THE CITY FROM COMPLEX SYSTEM THEORIES. AN APPROACH TO THE STUDY OF MALAGA URBAN AREA

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Abstract

For almost 100 years ago, many authors have understood that cities are the most complex artifacts built by humans. The very idea of the city is coeval at the beginning of sedentary life and agriculture, in the early Neolithic period about 10,000 years ago. Although it is as old this type of human organization, continues to present a paradoxical problem as possibly all humans have the ability to recognize a city, just as we recognize a forest, even if we are unable to explicitly express our appreciation. In this article, we will try to make an approach to the state of the town of Malaga from the perspective of the theory of complex systems.

Keywords: City, neighborhoods, complexity, theoretical model, diversity.

1. INTRODUCTION

Sedentary lifestyle, a way of life for human beings, is fairly recent, in relative terms (approximately 10,000 years ago), when compared with the emergence of the genus Homo, around 2.5 million years ago in Africa, Wong, K. (2015).

This, along with agriculture, was the hallmark of the Neolithic revolution. The first settlements developed in the area of the Near East (actually West Bank) and possibly at the same time in the region of Anatolia (now Turkey). Later in the Tigris-Euphrates Valley (5,300 BC) giving rise to the Sumerian civilization; and in the Indus Valley in the territory of present Pakistan Mohenjodaro flourished in A.C. 3000

Just a little over 100 years ago, some authors and authors have begun to reflect on what it means to live in a city for humans beings. In the words of Park, R. (1925), cities are "the most prodigious and complex human artifacts and at the same time, the 'natural' habitat of civilized man." Because of its complexity, both forests and cities are difficult to define succinctly. In fact, the multiplicity of definitions that have been made about it being a city, "the urban" gives an idea of its very complexity. As Capel, H. (1975, p. 256) expresses "One of the most interesting problems of urban geography is undoubtedly that of the very definition of "urban", the definition of the city".

It is a paradoxical problem as possibly all humans have the ability to recognize a city, just as we recognize a forest, even if we are unable to explicitly express our appreciation. Currently a shift in focus where it matters least try to define the city closed form is observed, the main objective is to understand "that" makes it as is.

This new view has its origin in the proposals of the "General Systems Theory" of Bertalanffy, L.V. (1992), and currently, in the field of what are termed as "Complex Systems

Theory." The analysis of the effects of scale in urban systems and its temporal evolution, from the perspective of Complexity Theory is the basis of studies GAVAIX, X. (1999); Batty, M. (2001, 2003); Batty, M. and N. Shiode (2003).

It is from this perspective that this communication is based on results and unpublished data from my own doctoral thesis, Escudero, C.A. (2012) is articulated and which is expected to contribute to the knowledge of the urban phenomenon.

2. FIELD OF STUDY, DATABASES AND GENERAL METHODS

This study was conducted for the city of Malaga, defined as the urban fabric that presents a clear solution of continuity. That is why the goals were out of a number of neighborhoods and districts, that although administratively belong to the municipality of Málaga, has no structural or building continuity with the main urban core. (Figure 1)
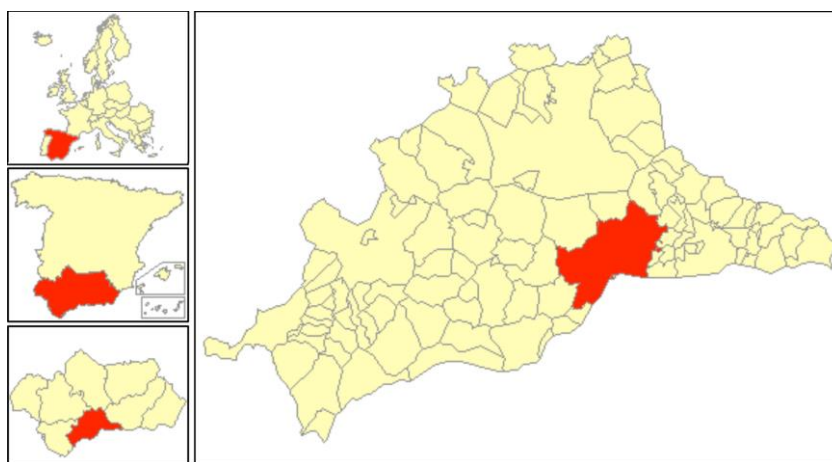
*Source: Instituto de Estadística y Cartografía. Junta de Andalucía.*
Figure 1: Situation maps and location of the area of study.

