DYNAMICS DAYS SOUTH AMERICA 2010
International Conference on Chaos and Nonlinear Dynamics

**INPE – National Institute for Space Research**
**São José dos Campos – SP – Brazil – July 26-30, 2010**

# SUSTAINABLE DEVELOPMENT THROUGH COMPLEX NETWORKS

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**keywords:** Applications of Nonlinear Sciences, Complex Networks.

## 1. INTRODUCTION

This paper regards a novel sustainable development modeling through complex networks and ordinary differential equations. The modeling elements are two: the first one concerns to a complex network with nonlinear differential equations involving the state variables, represented by nodes, and the second is an indicator system (indicators, variables components and dimensions) built on the state variables.

Finally, we also model the community perception. Modeling this situation is totally different from the previous one. Since each community member perceives different, we use random variables. We introduce also the information concept and perform statistical simulations in order to obtain significant data. Several questions arise such as if the sustainability actions must be thought in order to make the technical model identical to the perceived model.

Manizales sustainable development is based on an indicators system which shows the general picture of the development of the city. There are 128 basic indicators (collected by IDEA Manizales), which are organized into different categories: dimensions, components, variables and basic indicators. We pretend a new development modeling, through complex networks, with the following properties: better scenarios forecast, possibilities for control actions (sustainability actions), institutional planning and link with the actual system (IDEA Manizales).

## 2. SUSTAINABLE DEVELOPMENT MODELING

As we stated before, we will model sustainable development with two elements: the first one is a complex network with links among the spatial regions to be considered (bioregion, bio-neighborhood, and so on), and the second one is an indicator system, which can be by itself another complex network. Since some knowledge of the physical situation is available at the nodes, we prefer deterministic modeling to statistical-based models.

### *2.1. Complex networks*

A complex network is, mathematically, a digraph with nodes and links. Each node concerns to a different spatial region, say, for example a bioregion. At each node, a system of nonlinear differential equations containing parameters is stated, using polynomial, exponential and other nonlinear functions which define the nonlinear system. These equations also have control variables with sustainability actions. Control variables (sustainability actions) show the effect of political and administrative decisions, and are related to the so-called institutional-political dimension.

The links show the relations among the different spatial regions we consider in our modeling task. Depending on the modeling effort, the links can also contain some dynamics or can be purely static.

### *2.2. Indicator system*

Once the different spatial regions have been defined (the nodes of the complex network), and the corresponding links have been stated, we build, on each node, an indicator system. The indicator system can be itself also a complex network depending on the effort of the sustainability modeling. Functional dependence among the indicators, variables, components and dimensions can be of different sort. They can be static or dynamic, linear or nonlinear. Delays, periodic forcing and other functional elements can be introduced in the dynamic indicator system.

We consider ecosystem, social and economic as the development dimensions. Although political-institutional has also been considered a dimension, we think that it has a significant different meaning. Since it contains sustainability actions, mathematically should be considered as a set of control variables. Thus, we will not include it in the set of natural development dimensions.

### *2.3. A case study: Manizales*

In the specific case of Manizales, we will enhance the Observatory modeling from linear uniform static functional dependence to nonlinear static and nonlinear dynamic equations. Moreover, some links among different layers (indicators, variables, components and dimensions) will be also introduced. Thus a whole complex network will be considered at each bio-neighborhood, including also smaller towns which belong to the bio-region (see Figures 1,2,3).

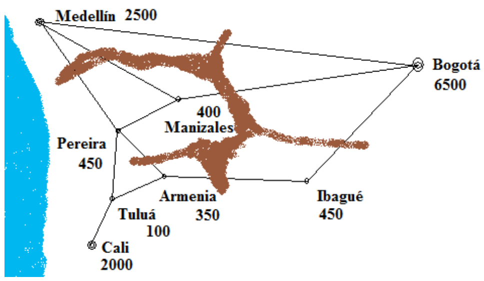


**Figure 1 – First level of the network**

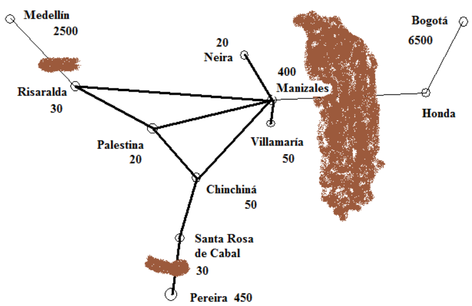


**Figure 2 – Second level of the network**

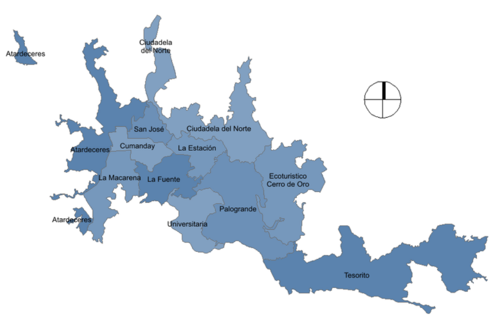


**Figure 3 – Third level of the network**

## 3. PERCEPTION MODELING

In this section, we propose how to model also the community perception. Modeling this situation is totally different from the previous one. Since each community member perceives different, and there is not much information about the perception process, we use random variables. We introduce also the information concept and we perform statistical simulations in order to obtain significant data.

We assume that the Technical System is the full set of characteristics and indicators as viewed from the political-institutional administration. In most cases, the members of the community have only partial information, and this partial information is different from member to member. Moreover, even the same information is perceived different by the members, according to their own interests and priorities. Thus, for each member, we have a different Perceived Model, through a perception function. Thus it makes the perceived model is a random variable depending on the indicators.

Several interesting questions arise such as if the sustainability actions must be thought considering the technical system or the perceived system. Or even if they must be taken in order to make the technical model identical to the perceived model.

## 4. CONCLUSIONS

We modeled a development system through a complex network where the nodes are related to bio-spaces and the links concerns to relations among the nodes. Moreover, an indicator system (which can be by itself another complex network) is also built on the state variables at each node. The perception process is modeled through statistical methods since the perceived model can be different from member to member in the same community. This novel view on the modeling will lead to better scenarios forecast and it will improve the sustainability actions to be taken by the corresponding institutions. Concretely, further work is directed to a software implementation which integrates this modeling concept, and will be applied to The Observatory in Manizales.

### References

[1] United Nations, "Indicators of Sustainable Development: Framework and Methodologies," New York, 1996.

[2] S. D'Alessandro, "Non-linear dynamics of population and natural resources: The emergence of different patterns of development," Ecological Economics, Vol. 62, pp. 473 - 481, 2007.

[3] IDEA, "Indicadores de gestión urbana. Los observatorios urbano-territoriales para el desarrollo sostenible. Manizales, Colombia (in Spanish)", available at http://www.eclac.cl/publicaciones/MedioAmbiente/3/LCL1483/lcl1483e.pdf.