On the information contents of urban layouts

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1. Introduction: the city as a system

The systemic approach is the dominant one in studies on the city, at least in those carried out in the last decade; this point of view, as is known, views the city as a complex object composed of interrelated parts. Some components of this system are fixed, rigid and not at all adaptable, such as the streets and the buildings, whereas others are movable and dynamic, such as the air, water, cars, people and information.

The fixed elements of the city have been the object of research and applied design proposals, by city planners, architects and geographers, just as the bibliography regarding structure, composition and other attributes of social dynamics is extensive.

Nevertheless, it has not been possible to define with clarity which is – or must be - the global behavior of the system, nor indeed has it been possible to describe in a satisfactory way, from the theoretical point of view, the modalities of interactions between these parts to produce the alluded global trajectory.

In spite of these theoretical insufficiencies, there is agreement in recognizing that the sustainable cities, habitable and efficient, which Ch. Alexander (1971) denominates "real cities[1]", are those that show an harmonic balance between the natural, constructed and social subsystems.

The "space syntax" is a theory, an operative method and a language to describe the constructed space (Hillier and Hanson, 1984:xi). In this theory the "configuration of the space" is a concept that is related to different socioeconomic, environmental and cultural processes. Different research developed in highly varied areas has demonstrated their remarkable capacity to predict the movement in the network of streets of a city, and the connections between the physical configuration and multiple economic and environmental aspects. Therefore, the "space syntax" is a theory, a method and a tool of urban design.

2. Objectives and hypothesis: the complexity as indicator of the structure of the urban layouts

The opening assumption of this article accepts that the structure of streets within a city forms a stationary system, very close to the balance, that interacts with the surroundings

[1] Ch. Alexander defines "a real thing" of the following way: "Something that is self accepted, that is consubstantial with its own nature, that does not have pretensions: something that is direct and simple, that is to say, total" . (1971: 91).

with which it maintains a series of ties, whereas it channels movement between the buildings. Therefore, its adaptive capacity is low, and its configuration exercises an intense influence on the movement, the location of the population and economic activities and services, and on the space use of the individuals. These and other effects, that are combined and added together, achieve such importance that this characterizes the nature of the territory in aspects such as centrality.

The “syntactic model” of the street network of a city, as all systems, contains information about its degree of organization. Our hypothesis maintains that each syntactic configuration takes associate information measures that can be used as distinctive indicators of their structural complexity.

Therefore, it seems possible to identify values of information corresponding to types of syntactic configurations, characterized by its degrees of efficiency, legibility and other pertinent attributes.

If these premises are valid, then the measures of information will be able to be used to great advantage in urban planning, to evaluate the suitability of a type of urban structure to satisfy specified conditions (to optimize the circulation of vehicles, to improve the peatonal network, etc.).

On the other hand, we admit that the very nature of the space imposes restrictions on the generative process of the plan of a city: all the combinations of elements (nodes, axial lines) have not the same probability of occurrence. For example, if we start with the basic condition of which all the buildings are connected, directly or indirectly, with the road, then the resulting space configuration is similar to that described by Hillier and Hanson, 1984: 59-62.).

But, if to this basic premise we add the necessity to maintain the continuity of the streets in order to facilitate the traffic, the visibility or for other reasons, the most likely result is an orthogonal plane, extending in a direction or in a circular projection. In both cases, the generating principle is the same, and the most probable intersections are nodes of third and fourth order (nodes in which three or four segments meet). Nevertheless, both models have different global and local functionality (figure 1).

