

# The Science of Complexity and Sustainable Futures

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**Abstract:** The overall performance of a society, i.e. its material and spiritual output in terms of quality, quantity and global competitiveness, is the result of an intricate process of interdependent and complex interactions among the individuals of that respective society, on one hand, and between that society and other societies, on the other hand. In either case, the elementary components that make up these interacting complex systems are complex systems themselves, and also in a continuous transformative evolution through permanently renewed self-definition and accumulation of history. This is a spectacular self-organizing process, notoriously difficult to observe, examine and understand with the standard and most widely spread paradigm.

## **Background, elements and importance of the new Paradigm of Complexity**

Such a "classical" paradigm is intrinsically related to, and limited by a linear approach that is still strongly tributary to reductionist thinking. For this reason, *sociology, politology*, as well as *all the economy-related sciences* are all in the same category and have the same major difficulties in defining Life, the Living/Alive Systems and their attributes or processes, being much closer related to Art than to Science according to the same "classic" definitions of these fields. Nowadays, **socio-economical restructuring**, the necessity to raise the **standard of living** and advancing/improving the human performance are, in general, topics extremely hotly debated and widely discussed. Nevertheless, in spite of this worldwide theoretical interest in advancing in these fields, little has been done practically. One of the main reasons for this inertia, despite the evident necessity for progress, is the lack of critical mass of people who, on one hand, are aware of the drastic conceptual limits of the "classic" paradigm and who, on the other hand, can understand, assimilate and operate coherently with the new knowledge resulting from the new Paradigm of Complexity, its set of rules and the corresponding consequences and results originating from its application.

Under the title of "**the new Paradigm of Complexity**", name that by itself generates confusion and misunderstandings, one can find grouped together a multitude of new models and theories which, unlike the "classic" sciences, are, in general, employing a **non-linear approach** in the study of the surrounding reality. This approach is based on

the following key principles and features that fundamentally define and/or characterize **complex systems**:

- A **complex system** cannot be analyzed as a whole by fragmenting it into parts. In other words, by definition, the complexity-related aspects of a system cannot be (fully or partially) observed by 'breaking' it into elements that are meaningful only within the framework of the analyzed system;
- A **complex system** has an *unpredictable evolution*, i.e. its analytic predictability can cover, at the most, a very short time interval in the nearest future, interval that is typically denominated as "the temporal horizon" for that respective phenomenon/system. In other words, a complex system can undergo any type of transformation, including extremely sudden and abrupt ones, even without any apparent external cause, and of any magnitude, i.e. at any scale of analysis. Therefore, as a direct consequence of this latter principle, when analyzed at different "zoom" scales, complex systems always exhibit different properties that obey seemingly different laws from the point of view of the "classical" approach and its definitions.
- A **complex system** is fundamentally different from a **complicated** system. One crucial difference is related exactly to the previously mentioned impossibility of formulating valid long-term and/or analytically-based predictions. In contrast with the popular belief, this impossibility is **NOT** due to the extremely large number of independent variables AND their interdependencies which are all affecting the system and its evolution (although this in itself would make the prediction much more difficult, too, for a system defined & studied "classically"). The cardinal point here is that the difference between **complex & complicated** systems and the resulting unpredictability of the former are intrinsically due to the sensitivity of **complex systems** to initial conditions, i.e. starting points that are dissimilar by only very small differences, will lead to extremely different evolutions and final end-points even for one and the same **complex system**. Furthermore, the **self-organization** effect of **complex systems** is also added to this sensitivity, making the entire picture even more intricate. **Self-organization**, by definition, is determined only by the elements of the **complex systems** and the interactions between among them, as a result of which organized structures, i.e. characterized and/or described by the so-called 'relationships of order', **spontaneously** appear by means of a *principally unpredictable* process;
- A complex **system** can be modeled and studied using an equivalent topological space, called '**the phase space**', in which specific notions can be defined, such as: **attractors and repulsors, attraction basins, trajectories, limit cycles, etc.** Within this context one can deal with, and develop a functional modeling, much more abstract and "untied" from any constraints typically imposed by the concrete 'anatomy' and 'physiology' of the real systems. Unlike the "classical" approach, in which one starts by approximating what is "seen", this functional modeling implies the identifying of an equivalent dynamic system whose behavior can be analyzed using specific methods with an extremely high degree of generality;
- A **complex system** has an evolution that does not result (and therefore cannot be deduced) from the simple analysis of, and/or the extrapolation from, the system's response to a given stimulus. In other words, the **dynamics** of a **complex system** and its **evolution** are two different problems, which require different and specific/dedicated solving approaches.

