PART 1

Sustainability: Toward the Unification of Some Underlying Principles and Mechanisms

Self-organization and unification of the principles Unification is crystallization: bi-terminated Herkimer diamond (Mineralogy – ParisTech)

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Toward a Sustainability Science

The concepts of sustainability have experienced much success for several decades and they are quoted in many projects and programs conducted by public institutions, corporations and academies worldwide.

1.1. Introduction

Now, we can discuss the emergence of a "science of sustainability". A science of sustainability requires the involvement of many people geographically spread all around the world in many collaboration fields to bridge the existing gap between theory, practice and policy. For the same reasons, this science needs for skills coming from various disciplines such as social, biological, life, physical, theoretical and applied sciences to answer a lot of fundamental questions.

Here, it is interesting to show the graph issued by E. Bettencourt *et al.* [BET 11], which gives a highlight of the sources of proceedings related to sustainability science.

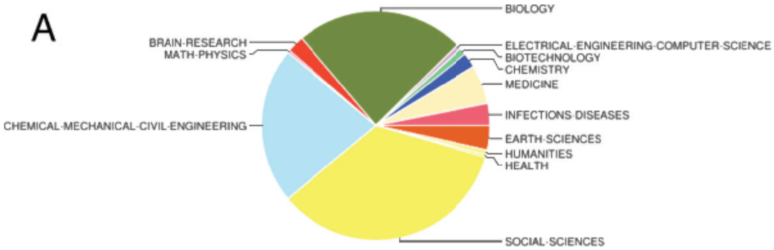

Figure 1.1. *Developments and literature in sustainability sciences [BET 11]*

In Figure 1.1, we can see that the largest contributions come from the social sciences, from biology and chemical, mechanical and civil engineering, and then medicine, etc.

This pattern conveys the universality of the concerns related to sustainability in so many activity sectors. But, what is most important is knowing whether they are subject to the same underlying mechanisms: this is a key question. Indeed, since many transdisciplinary people and skills are involved in sustainability, this is because the same theories and basic principles could apply everywhere for the same and global goal. This is also because traditional susceptibilities, in each field of application, are unable to fully describe the causes and sources, that is to say the foundations themselves of the sustainability.

What we try to show, in this book, are the basic principles and rules existing behind sustainability, listing some of their properties, in order to better understand their entanglement and to propose a cohesive and consistent view.

It is this kind of conceptual and technical unification that we have tried to develop.

1.2. What does unification mean?

Sustainability is the result of an emergence: it is suitable for any system or ecosystem resulting from the combination of many factors and fundamental concepts. It is a representation of the world, according to Aristotle. It applies to all the mechanisms and ultimate constituents of nature, whatever the level of complexification (microlevel subject to quantum physics, up to meso- and macrolevel of assembly).

In terms of processes, the system is characterized by the implementation of organized agents into an interconnected structure, which individually perform functions on, or interactions with, other agents, according to a given mode, in order to accomplish a given objective. The intrinsic activities of such multi-agents system and their external activities, as well, enable the transformation, production or manufacturing of some resources and raw materials: they form what we call a process and are governed by a set of rules, forces and procedures, etc.

Regarding forces, in nature, we refer to the four fundamental forces to explain all the well-known types of interactions:

– the first (discovered by Newton in the 17th Century) is the force of gravity, which is the cause of gravity;

– the second, because it ensures the cohesion of atoms making up the molecules of our bodies, and everything around us, is the electromagnetic force (achieved by Maxwell in the 19th Century, the unification of electricity and magnetism);

– finally, the two nuclear forces: the weak force (responsible for radioactivity and cohesion of an atom) and strong (which binds together the elementary particles: protons and neutrons in the nucleus of atoms, associated with the considerable energy that is released during nuclear reactions).

The "theory of everything" means a physical theory capable of describing, in a coherent and unified way, all the fundamental interactions we may have in the physical system. The unification of the theories is both a synthesis, an aggregation and a simplification of many concepts which require a lot of inductive and abductive reasoning. Again, why engage many factors, mechanisms and theories, apparently independent from each other and heterogeneous, as being from different fields and theories?