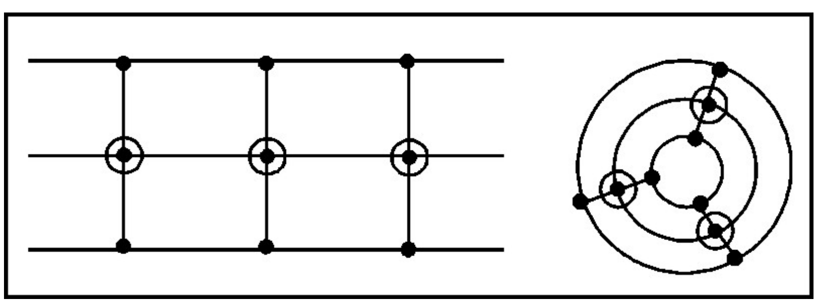

Figure 1. Two plans produced by the same generating principles: continuity of the streets and conections of all buildings. The first, orthogonal one, is developed from the axes of a cartesian coordinates system; the second, is produced by a circular projection from a point. Both have identical syntactic properties, but its global and local functionality is very different.

In order to consider the amount of information, we used the entropy measurement according to the equation of Shannon. I have added the nodes, absent in the "space syntax", as relevant entities, because they are objects with great carrying capacity of information. The study has been carried out on the city of Zaragoza, and to merely comparative effects, in two different parts, that are distinct, and in certain ways opposed, in its location, structures, history, appearance and its internal functionality in relation to the rest of the city: the historic centre and a peripheral area (Montecanal).

In short, this article has the following objectives:

- Emphasising the fundamental importance of the nodes as elements and locations in the configuration of the network of streets, that forms the physical ways of connection between the components of a city

- Proposing the measure of the diversity as an indicator of the structural complexity of the aforementioned system

- Suggesting that there exists a set of optimal values of complexity associated with more efficient space configurations in order to satisfy certain objectives; if such was the case, then the method would have great utility for urban planning and design.

3. Results: urban structures and their content of information

The varied compositions of the urban layout can be described from the structural probabilities of their more important properties.

The complexity is a function of the structural probabilities of the elements that define the system. The concept of structure is associated with that one of entropy and information; the information average of the state of a system is expressed by the equation of Shannon.

$H = -\Sigma p_i \log_2 p_i$
where:
$i = 1, 2, 3 \ldots n$;
p_i: probability of a event i
$\Sigma p_{i} = 1$
This result is expressed in bits/individual.

The method has been applied to "the atomic" components (indivisible parts) of the network that channels urban movement, that is to say, to the nodes and the axial lines and to the convex spaces, although the possibilities of the analysis are not completed in these elements.

3.1. Main parameters of the "syntactic model" of Zaragoza

The urban space of the present study is included in the circumvallation belt, and forms a quite compact continuum. The "axial map" on the plane consists of 2.936 axial lines, although some analyses have been carried out in a representative set of 1.152 lines.

Espace	Connect.	Integrat. global	Integrat. local	Sinergie	
				Slope	R^2
Zaragoza (1.152 lín.)	4,11	2,33	0,92	0,03	0,31
Las Delicias (90 lín.)	5,44	2,87	1,14	6,75	0,71
Actur (110 lín)	4,60	2,55	0,93	1,82	0,32
San Pablo (21 lín.)	3,81	2,34	1,18	5,58	0,74
Casco Antiguo (26 lín.)	4,69	2,52	1,11	3,55	0,71
La Almozara (21 lín.)	4,09	2,40	1,05	1,93	0,44
Las Fuentes (55 lín.)	2,75	2,39	0,88	3,15	0,60
Torrero-La Paz (92 lín.)	3,56	2,07	0,71	1,08	0,26
Montecanal (44 lín.)	3,66	2,18	0,69	0,34	0,16
Connect.: connectivity; Integrat.: integration; Source: Escolano, S. (2003). "La "sintaxis del espacio" construido..." p.2.					

Table 1. Values of the more important syntactic parameters of the axial map of Zaragoza

The syntactic parameters of this map have similar values to those of other European cities, and are somewhat lower than the average of a sample of that given by American cities (global integration (µ): 1,61; local integration (µ): 2,96; (Hillier, B., 2001).

As was expected in a city with such a history, the urban layout has registered the values, the technology and the city-planning styles of the periods in which it has been built. This diversity is reflected in the syntactic map whose global configuration emerges from the conjunction of several models: they can be distinguished from meshes with varied deformation degrees (San Pablo, Miraflores, the Delicias-University, Las Fuentes, Torrero, Valdefierro, Actur, Montecanal) to diverse irregular layouts (sector of the Magdalena, San Jose-Zaragoza la Vieja, peripheral areas). In an analogous way, the constructed space (urban blocks) displays in its size, forms and space organization similar variety.