More disciplines have appeared and consolidated in the last 50 years, dedicated to the study and exploration of all the above listed principles and their practical consequences and applications, such as:

- **Fractal Geometry:** It studies shapes exhibiting either spatial or temporal irregularities, characterized by self-similarity and measurable with non-integer dimensions  $d_f$  ( $d_f \neq D$ , where  $D$  = the classical Euclidian dimension, typically expressed only by integer values like 1, 2, 3...N, and  $d_f$  = the fractal dimension which can be expressed even in non-integer values, such as  $7/12$ ,  $\sqrt{2}$ ,  $\ln 2$ ,  $\pi - 2$ , etc.). Fractal geometry enabled the specialists to highlight new properties as well as hitherto unknown definitory features and differences of the NATURAL objects that can clearly demarcate and/or identify them from the ARTIFACTS. Moreover, the fractal approach clearly outlined the importance of iterative and recursive processes as simple and efficient methods for generating complex structures using simple algorithms made up of few and/or simple generation and evolution rules. Such studies are not limited to dry academic discussions of esoteric flavor, but can and do have pragmatic applications in various domains, some of which are:
  - ⑩ **Telecommunications:** Fractal antennae, neural networks architectures and/or algorithms;
  - ⑩ **Biology & Medicine:** Quantitative tumor evaluation, studying morphogenesis processes, operative diagnosis and evaluation of health, advanced signal processing in EEG or EKG; advanced image processing in computerized tomography, understanding rythmology and evolutive cycles in chronic ailments (e.g. AIDS), etc.;
  - ⑩ **Economical Sciences:** Stability diagnosis and prediction at macroeconomic scale, analysis and diagnosis of some economical processes, fractal market analysis, etc.;
  - ⑩ **Sociology:** Investigation, modeling and evaluation of crisis phenomena, examination, prediction and influencing the re-orientation and adaptation of economic units towards the free market; etc.
- **The Chaos Theory:** It focuses on the dynamics of complex systems and introduces both a new investigational methodology and novel concepts, such as: **transition to chaos scenarios, chaotic resonance, strange attractors**, etc. The discovery of the two so-called "chaos constants" made by Feigenbaum is considered by many specialists as the greatest discovery of the Twentieth Century, equaled only by the discovery of Pi ( $\pi = 3.1415926\dots$ ) and  $e$  (the number discovered by Euler, equal with  $2.718281828\dots$ , and which is the base of the natural logarithm invented by Napier). Applications:
  - ⌘ **Telecommunications:** Noise-carrier based signal transmission, chaos-based encryption for data transmission, etc.
  - ⌘ **Biology & Medicine:** Non-traumatic resuscitation for cardiac arrest, resuscitation from comatose states, diagnosis of the cardiovascular and the central nervous systems, etc.;
  - ⌘ **Technology:** The stabilization of mechanical processes, the control of chaotic processes, etc.
- **Synergetics:** It examines the cooperative effects within/between systems made up of more quasi-identical subsystems and which may evolve far from thermodynamic equilibrium, manifesting global behaviors that cannot be identified, deduced or predicted from local analysis. *Cellular automata* are a very good illustrative example of a tool in this family, due to its extremely significant and relevant features:
  - ⑩ They are algorithms that can act as a starting point in generating and modeling self-organization processes;
  - ⑩ They contain **Artificial Intelligence** and can be used to further self-generate such **Artificial Intelligence** (the neural computer);
  - ⑩ They allow to model and even to generate **Artificial Life**. Most of the applications in this respect outlined the difficulty in discriminating between

Life/Alive and Non-living, defined methods and techniques of evaluating evolution and enabled to clearly define the concept of **complex systems** as already was described previously.