The main sources of information were used in this study were: From the territorial point of view, the revision of land-use planning Malaga 1983, a division of the municipality proposed in neighborhoods Lopez Cano, D. (1984).

The neighborhood is a territorial unit built, which is defined primarily social. That is, are the social aspects of its inhabitants and their interrelations, the "neighborhood life", which gives it character, but certainly the type of built space will also contribute to their identity. The division was also used in Districts and Census Tracts, which is used by the National Institute of Statistics, as many of the data provided are referred to in this way.

Demographic and socio-economic data (total population, sex, education level, professional stratum) for neighborhoods, were obtained by aggregating data for census apples Population Census of March 1, 1981 corrected with updates Padron, of high and low municipal, as of December 31, 1981, which were used in the revision of land-use planning Malaga 1983. Another important source of information was the Census of Buildings and Commercial INE It is also necessary to indicate that in that same time, two important studies published city of Malaga, which favors the completeness of the information bases. "Socio demographics of neighborhoods malagueños" Lopez Cano, D. (1984) Figure 2 and the "Social Atlas of the city of Malaga" Ocaña, C. (1984).

For calculations of surfaces a graphical method was designed using Adobe Photoshop and is based on technical analysis of the "Monte Carlo Methods" Sobol, I. (1976) and exhaustively tested its suitability in a study on the mulched in Malaga, Escudero, C. (1994).
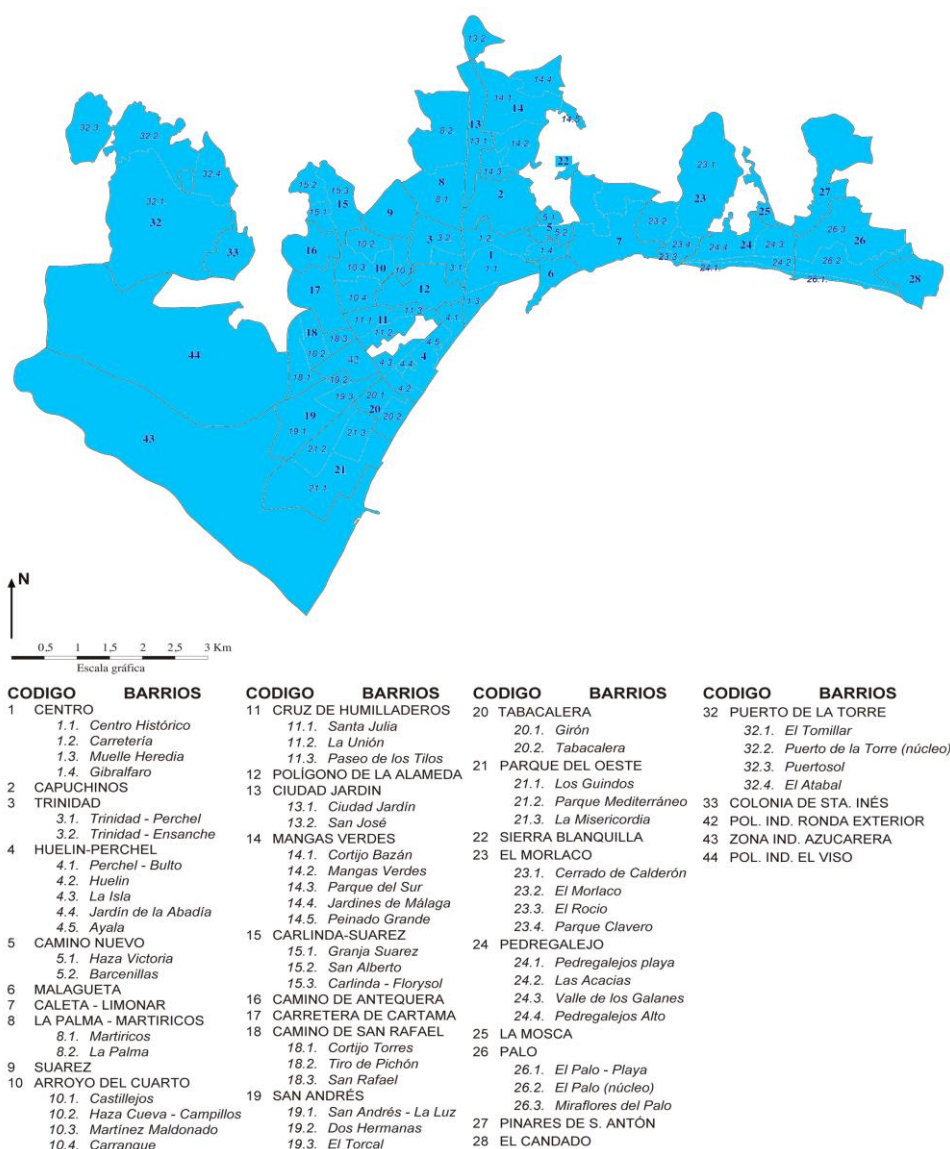
Figure 2: Division into neighborhoods and slums, of the urban nucleus of Malaga.