A consequence of this complex genesis is that the axial map of Zaragoza does not have "axial diameter lines", that is to say, they cross the whole system through the centre, and very few equivalent ones to the radius, unlike what happens in other cities that obey a unitary plan, or that the urban reforms have created these axes (Paris, Madrid, Manchester, The Hague)

Next to these and other peculiarities of local character, the syntactic model of Zaragoza has invariant properties of a global nature. Between these transcultural constants appears the distribution of the axial line length and the spatial pattern of values of some measures, such as integration (Hillier, B.: 2001).

3.2. The nodes: the location of the space decisions of the individuals

The street grid of a city conforms a very stable real network that supports a transport system of people and goods, generated by the urban activities.

This structure, as a physical layout of urban relations, is composed by links and nodes. The streets are fixed elements, more or less indifferent, that convey the movement. The nodes are locations where the information is increased: they are places where people have to take spatial decisions (figure 2). The study of the network of streets includes, then, two complementary aspects: the analysis of the nodes set and the relation between channels.

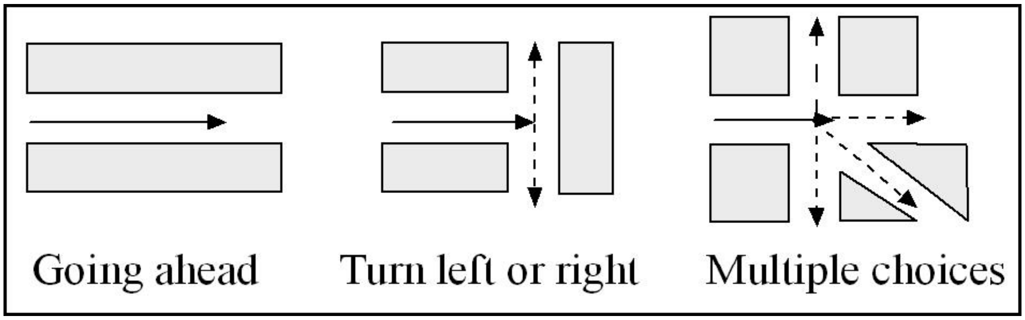

Figure 2. Space streets, nodes and spatial microdecision of individuals (adapted from: A. Moles, and E. Rohmer, p.190).

The network of streets is an essential part of the theory that conceives the urban physical structure as a "geometric labyrinth", maybe aesthetic, and a labyrinth of individual experience too, in which the social behavior of individuals and groups unfolds on diverse scales, (A. Moles and E. Rohmer, 1990: 183-204.).

In this paper we deal with the geometric complexity of the “urban labyrinth” measured on the nodes. We have used a simple method: each node is classified by its rank. The nodes of second order are formed where two segments of street come together; those of the third one where three segments converge, and so on. The equation of Shannon is applied to the resulting distribution. The values for the city of Zaragoza are shown in table 2.

Order of the nodes	Zaragoza	H maximum in a circular area of radius of (meters)				
		400	500	1.000	2.000	5.000
	Frequency	Frequency	Frequency	Frequency	Frequency	Frequency
2	470	3	6	19	21	183
3	2.465	33	47	138	258	1.410
4	821	13	18	64	148	612
5	50	4	5	8	10	35
6	4	1	1	1	1	4
8	1	54			1	1
Total	3.811	108	77	230	439	2.245
Diversity (H)	1,354	1,545	1,549	1,455	1,353	1,342

Table 2. Geometric complexity of the nodes of the streets networkof Zaragoza. Spectral function of the values of entropy

The whole city has a diversity (h) of 1,354 bits/node, possibly quite normal, but low with respect to the most complex natural systems (the higher diversity observed in natural ecosystems is around 5,3). There is a clear function that relates the order of the nodes to its frequency (figure 3; figure 4).