Since the first moments of the universe, these factors were not perhaps precisely so diverse and of different nature as understood. We have to keep in mind that the very structure of the universe comprises small agents subject to quantum physics. Also, the upper assembly of these agents is based on fractal growths, thus quite consistent and harmonious properties will emerge. It is the same with all the concepts and designs that have emerged from the mind and conscience of human beings.

As mentioned before, everything emerges from basic and common information. Then, at some specific scale levels and at a particular time, the flow of material, energy, data, resources and products, as well as the nature and intensity of interactions, become indistinguishable as they behave in similar ways. Moreover, despite some cyclic phenomena (knowing that many scientists assure that the climate is now changing and that warming over past century is primarily due to human-induced emissions of heat-trapping gases), we are faced with a global expansion and cooling of the universe, that is to say, its slowing-down process. Which leads to a progressive stabilization and to the decoupling of some elements, by distinguishing cosmological from individual forces, and makes the elements appear with different and specific properties. Similarly, the Earth's mass and volume is evolving. Therefore, some gravitational, local, or geophysical constants that appear will vary overtime. Under these conditions, even global sustainability is a dynamic concept subject to relativity.

In practical terms, to summarize a piece of the unification path, we may address part of the story in physics. It is a step-by-step process. Within this context, the electromagnetic force and weak nuclear force were consolidated into the so-called electroweak force (the 1979 Nobel Prize in Physics was awarded jointly to Sheldon Lee Glashow, Abdus Salam and Steven Weinberg for "*their contributions to the theory of the unified weak and electromagnetic interaction between elementary particles, including, inter alia, the prediction of the weak neutral current*"). The integration of the weak and strong nuclear forces went later, but was not, at that time, confirmed by strong evidence. Similarly, sustainability can be associated with "anticipation".

In this book, the purpose of unification is to get a consistent and simplified view of reality. It is, therefore, intended to replace several complementary representation models, with one more global model. This helps us to identify properties that would be impossible to emerge and describe from a single model, with a partial view of the system. This is what we do in economics or industry when replacing the representation of a production system, usually performed with discrete event modeling, with a more comprehensive model incorporating the nonlinear dynamics specific to the system considered.

We know that the grand unification objective is to embrace both the framework for nuclear and electromagnetic forces (special relativity with quantum physics) and the gravity (general relativity). It is still very speculative, but it makes sense to try having a single representation of the reality rather than constantly referring to several theories.

1.3. Coming back to sustainability: how many "sustainabilities"?

Since we are discussing unification, is it the same approach we have to implement for sustainability? Undoubtedly, the fact of unifying theories and integrating sets of agents, or things involved in a system, improves its consistency, so its sustainability. This systemic approach, however, is not always naturally embraced by the proponents of sustainability: thus, it follows some deviances. This is why, when some responsible people are talking about sustainability, it is advisable to determine if we are considering a kind of either "wrong sustainability", "convenient sustainability" or "good sustainability".

To illustrate this, we will describe how the problem of sustainability is addressed by many officials. In the following, we can see a general graph showing the three spheres of "sustainability". This pedagogical graph is agreed on by most: it focuses on activity sectors on which we have to act. Now, what can we observe?

1) *The "wrong sustainability"*. For ideological or ecological reasons, it is common to address sustainability in terms of the environment, as a priority. Progresses, in this area, should be implemented, according to them, to the detriment of economic imperatives and financial constraints. Likewise, they ignore some major societal needs: of course, we take into account safety and resources security needs or those related to the health. But, we forget to think about what is happening on other continents: a billion people are starving. How do we provide food and jobs to 9 billion people and give them access to a little comfort as in developed countries?

2) *The "convenient sustainability"*. Here, in this context, we broaden the concerns of the tenors of sustainability: the goal is to globalize the problem. It is, therefore, a more reasoned and less selfish approach: it consists of giving priority to issues related to the environmental protection, to incorporate the overall objectives at the global level (despite the imbalances between activity sectors or countries) and to perform savings (for instance, energy consumption), to limit the effects and consequences of wastes and mismanagement. Quite often, some focus is brought on agricultural or industrial abusive practices, or even deviances related to human being consumptions.

