ($s=1$ means an isolated habitation, $s=2$ means a pair of contiguous habitations, and so on). A careful examination of the Figure 5 reveals that s varies in the interval from 1 to 19. We can observe that there is a great number of small islands in each settlement, and as well a small number of big ones, a typical feature of complex systems. Another important characteristic of the settlements studied is that all they are embedded in urban networks and most of them submitted to very rigid boundary conditions. The development of these settlements occurs not as a spreading, but as a kind of packing process. Consequently, as the spatial limit of the settlement is previously defined, the diversity of size of its islands seems to be the response of the system to optimize the occupation.



Figure 5 – Morphological configuration of nine *favelas* in Recife, Brazil.

The settlements in Recife were compared to settlements in different parts of the world. In figure 6 one shows a synthesis of that comparative analysis (presented in its full version in Sobreira, 2002), with settlements from Recife, Bangkok and Nairobi.

Inspired in statistical studies of fragmentation dynamics in physical systems and in order to obtain a more complete description of the geometrical properties of the urban structures mentioned here, the authors measured a distribution function, namely $f(s)$, the frequency of islands with s contiguous habitations for each settlement. The discrete variable s gives a measure of the size or area of an island. They have found that the distribution $f(s)$ also obeys a scaling relation; it is given by

$$f(s) \sim s^{-\tau} \quad (1),$$

with $\tau = 1.6 \pm 0.2$,

independently of the settlement. This means that all the settlements analysed present a similar distribution pattern for built elements: a big number of small elements and a small number of big ones, all distributed according to a univesal scaling law (robust exponent of the non-linear function). The exponent τ can be also interpreted as a kind of fractal dimension of the settlements.

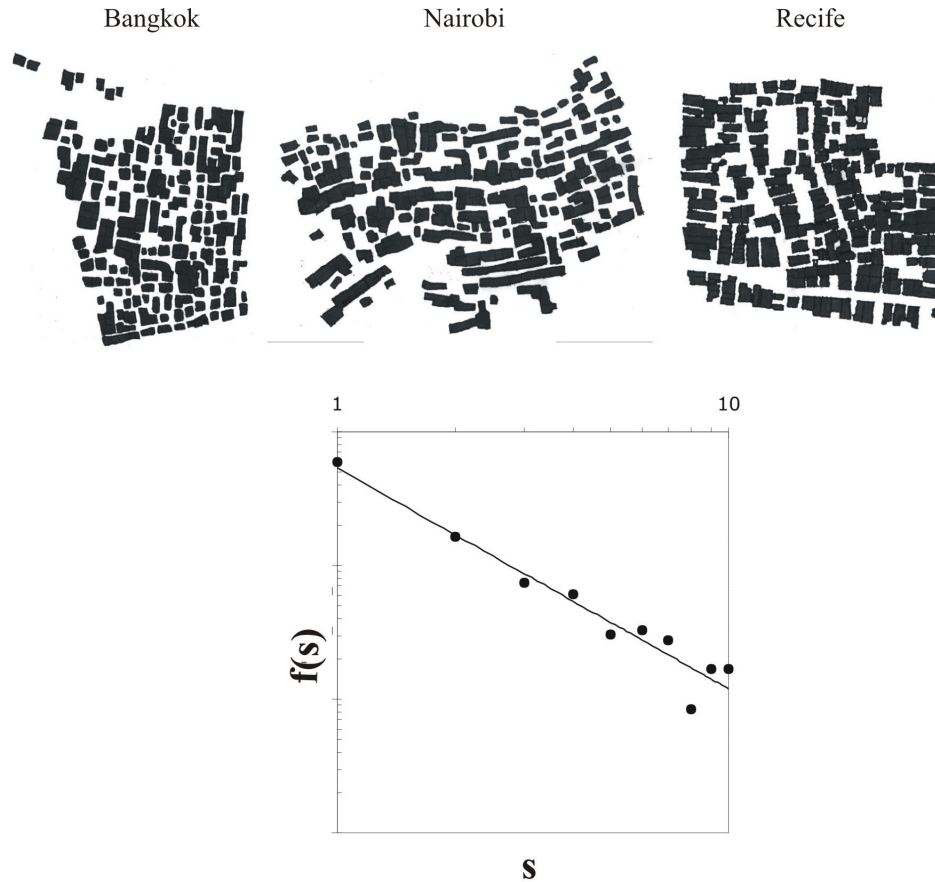


Figura 6 - (top) Squatter settlements fragmented morphology: Bangkok, Nairobi, Recife; (bottom) Universal Scalling Law – the same fragmentation pattern around the world. Source: (Sobreira, 2002)

