# THE GEOMETRYCAL COMPLEXITY OF THE URBAN LABYRINT: ELEMENTS FOR ITS REPRESENTATION

## 1. The scene: the city as a four-dimensional labyrinth of the individual experience

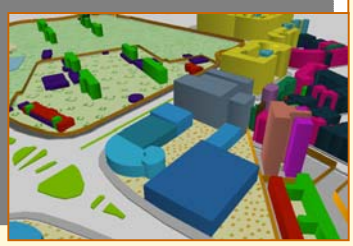
The city is an ecological system of antroposocial nature, generated by interaction involving individuals, the environment and social organization.

The constructed part of this system contains characters relating to social organization, while at the same time the physical configuration of the cities (layout of the buildings, structures of the net of streets) possesses some organizational properties pertaining to social life. In the relationship existing between the constructed component, the environment, and social organization lie the generative principles of urban dynamics; in these creative loops, the stochastic processes are of the utmost importance. .

The structure of the physical elements -streets, buildings- of a city makes up a stationary system, very close to equilibrium, that interacts with the environment with which it maintains a series of ties (s). Therefore, its adaptative capacity is low, but its configuration exercises a great influence on movement, localization of the population and on economic activities and services, and it on the social use of space by

ple and vehicles: a conduction space, rather akin a 4-D labyrinth may view the net of streets as a geometrical and topological

*The material configuration of a city is a 4-D structure populated by events: a material expression of social life (labyrinth 4-D; certain spaces are fenced off and they can*



*The net of streets forms a physical and regulatory system that conveys movement of people and vehicles: it is an interface between places of residence and centres of activity (a 2-D labyrinth with multiple solutions).*

## 2. The actors: the measure of the complexity (and the quantity of information)

The extraordinary complexity of the distribution of the streets, buildings and other physical elements of the city, although it may seem at times chaotic (and on occasions it is), always subtends some organizational grade that, with great difficulty, are reflected in the conventional planes of the cities.

The "syntactic model" of a city and the measures describing it, express, both, the order and urban structure. The properties of the "syntactic model" allow us to relate the genesis and functionality of the constructed space with certain features of the socioeconomic organization.

Our hypothesis also maintains that the measure of the geometric complexity is an indicator of the organizational aptitude of the built space and, therefore, is very useful when interpreting interaction among the fixed, or quasi fixed parts -streets, buildings- and the social and economic activity of people.

Complexity is linked to the presence of events and its sequence along a given path. Among the possible events -actors- I have selected the nodes, because they are localizations which convey a wide range of information; besides, they are in relation to spatial microdecisions of the individuals; they have, therefore, the added value of contributing to the formation of mental images of the city.

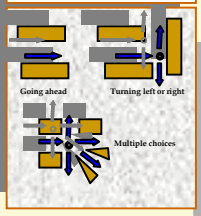
Complexity is a function of the structural probabilities of the elements that define the system; the information - entropy - of the state of a system is estimated by the equation put forward by Shannon and Weaver:

$H = -\Sigma p_i \log_2 p_i$ where: i = 1, 2, 3 ...n; $\Sigma p_i = 1$

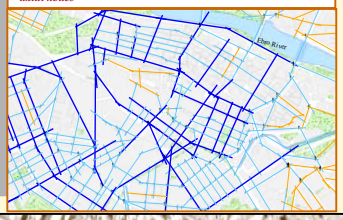
$p_i$: probability of occurrence of an event i;

The result is expressed in bits/individual

*The nodes and the spatial microdecisions of the individuals*



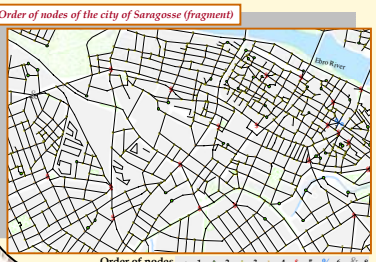

*Can this procedure be equally applied to the distribution of the "axial lines" and the "axial nodes"?*
*Map: global integration of main axial lines; global integration of "axial nodes"*




## 3. The characters and their function: the vertical and horizontal distribution of the complexity

We have measured the complexity of the distribution of the nodes of the network of streets following a simple method: each node is attributed to a class belonging to the same order. The nodes belonging to the first order correspond to dead-end streets, those belonging to the second order are formed where two street segments meet, those belonging to the third order where three segments converge and so forth. The equation of Shannon and Weaver may be applied to the following distribution.

