SYSTEMS SCIENCE AS A SYSTEM OF KNOWLEDGE: AN EXPLORATION RESEARCH OF ITS STRUCTURE

Isaias Badillo-Piña, Ricardo Tejeida-Padilla, Ignacio Peon-Escalante
Instituto Politécnico Nacional, México
Emails: ibadillop@ipn.mx, rtejeidap@ipn.mx, ignaciopeon@gmail.com

ABSTRACT

This paper presents a brief exploratory research work on the structure of Systems Science. To guide the exploration through the jungle of domains, concepts, theories and methodologies, the Domain of Science Model developed by John Warfield was used as a compass.

Given that Systems Science is itself a system, it is researched like a conceptual/real system, considering the consensual points of view expressed by theoretical and practical systemists in congresses as well as in traditional and recent research documents.

The exploration research helped to identity and elucidates the main components of the body of knowledge, which integrate the Systems Science as a whole, such as:

The domain of the Systems Science
The conceptual space and language of Systems Science
The theoretical relations inside the Systems Science
The methods of the Systems Science

Keywords: Science Model, Domain of Systems Sciences, Concepts, theory, methodology System

INTRODUCTION

The Systems Science is considered like a science in its first formation phases, there are a great variety of points of view, approaches and concepts about its nature, scope, degree of formalization and applicability. The table1.sample the great variety of approaches, as well as the quantity (257) of individual contributions to the Systems Science according to the disciplines (12) of the authors. This situation hinders the effectiveness but at the same time stimulates the advance of the progress in the processes of teaching-learning, communication as well as recognition of the theoretical research and the professional exercise.

Table 1 – Some streams of systems thought

STREAMS	AUTHORS QUANTITY
General Systems Theory	31
Cybernetic	14
Physical Sciences	21
Computer Sciences	18
Biology	23
Symbolic Systems	17
Social Systems	24
Mathematics	16
Ecology	12
Philosophy	73
Systems Analysis and Engineering	15
Encyclopaedias	3
Total	**257**

Adapted from Schwarz (2000)

After reviewing diverse definitions of what is a science: Campbell (1952), Chalmers (1982), Kerlinger (1973), and others, it is observed that there are some common concepts of what is a science. For example all authors coincide in that a science should have: 1) a field object or domain of study, 2) a set of concepts defined by special language, 3) a theory/philosophy and 4) a method for applications. See figure 1.

According to Dr. Warfield (2006,1986), the Systems Science should be able to cover four groups of activities, for which he proposes four basic components that integrate the Systems Science in order that it can play the roll of trans-disciplinary science. Shortly, the basic components are four sciences, as follows:

1 - Science of the description: to describe problematic situations of any nature inside the **domain** of the Systems Science.

2 - Science of the generic design: to design systems by means of applicable trans-disciplines through different disciplines, cultures and organizations that take into account the human being, the thought and the language of the systemic **concepts**.

3 - Science of the complexity: to develop a metric and modeling **theory** that facilitates the mensuration and interpretation of the complexity of the problematic situations as well as the design of systems and methodologies.

4 - Science of the action: to specify **methodologies** that solves problematic situations inside the domain of the Systems Science. Including laboratories for practicing Integrative Management, Team Sintegrity, Agoras, etc.

The underlined terms denote the four basic components of the Systems Science. The four integrated subsidence's forms the Systems Science whose practical purpose is to contribute the necessary and enough knowledge to solve problematic situations of any nature that arise in any part of the domain of the Systems Science. The four sciences leans on in the neutrality of the system definition:

"System is any portion of the material know universe (objective and subjective) that is selected mentally as separated from the rest of the universe, with the purpose of considering the different changes that can happen inside this portion of the universe under different conditions , organization, structure, processes and environments."