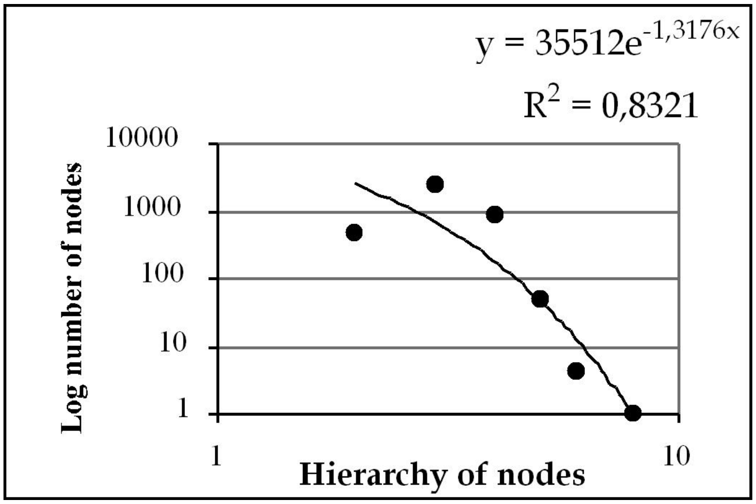

Figure 3. Relation between nodes rank and heir frequency of the grid streets of Zaragoza

Local variations can be observed in figure 5, that is to say: the values of diversity depend on the size of sampled area. Therefore, the complexity of a system is measured more completely when it is calculated for spaces of variable dimension; the distribution of nodes diversity is then a spectral function (table 2). These indices lead us to think about the way in that the complexity of the network of streets is generated, from two nonexistent extreme situations. If CN represents the classes of nodes and N their frequency, then:

$CN = N^{0}$ (extreme, nonexistent simplicity in the reality)
$CN = N^{1}$ (maximum complexity; nonexistent in the reality)
$CN = N^{k}$ (complexity of the networks of real cities)

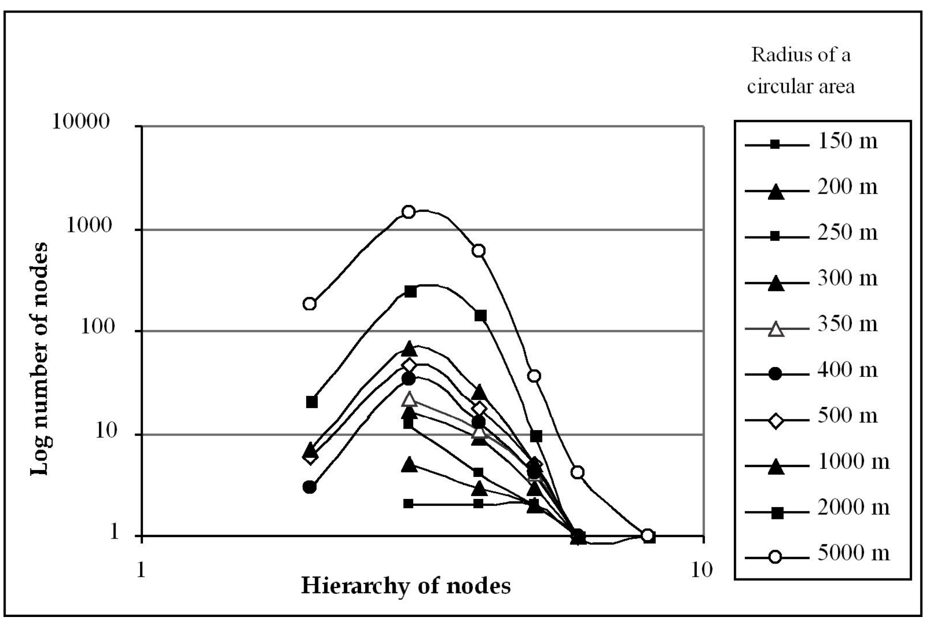

Figure 4. Relation between the rank of nodes, their frequency and area in the street grid of Zaragoza