It is important to stress that the evolution process of the settlements analysed in this work is not related to spreading, as the boundaries around the settlement limit the growth. Actually, it is a process of packing within a limited space for development. So, usually, when the number of islands increase, the boundary size of the settlement remains the same and the density of the system raises, as each new building added to the system is submitted to the constraints of spatial availability. If a settlement were composed only by islands of size 1 (isolated habitations), the resulting density would be considerably low, due to the large amount of void spaces, and we could conclude that in this case the occupation would be not optimized. On the other hand, if a structure were composed by a few amounts of really big islands, the rate of density would be really high. However, the resulting occupation would not be appropriate, due to some problems of access, privacy and salubrity caused by the lack of void spaces connecting houses. This would be, as well, a kind of non-optimized occupation.

The authors conclude that the best response to optimize the occupation of a decentralized system is through the diversity of size of its islands. According to those research results, there are robust (possibly universal) distribution functions associated to the fragmented structures of intra-urban spontaneous settlements. An important characteristic of the settlement studied is that all them are embedded in urban networks and most of them submitted to very rigid boundary conditions. Consequently, as the spatial limit of the settlement is previously defined, the diversity of size is the response of the system to optimize the occupation.

5. Favelas via Satellite – analysing texture patterns

In relation to the illegal and disordered urbanisation issue, some of the main challenges faced by cities are related to mapping and registering geographic information and social data spatial analysis. In this context, recent studies (Barros & Sobreira, 2005) have presented preliminary results from interpretation of cities fragments from the perspective of urban texture, using for this purpose, high resolution remote sense images. Considering that cities are fractal systems, and admitting that urban textures present a wide variety of patterns, how would one distinguish one texture from another? Or, how to identify differences within the similarities described at the previous section? Barros and Sobreira (2005) have developed analytical experiments of "urban tissue" samples, trying to identify texture patterns which could (or could not) represent distinct levels of urban poverty associated to spatial patterns. Such analyses are based on some complex theory concepts and tools, such as fractal dimension and lacunarity.

Lacunarity is related to the distribution of empty spaces (lacunas) of an image. Generally, if empty spaces in an image with fractal properties present a huge diversity of sizes, it will have a high lacunarity pattern of texture; or, if a fractal is almost invariant in its empty spaces distribution, lacunarity will be low. Several fractals can be generated and present the same fractal dimension, but nevertheless be characterised by distinct textures, related to different lacunarity levels. Applications to lacunarity were firstly registered in researches related to image processing in ecology, medicine, biology and other related fields (Gardner et al, 1996). The concept of Lacunarity was established and developed from the scientific need to analyse multiscaling texture patterns in nature (mainly in medical and biological research), as a possibility to associate spatial patterns to several related diagnosis.

Barros and Sobreira (2005) used lacunarity as an indicator of urban texture and as a preliminary tool that could associate satellite images to social and economic patterns. From the previous section one can conclude that the intra-urban and consolidated squatter settlements, despite their apparent disorder, share the same spatial features, regarding fragmentation and scaling of morphological structure, wherever in the world. But, if fragmentation patterns reveal what is the common feature in slums, on the other hand, a more detailed view of slums urban textures will reveal the socio-economic and cultural diversity that is so typical of these settlements. Lacunarity can be understood as a complementary measure to fractal dimension, as it describes the texture of a fractal or any other spatial pattern.