It was also used as a source of information databases power consumption. As a source of information listings electricity consumption, expressed in kilowatt / hour per year, registered for 1055 low voltage transformers, the town of Malaga were used. These energy consumption data are referred to the year 1982 and were supplied by the company Sevillana de Electricidad, which acted as sole operator on those dates in Andalusia. If from a systemic point of view, this is an important input variable, its equivalent from the point of view of output variable would be the Production of Municipal Solid Waste (R.S.U.).

As database listings daily weighing of refuse collection service of the City of Malaga in 1982. These lists were used were made from the weighing of trucks responsible for garbage collection, made at the end of service, go to download at the municipal landfill. These data are reported daily, along with incidents suffered by the truck responsible for collecting, so the factors that could affect data collection, such as strikes, breakdowns and other incidents were promptly appropriated. Obviously it had to adapt the surface collection R.S.U. sectors, by calculation, to the surface of the neighborhoods.

From the point of view of Melaine, M. and Koelian, G. (2001), analysis of urban metabolism involves characterizing the flows of matter and energy related demand for products and services of urban populations as well as the processes and activities that occur in urban space. The study of matter and energy balances, the intensity of the flows involved, as well as distribution and spatial and temporal variation is the basis of metabolic analysis of cities. As an indicator of the internal functional structure of the city Pielou E.C. (1975) Diversity Index, which is a modification of the Gini, C. (1912) index, was used.

$$D = \frac{\sum p_i p_j}{\sum p_i^2}$$

This index compares the probability of choosing randomly two elements (business premises) of the system (neighborhood or city) are species (activities) other than with respect to the likelihood that these are of the same species (activity). That is compared diversity (Σ pipj) against specialization (which was expressing the Gini index: Σ pi2). This use of diversity indices in the study of cities, was presented by the author at the First World Congress of Health and Urban Environment in Madrid. Escudero, C. and Guevara, J.M. (1998).

Using these variables and indices, which is what is symbolized schematically by the use of a flow diagram in Figure 3, he gave some very interesting results. Over the next section you will see its main features and what they mean in the whole city of Malaga, and by extension, in other urban centers with similar characteristics.
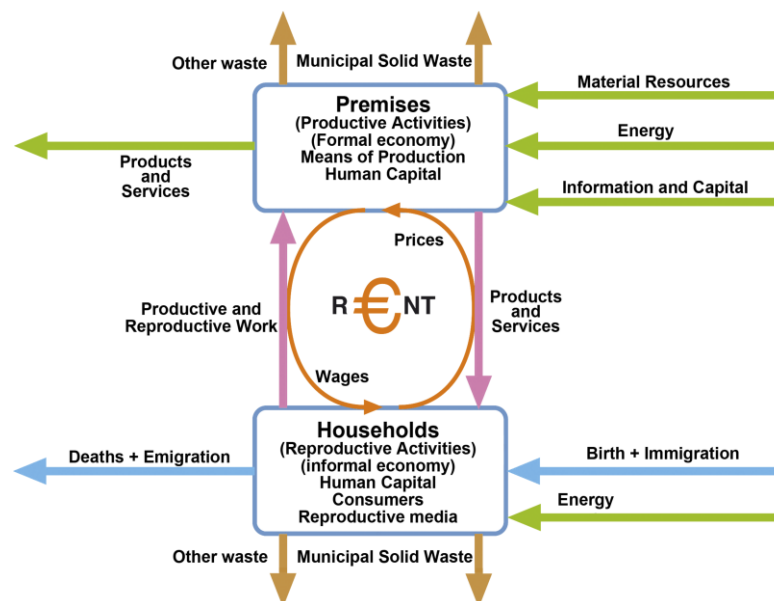