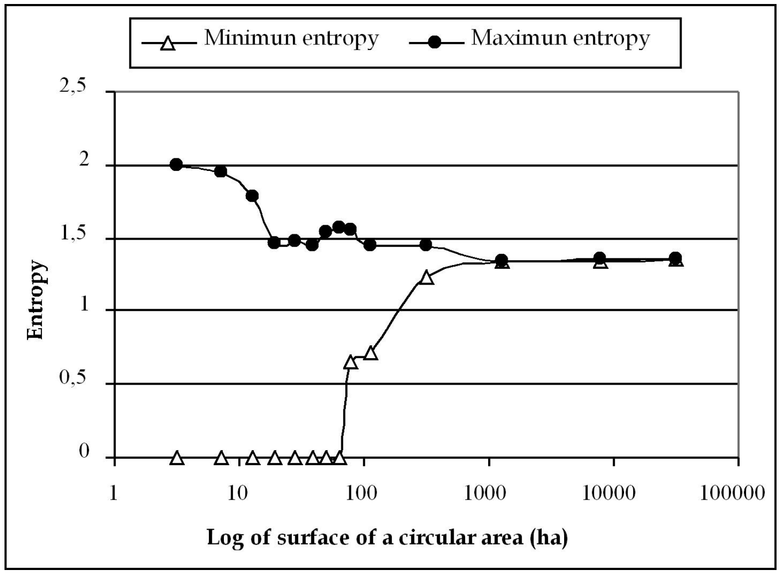

Figure 5. Spectrum of diversity of the nodes of Zaragoza

The k power (0<k<1) is a good indicator of the real diversity and reflects the processes that generate it. Surely, such processes come about from many compromises between several objectives, such as to optimize the efficiency of the circulation, or to maximize the rents of the land. These expressions admit that the system of streets of the cities has fractals and alometric properties.

The study of the plan of Zaragoza led us to assume that this case is a system composed by assembled parts, more or less complex. Some areas shows a simple structure and low complexity, with predominance of nodes of quarter and third order (orthogonal plan). Other ones, of longer history and that have experienced multiple reforms, display high diversity in the hierarchy of the nodes and, in addition, show a certain regular arrangement: the nodes of higher order connect with others of equal or immediately low order, through a quite regular sequence of ranks; it is the case with the historical center and some traditional districts.

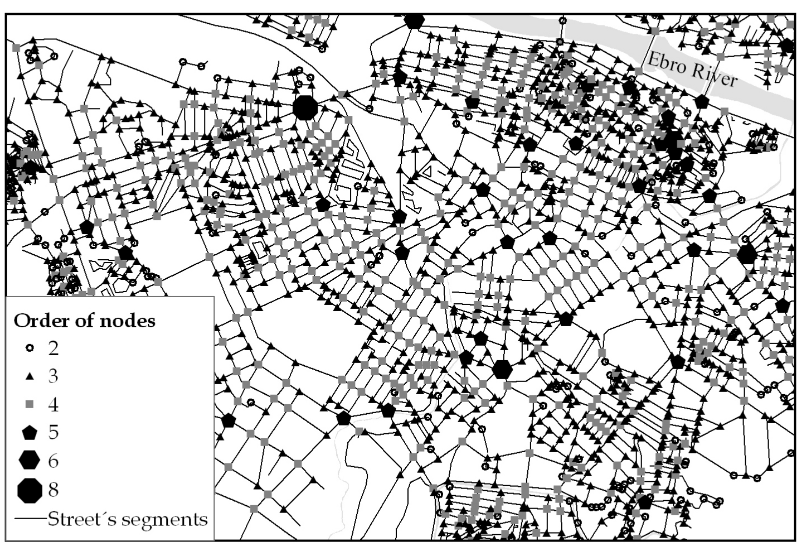

Figure 6. Spatial arrangement of nodes and links in Zaragoza.