Preliminary results seems to suggest that the urban tissue is fractal by nature, and from the distinct texture patterns it is possible to relate social pattern to spatial configuration, making possible the development of methodologies and computational tools which could generate, via satellite, alternative and complementary mapping and classifications for urban poverty (Barros and Sobreira, 2007).

Regarding texture analysis of urban spaces registered by satellite images, lacunarity is a powerful analytical tool, especially if associated to fractal analysis, as they are multiscalar measures, that is to say, they permit an analysis of density, packing or dispersion through scales. Lacunarity measures are not based on a unique scale, but through multiscalar graphs that reveal the texture variation at several scaling levels. At the end, it is a measure of spatial heterogeneity, directly related to scale, density, emptiness and variance. It can also indicate the level of permeability in a geometrical structure.

Ben Wu and Sui (2002), in a paper about urban segregation analysis in residential areas through lacunarity, present an algorithm based on a sliding box with a varying size. According to that algorithm, the lacunarity to a box (square section of an image) of size “S” will be:

$$1 + (\text{var}(S)/E^2(S))$$

Where: $E(S)$ is the average and $\text{var}(S)$ is the variance of mass values of boxes of size “S”. Variance is the square of standard deviation ($\text{var}(S) = \text{std}(S)^2$).

A low lacunarity, generally, indicates homogeneity, while high lacunarity indicates heterogeneity. The higher the lacunarity, the bigger will be the variation of pixels distribution in an image. In other words, high lacunarity means that pixels are grouped in a wide variety of sizes of islands, surrounded by a widely variant emptiness, indicating heterogeneity of spatial pattern or texture.

Figure 7 shows the main results obtained from analysis of samples in Campinas, São Paulo. As one can observe, it is possible to distinguish two groups of configuration and texture. The regular (formal) areas present, in average, higher values of lacunarity, what is probably a consequence of the outstanding emptiness of spaces, associated to large and regular avenues, and overall low density. On the other hand, when analysing the slums, the result is low lacunarity, indicating low permeability, resulting from typical feature of such urban structures: highly dense occupation and tortuous alleys.

Results from these experiments with lacunarity patterns seem to indicate the following important considerations: (a) If Fractal Dimension reveals that distinct parts of the city are similarly complex, Lacunarity complements that analysis, revealing differences of textures hidden by similarities in fragmentation and scale; (b) It is clearly possible to distinguish, through lacunarity graphs, differences of textures related to regular and irregular areas. When a comparison is established between slums, the differences of density, urbanisation, land parcelling and, probably, levels of urban poverty, generate distinct textures that will be reflected in lacunarity patterns.