- **The Catastrophe Theory:** It investigates the critical states and their singularities by creating models for the analysis and understanding the phenomena that take place at the **threshold** demarcating the transition of a system from one state to another. The models offered by the catastrophe theory allow observing and highlighting the **analogies** between phenomena, systems or processes apparently without any clear relationship or other obvious connection or commonality between them. Such studies can be, and are applied for a large number of various natural systems, from those studied by exact sciences like physics and chemistry, to those studied by psychology and sociology. In either case, the models of the catastrophe theory approach from a different angle the problem(s) of finding common features and/or universal laws, thus providing an entirely fresh and original point of view for the important topic of finding and using analogies in the know-how build-up and transfer. Furthermore, they also emphasize the great importance of the so-called **control parameters**, i.e. constants that, in an equation, multiply variables representing well-known physical quantities like speed or energy, in the actual stability control of real (natural or artificial) systems.

**Other disciplines**, in which intense academic studies were carried out and from which -at the same time- innovative practical applications resulted, are:

- ① **Cognitive Science** unites an assembly of concepts and techniques derived from numerous various fields, like psychology, artificial intelligence, semantics and semiotics, and even heraldry and hermeneutics. This assembly is fused in an original but coherent system that is useful for comprehending the mechanisms involved in perception, in reasoning and establishing the notions fundamental for thinking, as well as in the states of being associated to/corresponding with diverse neuronal processes.
- ② **Computational Science** plays a special role as it offers the indispensable framework and the theoretical and modeling infrastructure that are both necessary and capable to either closely and systematically investigate difficult and complex physical-mathematical problems (e.g. solving sets of nonlinear differential equations characterizing complex systems), or offer a tangible and substantial 'space' –*the space of numeric data and approximations*– within which one can approach an inventive and complete study of all the aspects involved in the behavior of a **complex system (genesis, dynamics and evolution)**. In this context the **theory of cellular automata** and neural **processing** are considerably important and used by an extremely widely spread number of specialists.

From all the domains and sub-domains detailed above together with their broad range and great significance of their applications one can easily realize the tremendous significance and original novelty of the **Paradigm of Complexity**. It thus becomes clear, we hope, that this novel paradigm, due to the beneficial applications and implications of all its domains above introduced, can become a most suitable and appropriate functional tool. As such, we strongly advocate that it can be fruitfully applied in extremely numerous and diverse aspects of the activity of the modern men in general, and especially of the responsible and sentient ones who operate as decisionary factors in either economical or political spheres, governmental or private. Therefore, the **Paradigm of Complexity** is addressed particularly for such individuals, organizations or institutions that are mindful to the ever increasing pace of change in the modern society, while at the same time aware of the new contradictions of the modern life. One such fundamental contradiction takes place

between the already limited capabilities of the 'classical' approaches incapable of breaking off with their own limitations (resulted from their aged and unchanged viewpoint) and thus unable to provide solutions to many real-life problems, on one hand, and the continuously growing (in quantity as well as in the complexity) of the problems posed by the modern activities, on the other hand. Consequently, the **Paradigm of Complexity** and its components should address exactly this audience that also is constantly growing, as is proven by the increasing number of **intensive courses**, attended by larger numbers of participants from year to year, that we have been carrying out for more than 10 years. Such courses were intended either for a general popularization addressed to non-specialists and/or the general public unaware yet of the disciplines and applications of the fields in the new **Paradigm of Complexity**, or were dedicated for various specialists (e.g. physicists, sociologists, psychologists, biologists, etc.) in order to update their skills and professional know-how and to become capable to understand and better operate practically with complex systems. We must highlight that such courses were undertaken for such large categories of audiences and at comparable or higher quality only in very few select places in the world, namely in several most prestigious Universities, like **Princeton, Harvard, and Cambridge**.

**A mission for those who understand the unavoidable and inherent crisis induced by globalization: avoid or heal the ruptures induced by it through pro-active participation (or desire to do so) in setting up a new post-globalization society with a difference, namely the Knowledge-based Society.**

*The Future neither arrives, nor awaits: it must and ought to be built!*

*Alexandru Caragea*

Few people clearly see and realize that an enormous gap has been created, and is relentlessly widening, between the quasi-exponentially increasingly wider spread and availability of infrastructural components (e.g. IT hardware and software) on one hand, and the degree of their understanding, assimilation and -therefore- their ultimately efficient and wise usage, on the other hand. This recent problem of our contemporary society is rapidly proliferating, not only in its purely 'technical' aspect related to the lack of access to such technologies by certain categories of people or nations (the so-called "digital division", and quite mediatized). It also encompasses other extremely important and influential aspects related to the interfaces and relationships between **individuals, society and economy**, relationships both within each category and between any of these large categories.