Similarly, governments are thinking for us: our society needs are defined by those who are governing. They are sometimes ignorant of the in-depth social, economic or social needs, sometimes they are influenced by political choices: consequently, our requirements and behaviors are dictated by laws, etc. Do you agree with the needs, as specified in the "social" part of the following graph? This graph is published by [CFT 10].

People, in our new world, are disempowered. Society is supposed to bring us solutions and social services through taxes and duties levied in the economy at the expense of growth, employment and wealth creation. The approach does not work for all. The pattern is unbalanced, and profits will not benefit everyone. In the future, ideology will turn into business, not for the benefit of the overall economy or society, but only for the benefit of some ones.

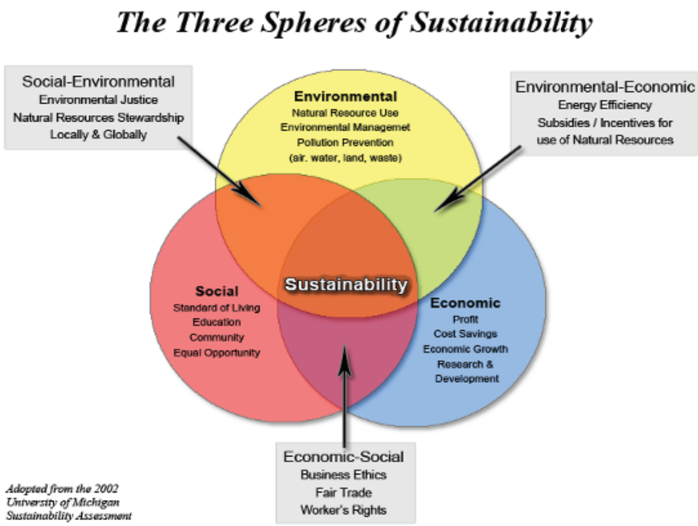

Figure 1.2. *Sustainability components [CFT 10]*

3) *The "good sustainability*". Here, it is necessary to rethink the above model: when analyzing the content of social networking, some weird information could emerge from the many exchanges and buzzs.

If theorists and think tanks could issue such a graph, in the past, now we could say that they are now subject to the influence of social networks. They are progressively embedded within an inclusive society: decision makers (i.e. leaders or rulers) are not alone, and must integrate the needs, beliefs, intents and requirements expressed by human actors or individuals directly involved in the process. The feeling about sustainability is evolving. For an individual, interested in the economy, it is not only the revenue of the net income which is of most importance (in addition, this parameter will generate jealousy), but also job satisfaction, performance of the enterprise, the development of which he/she contributes to. In a constrained context, wasting creates dissatisfaction, unnecessary expenses, greed and corruption are not well perceived.

About the social level, an individual seeks happiness: he/she must feel good, happy, etc. Motivation cannot be decreed: we are no longer living in a time where you have to keep your mouth shut: you have to feel good, want to excel and have fun at work in order to bring some achievements to the general interest.

In terms of environment, what must be emphasized is: what level of energy can we consume? Which debts, reserves in resources, assets and knowledge will we leave to the next generation?

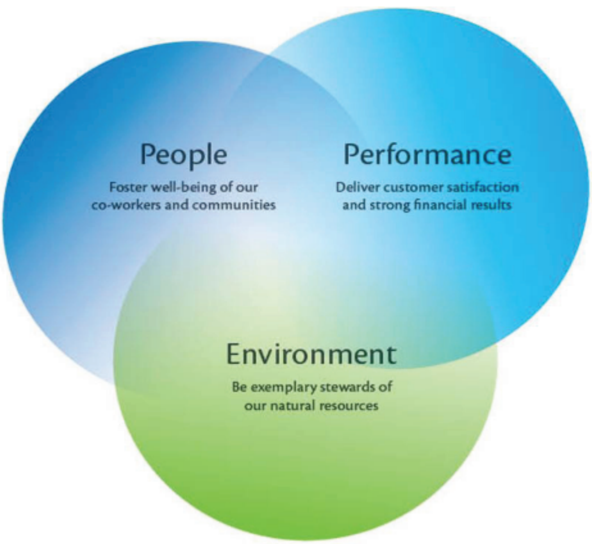

Figure 1.3. *Commitments to sustainability [NHS 14]*

As we can see, this perception of sustainability is quite different, but complementary. Just considering the first graph is not sufficient enough to get a sustainable approach. Merging the two graphs, that is to say, implementing the unification of both is a necessary step to get a “good sustainability”.