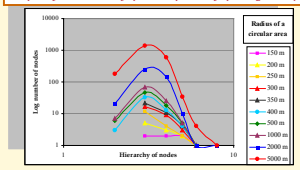
*Order of nodes of the city of Saragosse (fragment)*




The diversity for the whole city (H) is of 1,354 bits/node, which may be viewed as quite normal, but very low with regard to complex natural systems.

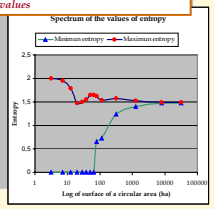
That is clear the function that relates the order of the nodes with its frequency.

*Frequency and hierarchy of nodes of the city of Saragosse (Spain)*




In the case of Saragossa it is understood that the system is composed of more or less complex parts, some assembled with others. Some of them display a simple structure and low complexity, in which nodes predominate fourth and third order (orthogonal plan). Others, with a longer history and that have experienced multiple reforms, present greater diversity in the hierarchy of the nodes, and greater complexity in their organization: the nodes at a higher levels connect with others of equal rank or immediately inferior level, through a regular sequence of nodes of several orders: it is the case of the old quarter and some traditional districts.

*Geometric complexity of the nodes of streets of the city of Saragosse. Spectral function of entropy values*




On the map we may observe that local variations of diversity exist, that is to say, the values of diversity depend on the extension of the sample area. Therefore, the complexity of a system is expressed in a more complete form when it is calculated for spaces of variable dimensions that form a spectral function. These indices lead us, in fact, to reflect on the way in which the complexity is generated by the network of streets, from two extreme, nonexistent, situations.

If CN represents the classes of nodes and N their frequency, then:

CN = N 0 (extreme simplicity, nonexistent in reality)
CN = N 1 (maximun complexity: nonexistent in reality)
CN = N k (complexity of the networks of real cities)

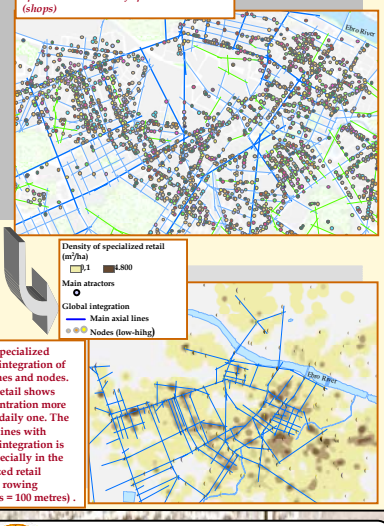
The normal explanation k (0<k<1) is a good indicator of the real diversity and reflects the processes that generate it, a result, surely, of compromises between several objectives, in order to optimize the efficiency of circulation or to maximize land income. These expressions admit that the system of city streets has fractals and alometric properties.

## 4. The play: "space syntax" and information at work

The models taken up by the "space syntax" and the measures of the content of information express part of the relationship between the structure of the physical space and the daily activity of people in the cities: the two categories contain aspects of the organizational loop defined by socioeconomic activities and the organization of the built space. Different theories have been advanced in order to explain this association. The ones that appeal to a single lineal and simple cause don't provide satisfactory results. In the presence of such a complex phenomenon, the most appropriate theories are those that try with the complexity and the self-organization: that on a microescale is rather like a brownian movement, it is, in fact, a system of movements that organises itself around poles or atractors. The myriad of movements generated in the cities is ordered and chained by means of loops of action /reaction, opposition/complimentary, random (stochastic)/necessity, with spontaneity and the *alea* always playing

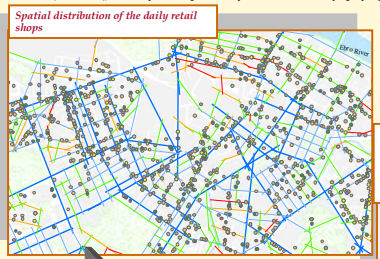
Model of distribution of population's density (method: kernel of radius = 500 metres). The disposition of the axial lines of higher global integration is coherent (makes sense) with the population's location; this relationship can be of great utility in the urban planning.

*Spatial distribution of specialized retail (shops)*




Intensity of the specialized retailers. Global integration of the main axial lines and nodes. The specialized retail shows patterns of concentration more intense than the daily one. The attraction of the lines with higher values of integration is very marked, especially in the types of specialized retail (method: circular rowing window of radius = 100 metres) .

*Spatial distribution of the daily retail shops*





Density of daily retail shops. Order of the nodes; local integration (r=3) of the main axial lines. The spatial distribution of this type of commerce reproduces, in general, the population's distribution, but it presents concentrations on the main nodes and axial lines. The association is more marked when diversity is measured (method: circular rowing window of radius = 100 metres).

*Background: bas-relief of an aerial photo*

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