**Figure 3.** Simplified schematic flow of matter and energy in cities.

3. RESULTS

To verify that relationship is established between the structural complexity of the neighborhoods, expressed from Diversity Index Pielou, and power consumption is necessary to take into account the size of the neighborhood factor, and therefore express the energy expenditure in the form of annual consumption per habitant. (Figure 4).
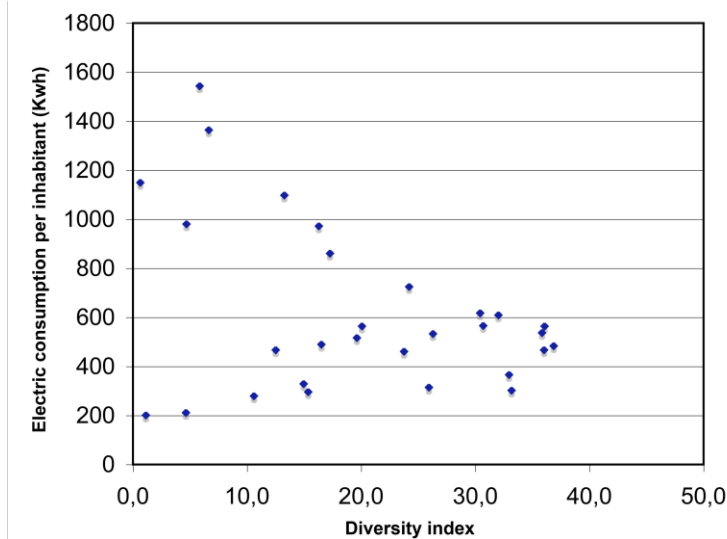
Souce: Sevillana de Electricidad.

Figure 4: Cloud points generated between the values of diversity and power consumption per inhabitant in the neighborhoods of the city of Malaga.

Apparently there seems to be no clear trend in that cloud of points. It would seem that has two branches, one upper and lower decreasing trend of growing trend. That was the first surprise, since it could be thought "a priori" that high levels of diversity should be associated with high levels of energy consumption. (Figure 5)
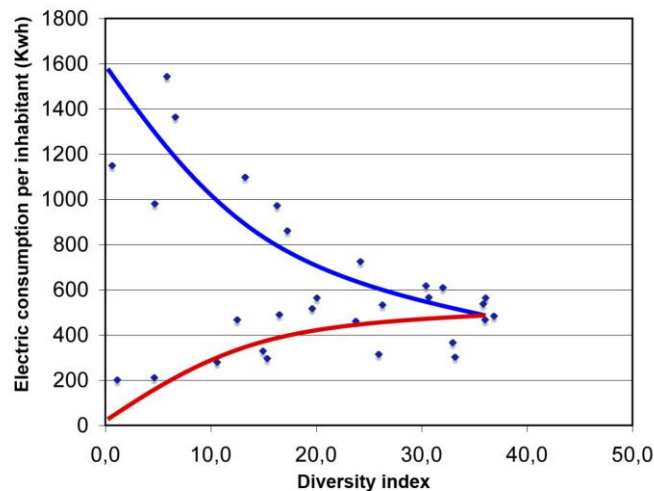
Source: Sevillana de Electricidad.

Figure 5. Sketch of the two trends detected in the relationship between the Diversity Index and Power Consumption. In the downward trend blue, red upward trend.

The second surprise holds the graph is that the maximum values of diversity are always associated with intermediate values of power consumption "per capita" values that are between 400-600 Kwh.

At first you might think that there is no way to set a function to the point cloud, as for the values of X the values of f(X) are not unique. However, during the work of analysis of the data some pretty amazing evidence, which gave an unexpected turn to the interpretation of the results obtained.