What has been done?

– we replaced the notion of economics with the one related to performance/competitivity;

– we replaced the notion of social goals with the inspiration and desires of people;

– we replaced, regarding the environment, the notion of resources/energy management with the desire to save nature and leave a heritage.

In summary, the unification must cover, in a complete way, all the interconnected parts of the graph. Moreover, instead of providing a greed underpinning graph for the sustainability, we extend this paradigm to cover a more human-centered and inclusive approach.

1.4. Sustainability: what kind of unification? An integration issue?

Many underlying mechanisms have been described and detailed to explain how to improve our efforts in the field of systems sustainability. Many comparisons were made, similarities highlighted, parallels and conclusions drawn and transposed in other areas of our business, environment and theories being developed in various fields.

Thus, we now have some technologies available to better address the problem of sustainability, whatever the situations encountered. However, when we look at how the concepts of “sustainability” are discussed around us, although there are interesting results through experiments, we may have sometimes some disappointment: it begs the question of why we have so many different or inconsistent approaches. Indeed, integration of concepts and parameters is different according to the subject matter under study, the technological approach, etc. There is no universal model; consequently, it becomes sometimes difficult to convince people, to adapt or change a strategy or tactics and to reach a consensus.

Is it due to a problem of skill? Ignorance? Or greed? A problem of standard and specification? Also, how can we measure the sustainability of a system? At first glance, what we can say is that there is a problem of "dimension": as soon the multidimensionality of a concept is defined, we are always able to determine the parameters and variables to be considered, and then the models, standards and specifications of the system under study.

To be limited to simple concepts, we recall hereafter that physical systems are modeled in the four-dimensional space-time hyperplane:

– *Regarding spatial coordinates.* Everyone knows that our physical environment is perceived in three dimensions (X, Y and Z). The problem encountered is that we are living in the mesoscopic level domain: thus, we simply ignore the constituents depending on the nanoscopic or macroscopic levels, to which we are interconnected. Usually, on our action and decision field, we voluntarily reduce the space of analysis and study (e.g. nonlinear dimensionality reduction by Local Linear embedding (LLE). Thus, this deprives us of contributions and influences, or interactions, leading to other areas. More importantly, we will just not be able to develop consistent solutions (as they are partial, incomplete, contradictory or multiple). As often suggested, the answer to this deficiency, is to implement a "global" or holistic approach, which is relevant to different multivariate system analysis and ways of thinking, provided that the K-connectivity is acceptable.

– *Regarding the "Time" coordinate.* The variable "Time" has the same logic. Very often, we develop solutions from snapshots or statistical images. Again, the border area of our temporal vision is not prominent: some "sources" of a phenomenon or event are masked, so our understanding of the situation is restricted and incomplete. We have a reduced vision of the system since we are limited by its *convex hull*: here, a hyperplane can be defined by a set of "N" variables; each state of the system is represented by a point including N coordinates, in this hyperplane. The convex hull is the minimal geometric set (deflating like a hyperplane balloon) which contains all the status points of the system. The resulting problem is the same as described previously.

Similarly, our horizon of action, in the future, will not exceed the tip of our nose, because of the lack of a holistic vision and our poor foresight regarding the effect of a decision or solutions.

1.5. What kind of paradigm do we have to integrate?

In the previous sections, existing dimensions commonly used in conventional physics were highlighted. Now, the question is whether or not we forgot some others. Also, the question is to know what kind of underlying principles and theories we have to integrate.

Within this context, it is important to remember that our evolution, as for scientific advances, adaptation of civilizations or changes in our society, must follow some "codes" (some would call them: "laws") to be "sustainable". In this work, it was argued that any sustainable development, whatever the relevant fields and their complexity, was depending on the following "universal codes":

– the code of matter (from the infinitely small to the infinitely large) including growth, gravitational problems and those of quantum physics;

– the code of life (with the world of biology and living systems) and considerations related to biology, genes coding, power laws, etc.;

– the code of thought and knowledge (which includes the concepts of information and knowledge processing, with our so complex and varied brain) which covers our ability to reason and the power of our consciousness;

– the code of energy (including the issues of thermodynamics, information coding, entropy, etc.);

– the code of complexity (new structural geometries, network theory, etc.) to handle the nonlinear dynamic approaches, predictability under uncertainty, chaos, fractals structures, etc.