Consequently, for one to survive and develop even further into becoming a competitive force capable of success under such new harsh and constantly changing circumstances, we strongly believe that it is imperatively necessary to generalize and pro-actively apply the following measures, on a scale and at a magnitude as large as possible:

- **Generate a new interactive Mass Media Environment:** It would allow achieving two fundamental and vital goals. First, it should be capable to diffuse the "products of the third culture" on a large scale by reaching a wide audience. Secondly, its interactivity would enable its constant re-shaping into new forms, elements and formats, according to the feedback, interests and talents of the participants themselves. Technically, such a solution can be accomplished by shaping it according to the well-known Internet model, and also additionally completing and complementing the Internet-based part by integrating it together with Radio, TV and WAP;
- **A thorough restructuring of the Educational System** so that its 'classic' fundamentals would be not only changed and improved but also expanded by including new elements, such as *Continuous Teaching/Learning*, **Nonformal and Informal Teaching/Learning**, **On-line/Remote Teaching/Learning** and **Self-**

**Learning.** This would make the re-structured Educational System to encompass, include and use the modern facilities that are presently available and at the same time prepare alumni who can easily grasp and adapt to the Shock of the Novelty and therefore function at their full human potential in (any) modern society. Moreover, besides these structural changes, the highest priority and attention will also be given to the seeding and development of the "soft" skills, such as:

- **Improving communications at interhuman and human-to-Technology levels**, according to the new developments and the last novelties in the field of telecommunications and IT; and at last, but not in the least,
- **Changing the mentality** at individual and society levels, both in governmental and private spheres, in order to establish an effective and lucrative Public-to-Private Initiative Partnership. The main target of this Partnership would be **the development of the Human Being as well as improving the standard of life. Engaging in the struggle to achieve and implement both these aims is vital as both these aims can actively contribute not only to the evolution of the Humankind in general, but -even more importantly- would specifically enable the survival of the National Entity in a world that is in an accelerated globalization. This would preserve national specific features, with direct consequences on creativity and inter-economical and/or inter-cultural creation of new outcomes, thus contributing directly towards the betterment of the quality of life and ensuring stable socio-economical growth.**

#### **A solution for survival: The Public-to-Private Initiative Partnership**

**It is imperatively obvious that the role of the State must change in this new context.** To be European or inhabitant of the Earth as member of the Humankind should not mean only having this feeling but also remembering one's own actual cultural dimension, without aberrantly distorting the innate abilities, typical to each Nation, that have been refined and transmitted from generation to generation along the history. Therefore, for a society/Nation to actively participate in a New World united under a new economical order it should have the capability to produce competitively, according to internationally recognized high-quality standards. This, on its turn, implies that, in that society, the following notions have already been diffused, understood, adopted/assimilated and practically applied at all levels:

- Professional competence;
- **Adaptability** to new conditions and requirements;
- Tolerance, understanding and even receptivity of (hitherto unknown) elements of thinking/mentality of foreign origin;
- Capability of integrating and working in multi-national teams (which is inherently linked with the previous feature);
- Setting up an appropriate educational system (as highlighted in the previous section) to continuously create **new skills and abilities.**
- Generating new meanings for topics that, before the Globalization Era, were crucial in preserving the National Identity, both at physical level (border defense) and spiritual-cultural level, but which may become obsolete or totally reconfigured in the new circumstances. With the dissolution of borders and the unrestricted flow of goods, defining and applying such notions that set apart the National from the International should thus be charged with new significances. At the same time, undertaking actual actions, like protecting one's own citizens, become more difficult to define and much more subtle to interpret. A new contradiction also appears between the requirement of an increased permeability and openness towards the External elements (the

Globalization pressure) and the more imperious necessity to guard and protect strategically important information, data and skills. Thus, defending vital socio-economical know-how becomes a complex problem as one has to connect and transmit necessary collaboration data and information to his partners, but nothing more. Defending all these new re-defined borders and skills that are much more difficult to define and evaluate cannot be done without a population who is **aware, conscientious, educated, and able** to understand both the **tangible** and the **abstract**. However, it should be obvious that such a population does not appear spontaneously but has to be actively prepared, educated, **cultivated** in order not only to understand the massive and crucial transformations that are required and which objectively have to be realized, but also to participate **creatively** and **innovatively** in this transformation process. Seen from this new perspective, the role and the responsibility of the State is not diminished, but on the contrary, it actually tremendously increases in order to support and encourage the modernization process of the educational system and its re-shaping in a **modern platform of continuous and interactive education**.