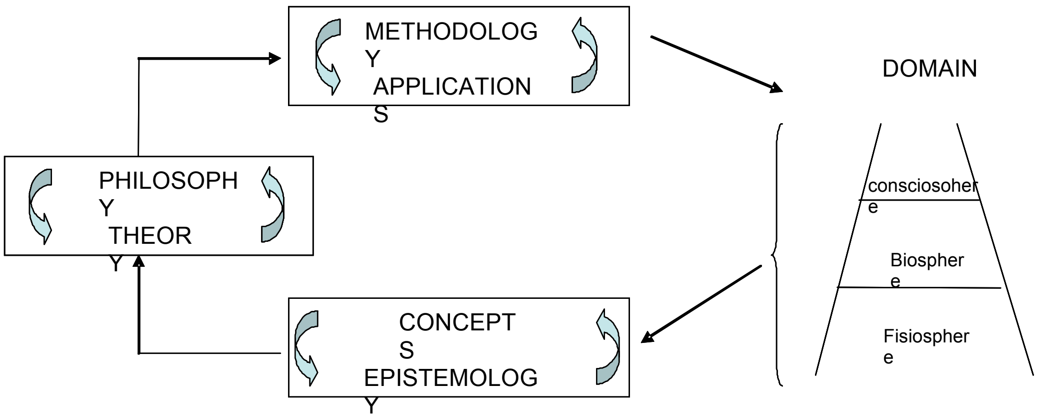


Figure 1.- Main components of Systems Science

DOMAIN OF THE SYSTEMS SCIENCE

Due to the general trans-disciplinary character of the Systems Science, the domain of this science is constituted by the whole known universe where systems exist. Only to facilitate the study of the systems several taxonomies they have been developed by investigation areas, by evolution approaches, by approaches of objectivity-subjectivity, by approaches of complexity, etc…

The development of taxonomies of the universe of systems is not exclusive of a civilization or time, in the western civilization they have been practiced in the European and American culture, for example, alone to mention a Mexican case, Nun Juana Inés of the Cruz (1692) in her essay “First Dream” she apprehends the systemic cosmos making abstraction from the particular things until the universal ones highlighting the harmony of all with everything. In this process, she tries to embrace the entirety of the scientific knowledge of her time, from Plato, Aristotle, Nicolás of Cusa, R. Descartes, etc…

The essay “First Dream” considered the master work of the Nun Juana Inés of the Cruz, is written in heptasyllabic and endecasyllabic verses (Del Rio, 2006).

The outline derived from this essay, is similar to the one formulated 300 years later by Teilhard du Chardin (1965) and Erwin Laszlo (1996). (See figure 2) .

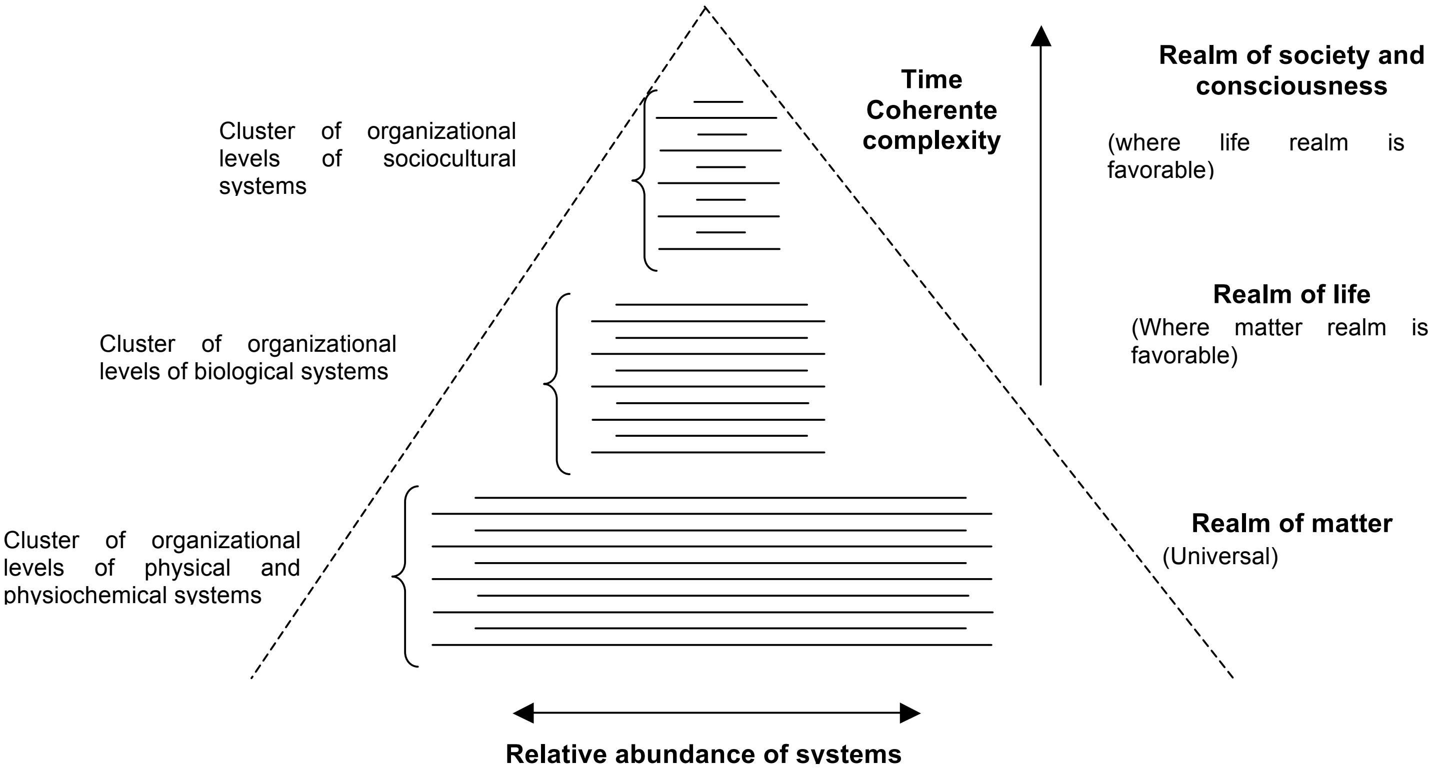


Figure 2 Domain of the systems science

Source: Adapted from Chardin (1967), Laszlo (1996) and de la Cruz (1692)