First it was found that there was a plot quite faithfully reflected the trends observed in the point cloud. This graph corresponded to the solutions of the semi-parabolic equation:

$$4a^3 + 27b^2 = 0$$

This equation, whose solutions to the interval [0 to 6.75] are shown in Figure 6, is quoted by Rene Thom (1985) in the exhibition of his Catastrophe Theory, as a representation of "control plane" of the "Catastrophe Elemental in Cúspide".
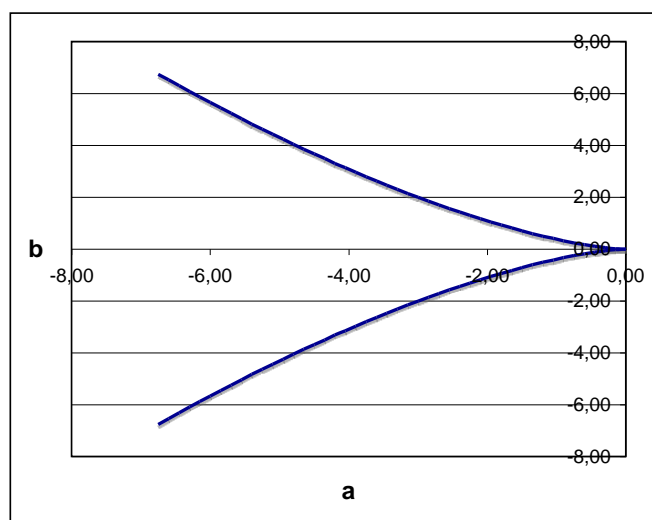
Source: Made from René Thom (1985) "Parábolas y catástrofes".

Figure 6. Graphical representation of the solutions to the equation 4a3 + 27b2 = 0. It is remarkable similarity of this graph with trends reflected in the above.

The "Catastrophe Theory" was proposed by Rene Thom in 1972 in his book "Stabilité structurelle et morphogénése" as a mathematical theoretical explanation to the problem of "discontinuities" in the behavior of systems. Is the appearance of " jumps" in the variation of the variables that define them. Perhaps the term "catastrophe" that popularized the theory, not too lucky because it implies a negative character changes when this theory really just trying to systematize the motives of the "abrupt changes".

The theoretical framework of the "Catastrophe Theory" and its counterpart "Chaos Theory" has been used by some authors to explain the evolution of urban centers. Popolizio, E. and Schneider, V. (2001) applied these concepts to analyze changes in the urban dynamics of the city of Resistencia (Argentina), finding that urban migration and consequent growth of the city, was the main agent generator instabilities that helped dramatically change the structure of the city and its dynamics.

Ilya Prigogine (1983), (Nobel Prize in Chemistry in 1977 and author of the "theory of dissipative structures" and "dynamic systems far from equilibrium") applies the concepts of "order fluctuations" and "bifurcations of the system", a configuration analysis and temporal evolution of hierarchies of interconnected urban centers, as a result of the emergence of new economic functions and actions of communications and transport.

Usually these abrupt changes are associated with bifurcation points, i.e. to situations in which the system chooses between two or more solutions stability. One way to visualize this concept is to imagine a glass with a marble in the background. If we push the marble, it will rise and fall a little by the walls of the glass to re-stabilize at bottom Figure 7.
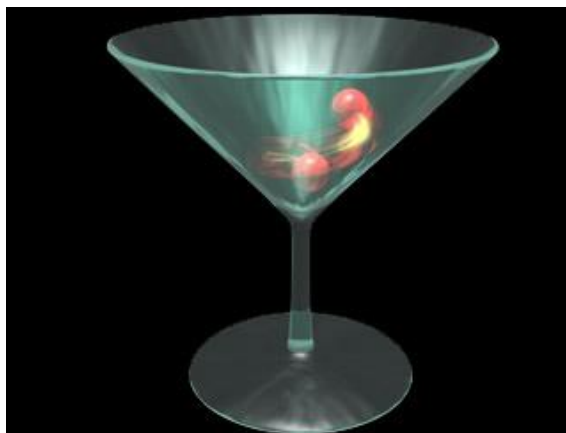

Figure 7. A small disturbance on the marble at the bottom of the cup makes this swing around the point of maximum stability until it recovers its initial state.