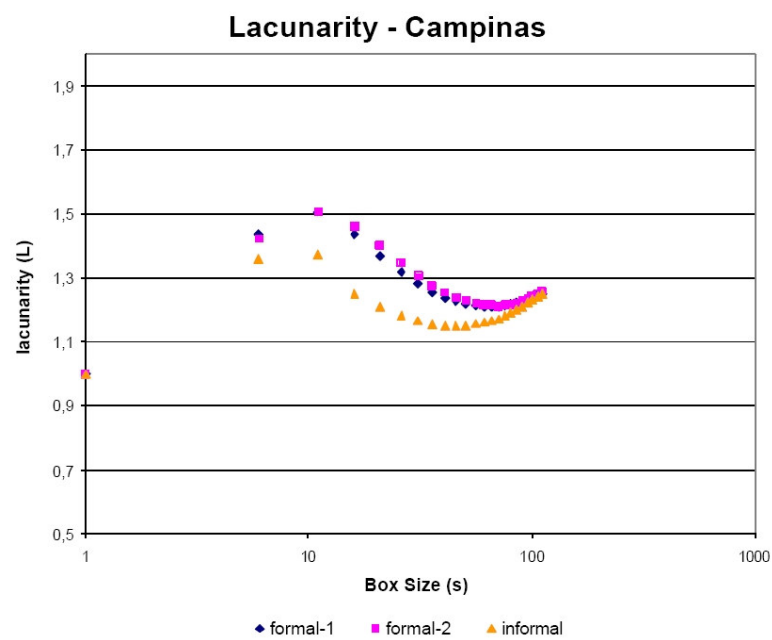
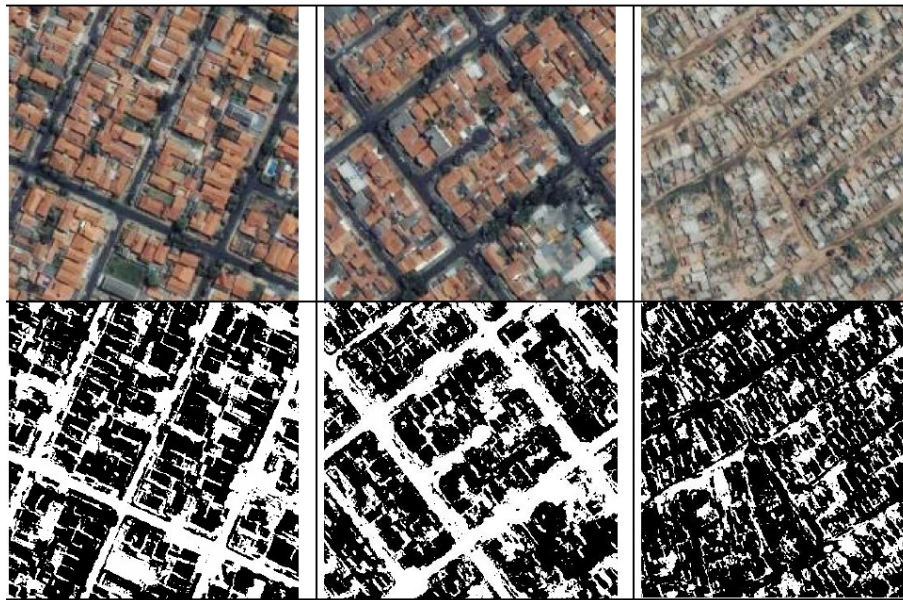


Figura 7 – Top: samples of satellite images; Centre: binary versions of satellite imagens; Bottom, lacunarity graph, describing variation through scales. One can notice the low level of lacunarity in the informal settlement, which means low permeability and high density. Sattelite images source: Quickbird.

6. Conclusions

The fragmentation of squatter settlements in northeastern Brazil has been investigated and compared to settlements in Thailand and Kenya, and a nontrivial scaling function describing these urban structures has been found, revealing a universal pattern of fragmentation. The statistical analysis used here has been inspired by recent studies of fragmentation dynamics mainly in physical systems. We have shown that there are robust and possibly universal distribution functions associated with the fragmented structures of these spontaneous settlements. The scaling laws presented in this paper are the mathematical expression for the urban form in all squatter settlements. An important characteristic of the settlements studied is that all they are embedded in urban networks and most of them adhere to very rigid boundary conditions. The development of these settlements occurs not as a spreading diffusion-like process, but as a kind of packing process. Consequently as the spatial limits of these settlements are previously defined, the diversity of sizes is a response of the system to optimize its spatial occupancy. If there are no rigid boundaries or pressure for occupation, the response is trivial: houses would be distributed in a disordered way. But inside urban networks all they grow and consolidate through the same logic of fragmentation and diversity.

Regarding the satellite images analysis, one could infer that, considering these preliminary results, when the high resolution images are combined to computation tools, analytical procedures and theoretical concepts based on Complex Systems approach, they can be powerful instruments to management and monitoring urban spaces. At the same time, if on one hand one can observe how complex and similarly fractal the urban structures are, on the other hand, one can not deny the diversity of patterns and textures behind similarities. Fractal dimension reveals what is in common among those structures, that is to say, the multiplicity of scales and inherent social complexity. Lacunarity reveals a possible relation between texture and economical, social and cultural patterns.

Finally, from those studies one can infer that inner-city squatter settlements, *favelas*, *barriadas*, *bustees*, *kampongs*, *bidonvilles* and *barrios* are only distinct denominations for the same morphological dynamics, which presents an universal pattern, characterised by fragmentation, diversity, non-linearity, complexity.

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