Another of the most complete domain of systems science was presented by Wilber (1997), Figure 3.

This domain of systems science is based on the complementary principle in order to integrate the two main western cosmo visions: Idealism and Materialism.

Wilbert propose four sub domains:

Interior Individual, mnemonic I – for Subjective Systems.

Interior Collective, mnemonic WE – for Intersubjective Systems.

Exterior singular, mnemonic IT – for Natural and or designed Systems.

Exterior plural, mnemonic IT´S – for Social/Ecological Systems.

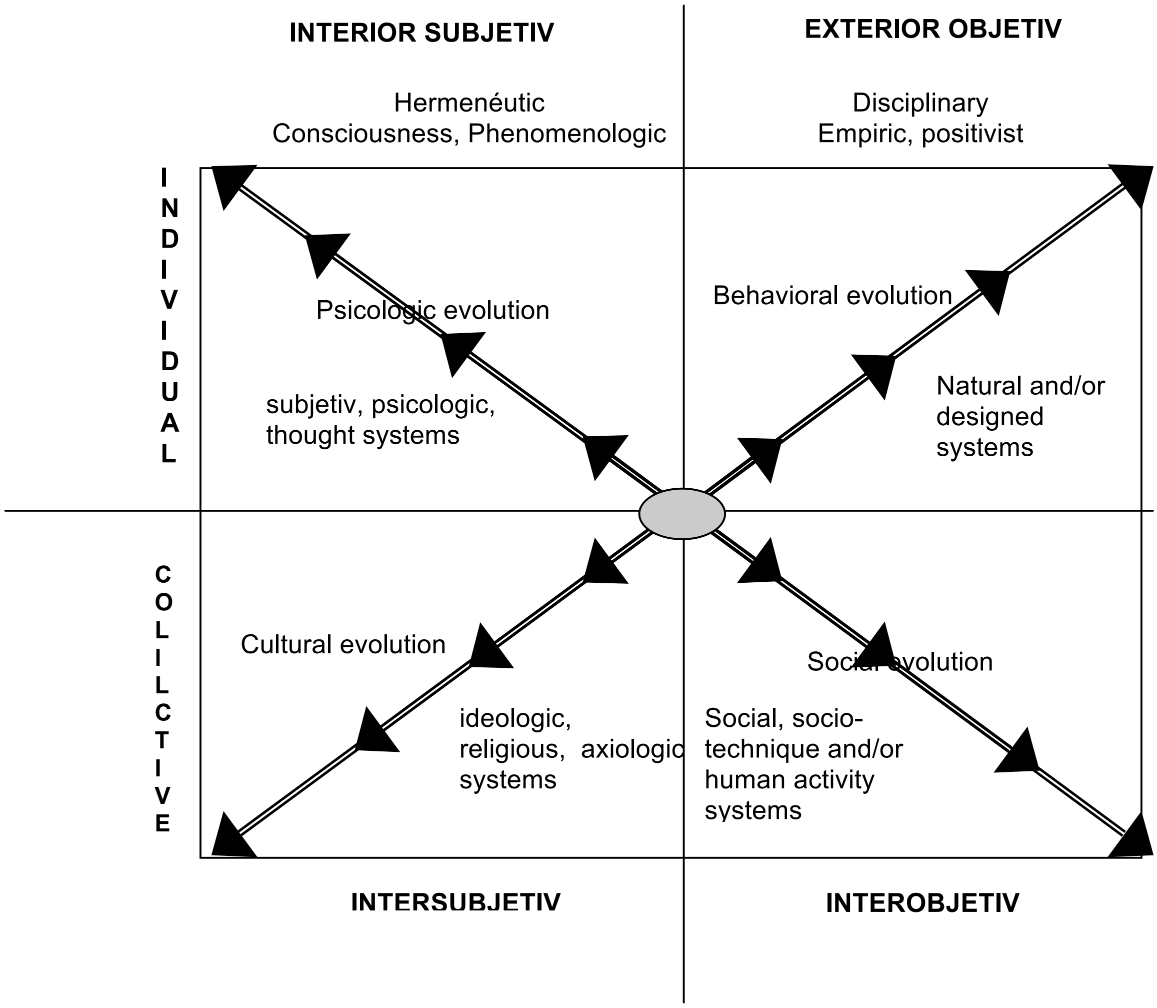


Figure 3 Domain of the systems science
Source: Adapted from Wilber (1997) and Kira et all (2008)

CONCEPTS OF THE SYSTEMS SCIENCE

The traditional sciences operate a long the continuum duality of form –matter postulated by the Greek civilization, more than 2000 years ago. The form includes ideas, concepts theories, assumptions, etc and the matter includes observations, experiments, facts and data.