If the push is greater, the vagaries of the marble will be broader and persistent Figure 8 before returning to its rest position. That is, the marble system responds with greater fluctuations, continuously, to disturbances that affect them. But it always ends in the same place, at the bottom of the cup.
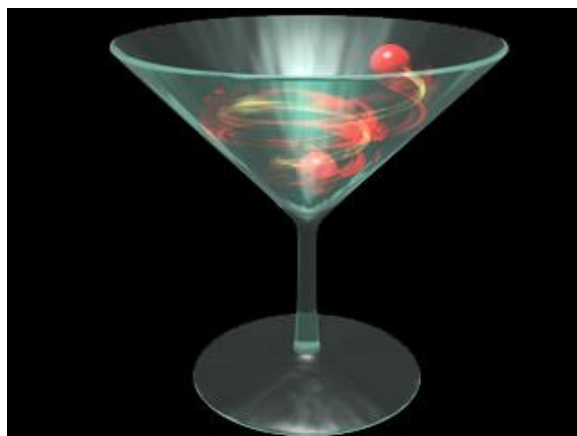

Figure 8. Higher disturbances cause greater fluctuations farther and longer at the marble of its stable state.

Now imagine that the cup is surrounded by other empty glasses, if the push that we give the marble system is strong enough, you can make your trip ends in the bottom of a different from the original own cup. In this case the system has "jumped" to a new state of stability, Figure 9. It has come to a fork: the edge of the original glass, and has fallen to a new state: the bottom of the new cup. What has been the catastrophe?: The jump from one cup to the neighbor. Although it also falls within the jump he may have led to the marble to the blackness of CHAOS.

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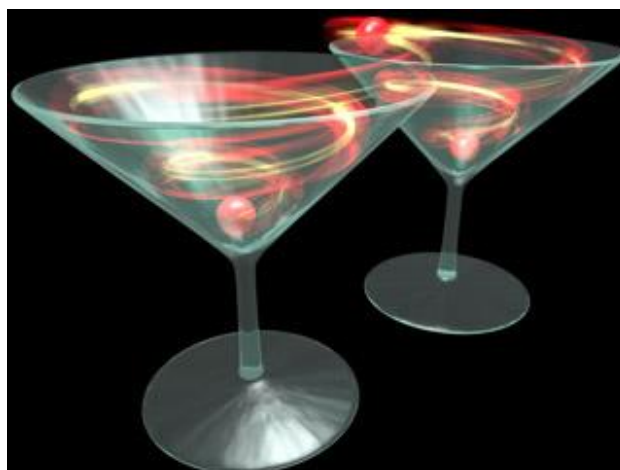
Source: PhD thesis Escudero, C.A. (2012).

Figure 9. If the shock is strong enough, can throw the marble to the edge of the cup, where his career can now lead her to a new, different from the previous stable state. Or send the ball into the abyss of chaos. The edge of the cup defines the boundary of a catastrophe.

In a complex system where multiple factors interact affected by any number of sources of disturbance it is much more difficult to determine the possible paths of evolution of the system. However, in the case presented is feasible to think that have been isolated, or at least recognize, the variables that define the space control.

In Subchapter 3.2. of my thesis was ascertained that the socio-economic status (voiced by level of education) of the inhabitants of neighborhood had a very strong influence on the intensity of energy consumption. When graphed in 3D space (one dimension for each variable) for each neighborhood, their values: percentage of graduates; diversity index and electricity consumption per inhabitant the following result (Figure 10) was obtained.
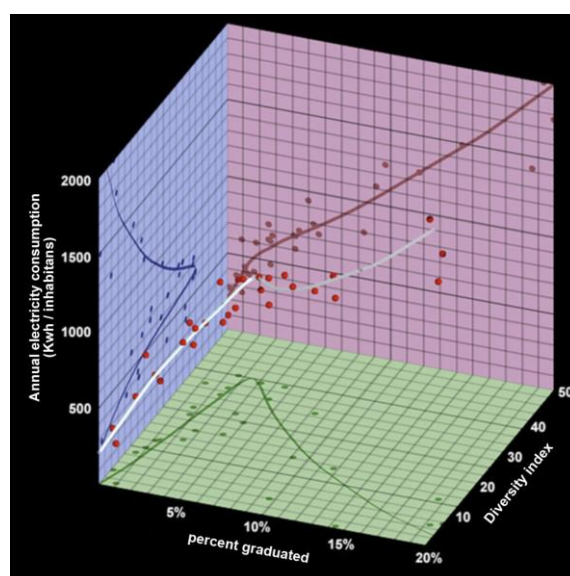
Source: PhD thesis Escudero, C.A. (2012).

Figure 10. Representation of the values of percentage of graduates; diversity index and per capita electricity consumption for the neighborhoods the urban nucleus of Malaga. It has drawn the trend line on the point cloud.