Referring again to the role that should be played by **companies and corporations and the business sphere in general**, we must outline clearly that their mission and participation in this new process for the development of the Human Being is not a charity or sponsorship, but a coherent activity carried out for their own interests, namely cultivating the socio-economical and professional skills that would allow them to survive and be successful in the market! To be at the "top of the pyramid" means to constantly modernize oneself, to find out and assimilate the latest cutting-edge equipments and technologies, and to permanently re-shape the mentality and view-points of your staff. All these can be properly achieved only by employing adequately educated and skilled personnel, **which is increasingly difficult to find**. An innovative company is valued in direct relationship with the value of its employees, and from this viewpoint no top management team or small-business entrepreneur can afford to wait the arrival of the "most suitable specialist" but rather to identify the "suitable seed" which can be cultivated, nurtured and grown into fruition! Furthermore, the success in the market is ultimately conditioned by the company product's capacity to satisfy a need, capacity that itself is conditioned by the buyer's own cultural, social and economical understanding and needs (and, therefore, dependent on the buyer's educational and professional level, too).

**Consequently, the "diffusion rate" of the knowledge/know-how within a Nation drastically and most significantly influences its own development and evolution. This may seem a rather trivial and evident assertion, but which can and does have dramatic consequences when it is ignored, particularly under the present circumstances brought by the globalization process. The result can be the transition from People to Population, with all the socio-economical consequences derived from such a conversion. This is an acute problem that confronts the contemporary Civil Society, the economical structures and all levels of entrepreneurial management, as well as the governmental divisionary factors and whose finding an efficient and reliable long-term solution to this problem is essential for the well-being of the next generations.**

Such a change may not be easy to accomplish but we hope that its necessity is outstandingly clear. Moreover, there already are terms of comparison in other parts of the world: countries like South Korea, Taiwan and Singapore have clearly demonstrated that massive and substantial changes throughout the entire socio-economical structure are possible and in their cases such changes were indeed achieved in an astonishingly short period: their leap from Third-World to First-World status has been carried out in about 50 years, i.e. in almost one generation! This demonstrated that success in endeavors like that

suggested in this report is critically based on some key aspects that were practiced and displayed by these Nations: clarity of vision, decisiveness and focus in action, extreme discipline and tremendous hard work for the entire population, easy control of all the key factors of influence in the areas under attention, heavy and constant governmental engagement and support at all levels, minimizing and simplifying bureaucracy and eliminating corruption, attracting foreign investments and actively promoting an entrepreneurial attitude for their own citizens, etc.

Nevertheless, their experience has its own shortcomings and typical features, such as:

- Very little (if any) regard towards environmental and ecological aspects;
- Little or no attention for the Human Rights as their progress was essentially imposed by an 'enlightened' but dictatorial or -at the best- mono-party authoritative strong-handed 'elite';
- Vital dependency on foreign markets (especially the Japanese and the American ones) and -at the same time- on a constant source of cheap and obedient labour force working in a totally unregulated environment;
- Their progress is most visible only in material and economical terms and they had some success into other modern areas like IT technology, its usage and spreading. However, it is most importantly to highlight that their metamorphosis had only little impact on "soft skills", and was without any relevance into the other cardinal areas that are essential components of the proposed **New Paradigm** change: mentality shift, education reorganization, adapting new view-points and new approaches in scientific, economic and social spheres, etc., etc.

Seen from this perspective, the **Partnership Public-to-Private Initiative** can also be considered as a "flower bed" in which the seeds of the Knowledge-based Society should be cultivated and patiently, with effort, time, money and dedication they would finally germinate into a **survival solution** for the entire mankind, based on the **respect of the individuals to one another and of all towards the Nature**. In this complex process of metamorphosis induced by globalization, Romania can initiate a novel package of programs meant to lead towards the aforementioned solution and, thus, to the **discovery & implementation of Peace as a state of Being** resulted intrinsically from the profound reconciliation between **Spirit and Matter, and from the synergic integration of the two approaches inherent to the Man: Contemplation and Action**.

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