The concepts represent abstractions formed by generalization of particular facts observed and experimented. For example "complexity is a concept which represents many observation of systems whose attributes of systemhood are nonlinear, involving multiple feedback loops, in spite that it structure, patter and processes are coherencies.

Constructs are new concepts created for specific porpoise inside a research work. Definitions are limited concept limited with other conceptual expressions. Definitions could be descriptive or operational.

The four concepts frequently used in applications of the Systems Science located in the Collective External domain (Systems of human activity): " Holarchy ", " emergency ", " communication " and " control " can be defined operationally starting from observations of the real systems of human activity; on the other hand the concepts of " synergy ", " Evolution " and Cybernetics of second level", alone they can be defined descriptively starting from the first ones. See Figure 4.

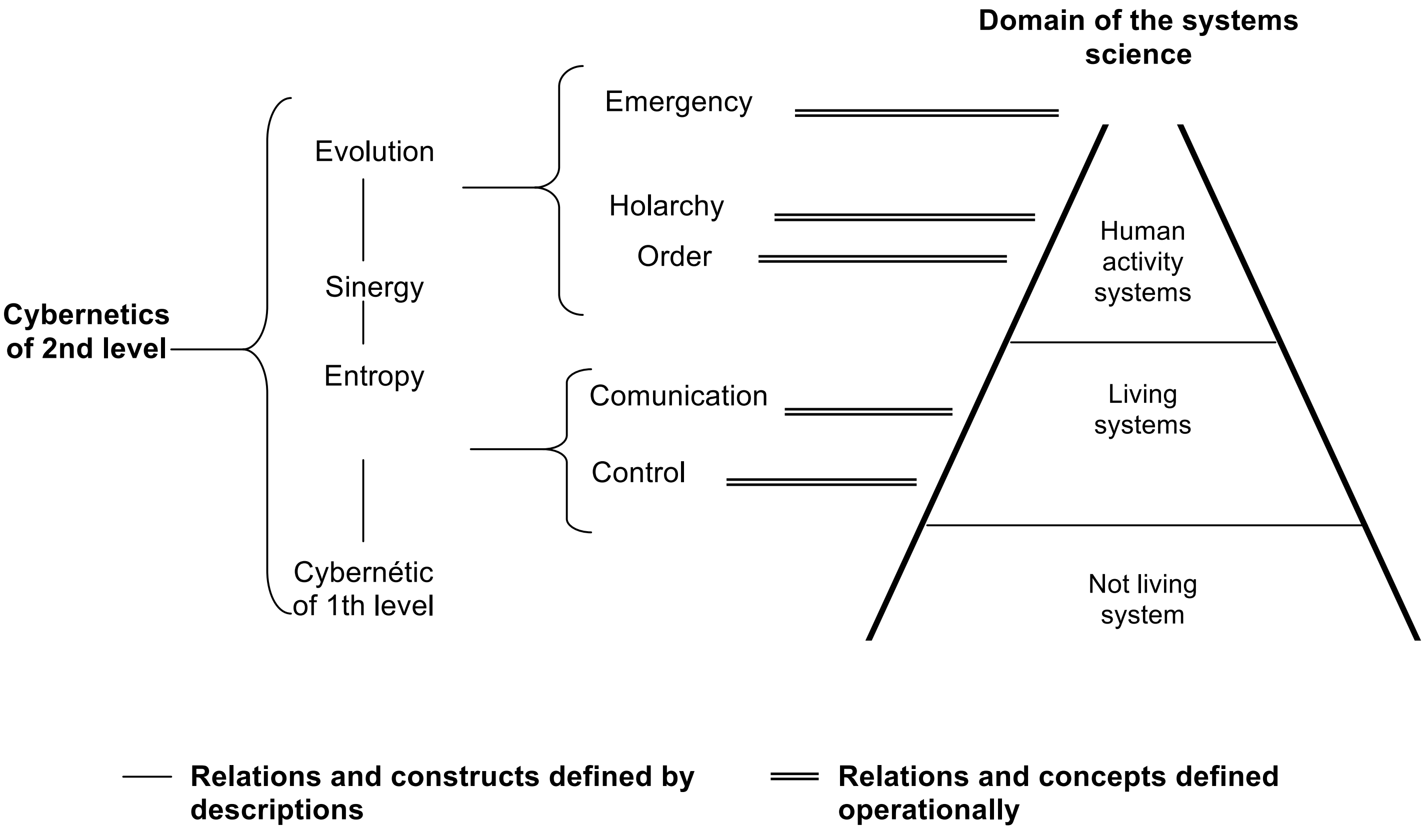


Figure 4. Constructs Concepts and definitions
Source: Adapted from Kerlinger (1973)

The encyclopedia of systems and cybernetics published by Charles Francoise (2004), gathers 3807 concepts of the Systems Science, defined descriptively.