The graph is observed as with increasing the percentage of graduates in the neighborhoods, electricity consumption increases and from a greater than 5% of graduates, gradually decreases the diversity index.

Rueda, S. (1997, pp. 4) suggests that the ratio of energy consumed and Diversity (E / H) in an urban area, it would be a good indicator of the organization, and therefore robustness and stability. Diversity increased (H) implies an increase of the interconnection between the elements and increased internal regulation circuits. The same author states that: "... On the other hand, the instability generated by the dispersed city, must be offset by a greater contribution of energy and resources as control circuits are to deliberately create, which does not happen in the compact and diverse city since, as already said, the systems composed of heterogeneous parts include more recurring regulating circuits.".

The appearance of control circuits is associated with increased system complexity. As it increases, a greater number and variety of elements interact with each other creating regulatory loops modulating system variation against disturbances. The system increases its resilience to external shocks, internalizing variations (Margalef, R., 1991). This would say that by increasing the complexity of the system acquires a greater number of strategies to cope with the changes without altering its structure.

The systems are very homogeneous have fewer strategies against disturbances. In cultural systems like human societies, can be "purchased" outside in exchange for a high cost, energy and economic strategies, and through extensive use of transportation. A residential complex of high purchasing power, consisting of single-family homes, persists over time because its residents use a lot of energy and economic resources, consumer goods carry their homes and keep them in living conditions.

At the opposite extreme are the nuclei of substandard housing self-construction, or other meanings: shanties; favelas; bidonvilles; etc. In most cases, associated with strong temporary immigrant population flows very low purchasing power, or excluded social groups. In all cases are highly vulnerable urban subsystems (Díaz Díaz Muñoz Castillo M.A. and C. 2002, Gonzalez Garcia, I. 2003). The latter author bases his vulnerability assessment based on a number of both socio-economic factors (income level, education level, associations...); as structural (equipment, infrastructure, quality housing...); functional (accessibility, economic activity; public projects...) and environmental. From this perspective Gonzalez Garcia, I. 2003 re / sp1 states: "The vulnerability (of these areas) belongs to a blind spot of social and institutional perception. In a social structure that delegates the resolution of the problems in the various administrative levels, the perception of the vulnerable does not surface, only produce their exclusion from everyday acts, the most marginalized spaces are circumvented, and verbalization of the problem is circumvented next.". Therefore, these spaces remain while they remain excluded from everyday life. If for any reason they hit the network partner - economic city (revaluation of land they occupy, by political interests or social conflicts with the neighboring population) they are simply wiped off the map and displaced people to another marginal area.

Barros, J. and Sobreira, F. (2002) have made an interesting analysis of the dynamics of these marginal human settlements and their clash with the planned city, from the point of view of the Theories of Complexity. Apparently, from this perspective, the spatial and temporal persistence of these subsystems is only possible while holding spaces are not desired by the orderly city, and are able to increase their internal complexity and self organization so that they can successfully defend their own persistence. These situations are seen in many Third World cities.

Between these two extremes of any city neighborhoods are located. Intermediate situations of social, economic and structural nature define the urban fabric. They wanted to visualize what the stability - vulnerability of different neighborhoods of the city of Malaga,

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[1] re/sp abbreviations will be used to indicate the source of the quote is an electronic magazine unpaged. In the bibliography accompanying these references with your hyperlink.

superimposing the results of Figure 10 on the space control Catastrophe Type 2 "Cusp" René Thom. (Figure 11).
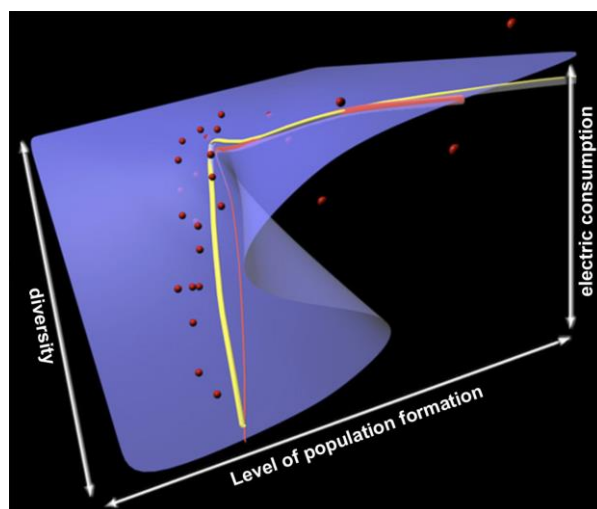
Source: PhD thesis Escudero, C.A. (2012).