At first glance, some might say that everything, in each or between the codes, is separate and independent. Others will say: what is the link between a code and sustainability? Finally, for convenience reasons, because of politics or ignorance, we will have to consider only certain limited aspects of these codes, during the sustainability improvement process.

In fact, as has been often mentioned, everything is based on the determination of a good balance which implies ambivalence and complementarity:

1) At the microscopic level, quantum physics applies to each elementary particle. One main principle of superposition states applies: how? Our surrounding world can be in any configuration, any possible arrangement of particles or fields. If the world, however, can be in another configuration, then it can also be in a state which is a superposition of the two, where the amount of each configuration that is in the superposition is specified by a complex number. This is what happens for instance at an upper level of assembly, like macroscopic life: the behavior of a living being always results from the combination of two superposed opposite or antagonistic states (also called an ambivalence).

2) In nature, everything is based on ambivalences and asymmetries (as part of the nonlinear dynamic systems). For example, if we focus on codes of life, it is normal sometimes to get a behavior based on selfishness, and sometimes on altruism; similarly, the level of our thought is the result of a proportionate blend of rationality, absurdity or emotionality, etc. Depending on the circumstances, it will have to amplify, or mitigate, a given mix of properties to get a particular form of ambivalence. This shows that, in terms of system control, nonlinear type "power", exponential or sigmoidal functions will be activated to quickly react to an unexpected event.

3) Nature is a whole: when a phenomenon occurs that is not due to a single cause, but a coincidence of several factors or causes. The emergence of a variety of species is never due to a single domain of actions and controls, but many: so, the fact to consider several "codes" in the emergence of a phenomenon is a wise decision. We will also notice that these apparently very different codes are often interdependent. So, there is a complementarity that cannot be overlooked.

All these above codes and ambivalences, taken together, lead to new theories (or sciences), hence making new paradigms emerge: in fact, it is natural to say that in any approach to "sustainability" (as described in the book), nature itself being a "sustainable" system, its only own objective is also its own evolution, the most harmonious and most elaborated possible to achieve an ultimate or supreme "information level". In organization theory, it is said that it all starts with organization and everything ends up in organization. Similarly, in nature (the universe), everything starts with information and everything ends up with information.

Just like is done in physics, in social sciences or even still in life sciences, the question is not how we will switch from one theory to another, when they are complementary, but how we will integrate them all together: it is really a problem of unification that we face. Indeed, it is important to note that we cannot ignore a particular code because every underlying principle is interdependent; either within a given code, or between different families of codes. Behind an apparent clustering, there is a large and universal consistency. We cannot consider only one cause or underpinning mechanism as a cause of an event without mentioning another.

This is true everywhere:

– in industry, operation research: a solution often requires the combination of several mechanisms (e.g. conventional optimization and genetic algos);

– in medicine: some diseases are often caused by the combination of several active genes;

– in cooking: the global flavor of a dish, the taste of a wine, is the result of several actions in chemistry, physics and biology fields.

We cannot build a new theory or a strategy only based on one or two codes: ignoring this means we are probably "simplistic" so incomplete, inconsistent and inharmonious.

In this chapter, our effort is focused on how to generalize a kind of theory of "sustainability", and then to suggest a unification of all theories and "codes" that could interest us, within the context of system sustainability. As a result, such unification of underpinning principles requires us to introduce new dimensions, not in terms of factors or fields to be considered (as seen in many documents) but in terms of measurement parameters and variables (which are able to generalize a concept) in order to model and control satisfactorily a sustainable system.