L. Troncale (2008), and his collaborators of the university of Sonoma, have identified 102 concepts of the Systems Science, many of them defined operationally and interrelated forming one of the new theories of systems science. Dr. Troncale denominates these concepts “system processes” (SP) or patterns and the total interrelates of network system processes is called “the systems of systems processes (SoPS).

Peter Checkland (1991), recommends to form an epistemology of systems, gathering the different concepts of the Systems Science coherently in four levels. 1) Basic concepts, 2) Concepts of processes, 3) Concepts behavior and 4) perceived Concepts. See figure 5.

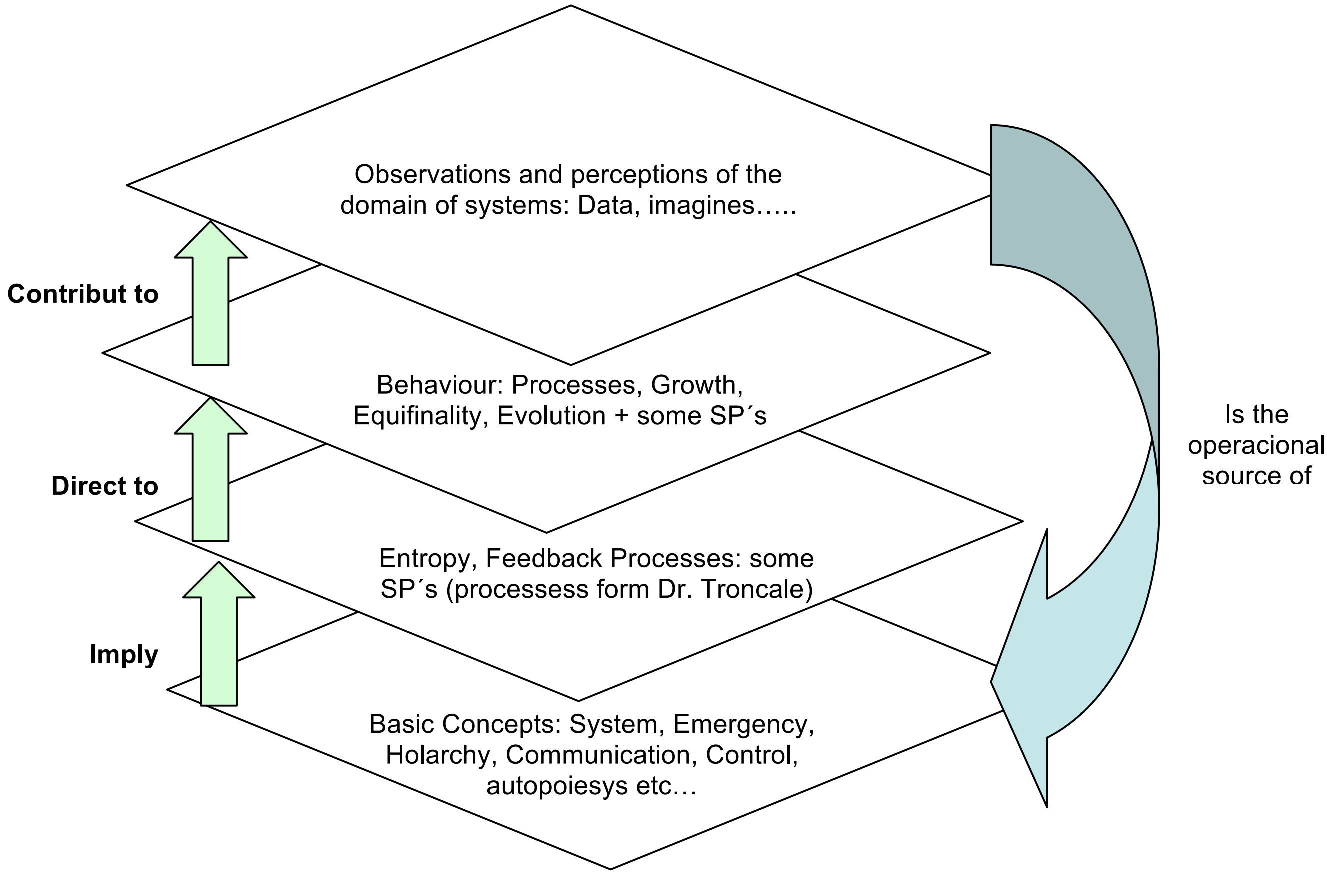


Figure 5 Coherent Epistemology of Systems Science Concepts
Source: Adapted from Checkkland (1991)