Figure 11: Translation at control space cusp catastrophe, values education level, diversity and power consumption of the neighborhoods of the city of Malaga type. The red dots represent the values for each neighborhood, the yellow line is the adjustment was made to the point cloud, the red line marks the border "jump" batch in control space.

4. DISCUSSION

Increasing activities developed in a neighborhood causes an increase in energy consumption for two reasons. The first is directly due to the energy needs of the activities developed. The second is a result of increased activities in the neighborhood increases the chances of meeting the demands of consumption of the resident population. This may make the neighborhood to potential residents, in a market structure will favor those with sufficient purchasing power (or capable of risking greater economic effort) to change their place of residence more attractive. As discussed earlier, the purchasing power is related to the level of income, and this with the level of instruction. Therefore, the neighborhood tends to gradually increase the proportion of graduates and since these have a higher consumption capacity, will increase the net energy consumption and indirectly encourage the implementation of new activities.

So far the system seems to be developed by fluctuations fueled by positive feedback loops: Population growth increases the number of activities, they attract and increase the proportion of the population with higher purchasing power and both events do increase energy consumption. However a controlled only by positive feedback loops system is unstable because it would be amplified without limit fluctuations.

Really the system is stable because also appear negative feedback loops: As housing neighborhood and local availability decreases, thereby factors built competition for space (and therefore prices) increase deal. This acts as a deterrent to potential occupants.

On the other hand, the increase of activities and population density (both resident and visitor) causes an increase in noise, waste production and pollution, reduced parking spaces, increased neighborhood conflicts, further deterioration infrastructure and street furniture, etc., and therefore a general deterioration in the quality of life in the neighborhood. This will act as a deterrent to those with economic capacity to choose an area that meets your wishes "Quality of Life". (Figure 12)
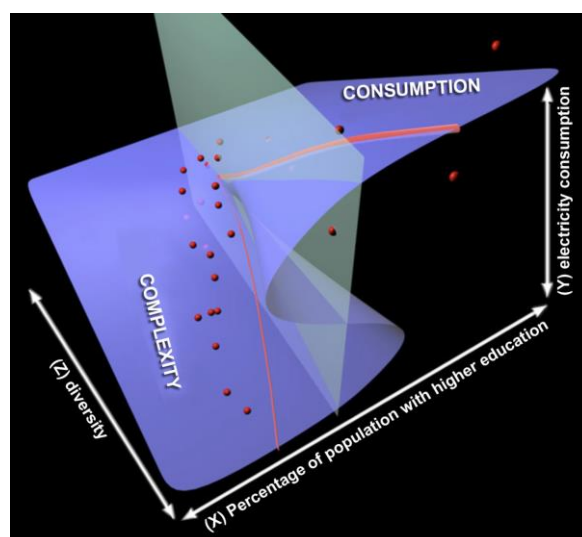
Source: PhD thesis ESCUDERO, C.A. (2012).
Figure 12: Distribution of Malaga neightborhood between the lower and upper levels of the cusp catastrophe model. It is noted as most of them are located in the area where strategies increased complexity are more relevant than energy consumption.

From this point of view, it is possible to say that urban systems maintain their stability two opposite ways: either by increasing their structural complexity and dynamics; or by the ability to maintain high energy consumption "per capita". You could say that in the lower plane of the cusp catastrophe model strategies increasing complexity are developed, while the higher consumption strategies dominate. Interestingly, like most neighborhoods of the town of Malaga city they were at the lower level, encompassing the increase of energy available with increased organizational complexity.

It is not surprising to find that the neighborhoods that are in the area dominated by high consumption strategy, are the neighborhoods of the city of Malaga more residential component of high socio - economic level: the neighborhood 7 (El Limonar); Neighborhood 23 (El Morlaco); Neighborhood 24 (Pedregalejos); Neighborhood 27 (Pinares de S. Anton); Neighborhood 28 (El Candado).

However, we should not forget that most districts do not follow this strategy. This makes a whole city as a complex system works well structured. The neighborhoods of the strategy remain consumption thanks to the existence of a city where dominate maintenance strategies or increased complexity. Or at least that was what happened in the city of Malaga in the late twentieth century, it might be interesting to see what happens today.

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