3.2. The nodes and the “space syntax”

Our proposal suggests that the nodes, as they have been defined, could be added to the “axial lines” and the “convex spaces” as elements to describe the “space syntax” of the cities. The set of nodes allow to characterize important locations (different from the “axial lines” and the “convex spaces”) with syntactic measures.

We have calculated for the nodes of the syntactic model of Zaragoza their rank and their values of integration according to the equation:

$In_i = \Sigma r \, Ial_j / 2$

Where:

In_i value of integration of a node i

Ial_j value of integration of the j axial lines that come together in node i

The map of figure 6 shows a more complete and more complex image of the space organization of the values of integration, that the produced one only by the axial lines.

Structural measures of diversity, as well as of any other syntactic variable, can also be obtained for these nodes.

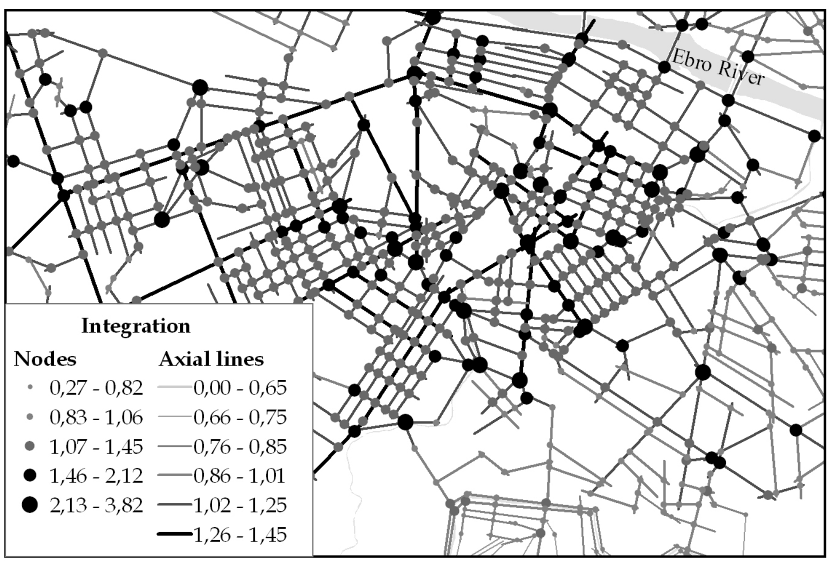

Figure 7. Nodes of the axial map of Zaragoza. Integration

4. Conclusions

The information measures are indicators of the complexity of the network of streets of the cities and their “syntactic models”. The inclusion of the nodes contributes to defining with more precision the geometric structure of the network of streets, since these represent essential locations in the urban space. The nodes are places where the individuals have to take decisions on the movement in the city, and also are important locations for the construction of images of the urban landscape.

An aspect of interest for researching is to see if a space configuration of nodes and links (also their syntactic model) could be more efficient and stable to fulfill its functionality for structuring the city. Such a combination could correspond to the state of maximum entropy of the system.

Further research should be done to see whether particular configurations of a net that maximize the diversity in relation to objectives of urban planning could be defined; the method presented here would then contribute to the production of very useful information for urban planning and for designing the urban form.

Bibliography

Alexander, Ch., 1971, *Tres aspectos de la matemática y diseño. La estructura del medio ambiente,* Barcelona, Tusquets.

Hillier, B., 2001, "A Theory of the City as Object. Or, how spatial laws mediate the social construction of urban space", *Procedings, 3rd. International Space sintax Symposium,* Atlanta, pp.: 02.1-02-28.

Margalef, R., 1991, *Teoría de los sitemas ecológicos,* Barcelona, Universitat de Barcelona.

Escolano, S., 2003, "La "sintaxis del espacio" construido de la ciudad de Zaragoza", *Actas del X Congreso Iberoamericano de Urbanismo,* DGA-AETU, Zaragoza (6 páginas).

Hillier, B., Hanson, J., 1984, *The social logic of space*, Cambridge University Press, Cambridge.

Moles, A., Rohmer, E., 1990, *Psicología del espacio,* Barcelona, Circulo de Lectores.