Same as other sciences, the Systems Science needs of certain language constituted by concepts and symbols that express the elements of the systemic speech, as well as the relationships that exist among concepts. This group of concepts and symbols constitute a notation or own language. The effectivity of an own language or notation is decisive since it represents an essential tool for the realization of the logical or qualitative operations that are made with more facility and less ambiguity that with the symbols and concepts of the ordinary language.

Actually, the Systems Science considers more than 3000 concepts described in the encyclopedia of systems (Francoise, 2004), many are interdisciplinary synonyms or "discinyms".

One of the most important concepts, settled down in the objectives of the ISSS is the search of interdisciplinary isomorphisms. The word isomorphism was not invented by the scientific sistemists. The mathematicians use it to describe formalisms and equations that maintain similar form through many levels and in many disciplines.

The existence of the same interetstion in many different levels implies that the systemic isomorphism is at the same time fundamental and real, maybe more fundamental and real than the components in the different scales of magnitude in which is manifested the isomorphic relationship. In this formulation the trans-systemic abstract isomorphic and the physical manifestations of the systems are equally real. The physical systems are in this way indeed, single different exchanges of the primary reality that are the "isomorfics". With this perception of the isomorphic concept an explicit overturn is giving, to Plato's idealism, just as it has happened in the theoretical physics (Francoise, 1992).

THEORIES OF THE SYSTEMS SCIENCE

A Theory is a system of concepts, definitions and propositions that presents a vision of a class of phenomena by means of specification of the relationships among the concepts, with the purpose of classifying, explain and/or to predict these phenomena.

This definition highlights three important aspects:

1. - A theory is a group of propositions consistent in interrelations of concepts (conceptual system).

2. - A theory establishes the interrelations among concepts forming a representation of the studied phenomenon.

3. - A theory explains the phenomena studied by means of the specification of which concepts are related with which other and how operate these relationships, allowing the possible prediction of a phenomenon or certain new concepts derived from others.

The true nature an power of a theory lies in its predictive and explanatory capacity.

Most of the theories of Systems Science are in the descriptive phase with mensurations of the nominal and sometimes ordinal level. Such are the cases of the theory of viable systems of S. Beer, the theory of organizational entropy, the theory of Ashby's law used to diagnose communication problems in the organizations. It is the well-known law of the requisite variety, which is expressed this way: "The variety of states of a system is controlled with a quantity of same or bigger variety that that of the system". When this law is used in the diagnose of the communications of a production system, it settles down as comparison pattern, that the variety of the management should be bigger or the same as the variety of the production system and the variety of the production system should be bigger or the same as the variety of the served market.

Theory of the Autopoiesis

This theory is about the dynamics of the living systems where the authors captured its invariable characteristic (auto-creativity) on which operates the "natural selection". The autopoietic system keeps its own organization made up of homeostatic processes, to maintain constant the structure, as long as the internal changes that take place are always subordinates to the conservation of the organization (Maturama and Varela en Briones, 2007).

Recent theory of systems: the system of systems of processes (SoSP)

One of the recent theories of the Systems Science is the one developed by the Dr. L. Troncale in the University of Sonoma in California. This theory is based on a fundamental conjecture called the **mutuality conjecture**, which settles down that “all the 102 concepts of the Systems Science, interact mutually or they manifest influences one with another as a system of subsystems". Several ways exist of containing the 102 concepts, a way is following the cycle of life of systems in general, another way is a directed graph or web in which the names of the isomorphies (systems processes) act as the nodes. The SoSP form a self-organising, sel-generating, mutually reinforcing set. See fig. 7.

The possible applications of the resulting theory of this linked system of systemic concepts are among others, the following ones:

To enrich the meaning of each main systemic concept.

To enrich the understanding of the origins of the corresponding phenomenon denoted by each concept.

To take conscience of the dynamics of the processes in the systems helps to discover other isomorphics.

To increase the predictive power of the general systemic models.

To provide a reference mark to evaluate the rigor and completion of the models and the simulations proposed for the systems under study.

To provide a precise and efficient tool to make more easy the teaching of the General Theory of Systems.

A formal theory of systems

Klir (2004), had proposed a formal theory for the Systems Science, defining a system like S = {T,R} where S,T,R denotes, respectively, a system, a group of objects, and a group of relationships defined on T. This definition allows to specify when a system is or it is not: an object is a system if and only it can describe himself with the previous formula, consequently the Systems Science is defined as that science which study objects (systems) defined by the mentioned formula.

The formula contains two basic properties of the systems: The concrete reality of the objects denominated **thinghood** and the property denoted by the relationships denominated **systemhood**. The Systems Science is guided basically to the study of the systemhood properties, that is to say the relationships among **attributes** of the objects that constitute the system more than to the objects.

The traditional sciences are guided predominantly to the study of the thinhood properties of the objects and the Systems Science is mainly guided to the systemhood properties.

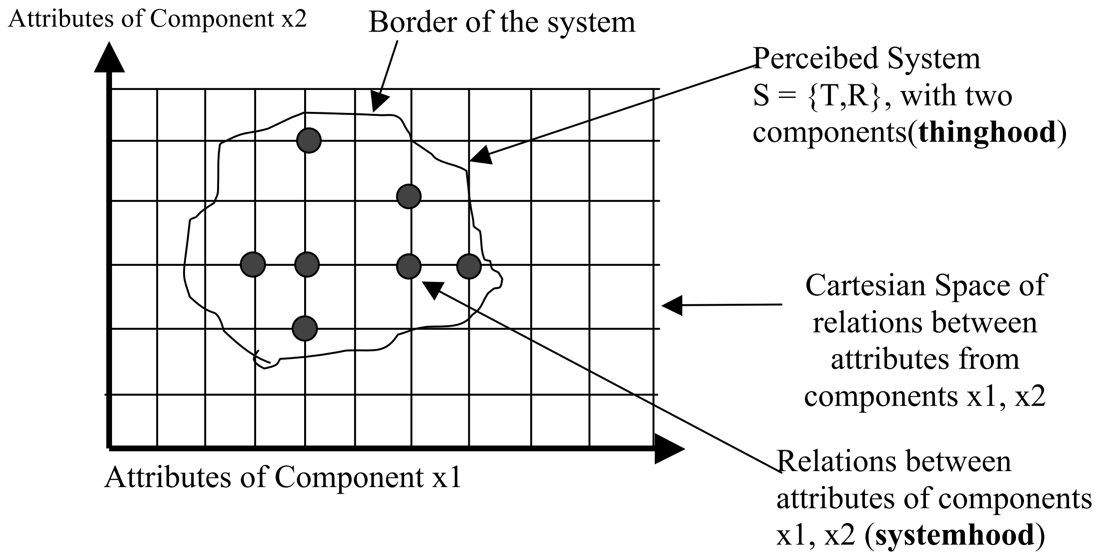


Figure 6 Graphic representation of a system with two components
Source: Adapted from Mesarovic (1962) and Klir (1991)

Bertalanffy (1967) suggested to represent a systems by mean of matrix of differential equations:

$$\frac{\delta Q_1}{\delta t} = f_1 (Q_1, Q_2, \ldots\ldots\ldots Q_n)$$

$$\frac{\delta Q_2}{\delta t} = f_2 (Q_1, Q_2, \ldots\ldots\ldots Q_n)$$

$$\vdots$$

$$\frac{\delta Q_n}{\delta t} = f_n (Q_1, Q_2, \ldots\ldots\ldots Q_n)$$

"Any change in some magnitude Qi is function of all the elements Q1 to Qn"

The formalization of the Systems Science has been the theoretical objective more looked for since its origins in the years 50, for the initiator of the General Theory of Systems L. Bertalanffy, continued by M. Mesarovic, R. Ashby, Rappoport and others.

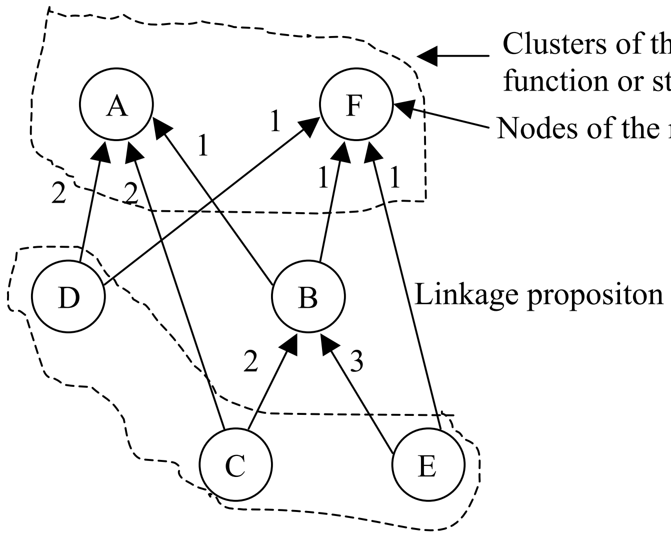
"Everything is related with everything" and " the Whole is greater than the sum of the parts"

To give a formal base to this Aristotelian principles Barabasi (2003) intends to use the theory of the graphs which has been applied to several nets composed by nodes and connections among nodes, for example the physical nets of internet, airports and airlines, highways and central of buses, friendships, epidemic, ideology, political, criminal sexual networks, etc. has been discovered nine different critical exponents associated to the exponential laws that emerge in the representation of the growth of the nets. The nets grow forming central axes of clusters, to this axes the new nodes unite giving probabilistic preference to the oldest nodes, this means that there are attributes in the concentration axes that makes them more attractive, such as the seniority, the wealth, the talent, the creativity etc.

Practically the graphs theory is used to represent the web of the System of System Procesess (SoSP) or net of interrelations that connect all the raw materials, assembles, and the finished products in the manufactory industries. The used equation is the following one:

$$Y = (I - A)X$$

Where:
Y = Vector of finished products; I = Identity matrix; A = Matrix of assembles;
X = Vector of raw matters, assembles, purchase parts and the finished products



Influence Matrix

	A	F	B	C	D	E
A						
F						
B	1	1				
C	2		2			
D	2	1				
E		1	3			

Figure 7. A directed network and its matrix

The same net can represent a simplified System of Systems Processes (SoSP) integrated by six isomorphies or System Processes (SP's): A, B, C, D, E, F connected by 8 Linkage Propositions (LP) each LP is a working hypothesis or a specific influence of one isomorphie on another, expressed in a language and logic, formulated from empirical natural science research.

METHODOLOGIES OF THE SYSTEMS SCIENCE.

In the Systems Science methodology doesn't mean treaty of the method or correct method that it is continued to obtain a result, but rather it means a creative approach to understand the phenomena of the reality.

The method directs the search toward knowledge by means of an exact procedure, for example the method simplex in lineal programming or the scientific method of the traditional sciences, while the methodology is based on the use of the trial, common sense, responsible principles, metaphors, interpretations, phenomenology, etc.… that serve of guide for the research.

Diverse systemic methodologies have been developed, most of qualitative type, in which it is fundamental to consider the interpretation of the data. Two of the authors that has deepened on the concept of interpretation of the reality are: Edmund Husserl (2005), by means of their phenomenology and Martin Heidergger in Gaos (1996) by means of the Hermeneutic methodology.

These authors apply the qualitative process of interpretation to the forms of knowledge and interpretation of the reality of ontological and epistemological type. The interpretation considers the cultural context and space of the phenomena that is studied as well as the consensual interpretation of diverse actors with theoretical and practical knowledge.

The phenomenology process is the base for construction of the phase 3 of the Soft system methodology by Checkland.

Very shortly the phenomenological methodology specifies the following stages:

1. - To approach (to settle down) the phenomenon inside a frame of pure evidence (real data).

2. - To take off (to give up) in the conscience all the pre-asuntions, interests, desires, about the phenomenon. This means that the given data should not be preexplained, because the preexplanation is in fact a reduction.

3, - The data given should not be preexplained so that the phenomenology is impartial and descriptive.

4. - To trace all the renunciation forms or indifference except the own ones.

5. – To trace all the correlations among the parts of the object of study.

6. - To carry out a dilucidatory analysis (what distinguishes to the phenomenon under study, fundamental, essential, necessarily. In this stage the author of this paper recommends to carry out the following autoquestions by the researcher sistemist.

Autoquestion	What the system does?	How the system does, what it does?
Fundamentally		
Essentially		
Necessarily		
Distinctively		

7. - To carry out a report of the previous analysis.

CONCLUSIONS

The global or total knowledge (Renaissance type) is impossible to day at the individual level. What is possible is to build collectively cohesively and as global as it is allowed, a system of knowledge, concepts, theories and methodologies by means of systemic tools as the sintegrity teams, agora, nominal groups, etc.

It is not convenient that the specialists become general sistemists, because they know perfectly the domain of the disciplines where they investigate or they work professionally. It is convenient that the Systems Science provides them a systemic transdisciplinar metalenguaje with which they can intercommunicate to solve complex problematic situations. The encyclopedia of systems with their content of 3807 concepts and systemic terms is in that address.

The thought of systems produces a mental and psychological reorientation in people that study it and they adopt it like a new form of explanation of the world and the paper that the human being carries out in that world.

The thought of systems promotes that the conscience notices of an implied order (as the one that Teilhard of Chardin proposes in its rehearsal on the evolution of the human phenomenon, as well as David Bohm in its theory of the implied order and explained. As much the evolution as the implied order can show in the concepts, theories and methodologies of the Systems Science.

In summary the Systems Science will help to the sustainability of the planet.

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