1.6. The issue and the implementation of a new dimension

1.6.1. *Preamble: code of matter, power of laws and balance of powers*

Let us start with an example: we are living in a mesoscopic world where space-time is a four-dimensional hyperplane. This is true for the physical matter, but it is also related to all of our human activities. For example:

– in industry, like in logistics, usages of electromagnetic or gravitational forces are well known. Their effects decrease as the inverse of the squared distance between a given measuring point and the origin of the source;

– in communications or telecommunications, it is the same regarding either the mitigation of the voice, the significance or virtual scope of a message, or a signal strength. This is why we are forced to use relays (human relay operator), automatic repeaters, or amplifiers in optronics, etc;

– in the area of governance, we know sayings like "out of sight, out of mind", or even "when the cat is away, the mice will play". It is just a problem of influence and control (as for gravitation): that is the reason why we need specialized human agents responsible for rebroadcasting and amplifying orders, operative sets or programs, concepts, rules or laws (as biology does via the DNA and RNA), to ensure that they have been "relayed' in a safe way and even to self-correct them.

Here, in comparison, it should be noted that such signal amplification is also provided by the social network applications themselves: ideas, intents or needs are exponentially multiplied, instantaneously, and worldwide. Their control is self-organized and managed by Internet users. Here we see a kind of necessary ambivalence towards sustainability, where state or corporate governance gets counterbalanced by the citizen governance.

Hereafter, we can quote some geometric properties for these phenomena:

– our space as human beings is mesoscopic and, most of the time, of Euclidian type (three dimensions).

– we are exchanging products, goods, services and information on our spheric planet. We are living in an orthonormal space: things on this surface are proportional to the square of its radius (the cube for a volume).

Consequently, to maintain a flow associated with the field, the intensity should decrease as the square of the distance. Locally, however, for a given small distance between agents or components, the situation is quite specific: for example, in electronics, systems consist of components and basic objects integrated in a small volume, as in a biological cell, as also in a collaborative team: each time, the environment is tenuous; we are in the realm of quantum physics, Brownian motion, erratic and uncontrolled behavior between individuals. In this case, the macroscopic perception of space and time does not matter.

1.6.2. *The addition of a new dimension: gimmick or necessity?*

Very recently, we saw that links existed between the "Quantum Mechanics" (at the microscopic level) and the theory of "General Relativity" as defined by Einstein. Such a result is important because we are facing the same problem that arises when trying to connect the conventional systems theory with network theory and the theory of complex systems.

By analogy, what separates or connects several theories is a simple matter of "dimension". It is an opportunity to highlight some facts and observations:

– in a physical system, as in a programmable array, the density of the interaction or the intensity of forces (electrostatic, behavioral, etc.) between two agents is not always proportional to the inverse square of the distance;

– in a social system, and below a given distance between people (so-called limit or boundary of freedom), any collaboration becomes more difficult. The stress level increases and exchanges between people may become more tense and considered as unsustainable aggression. Thus, depending on the distance between individuals, human behaviors are changing to be more or less consistent.

Other factors are involved at the mesoscopic level. Let us take some examples, for instance:

– in 1920, Theodor Kaluza and Oscar Klein showed that the existence of extra dimensions may lead to a unified description of the fundamental interactions;

– similarly, the observations that we make in our own space-time universe at both mesoscopic and macroscopic levels in the Minkowski four-dimensional continuum, called Spacetime four dimensions, may be the result of some complex phenomena deducted from a system belonging to a wider five or even six-dimensional world, after an orthogonal projection onto a reduced hyperplane.

In this way, in cosmology, physicists now suspect quantum phenomena on the outskirts of a black hole: this observation would show structural similarities between the micro- and macroworld. If we can establish and manage such a link between the micro- and macroworld, that is to say, if there is an invariance of scale, then we can assume that the same property will be valid at the mesoscopic level.

To borrow an image: now in social economy, we talk about sustainability. This property could be just considered as a "relative sustainability" issued from a holistic view called: a "general sustainability".

Methodology: in the field of modeling, nothing precludes the idea that rules applicable to sustainable systems, in our universe, come from a broader concept. Indeed, if we focus on a production system, ignoring its logistic aspects, this is equivalent to initially considering a global value added system, described in a wide "N" dimensions, and then extracting from it (like a projection into a hyperplane of n, with "n < N") a model of "n" dimensions, in order to get an understandable and viable world, and to handle it at our level of cognition, within the meaning of more conventional theories.

1.6.3. *Integration of time and dynamics*

Time is commonly considered as discretized and discontinuous. The same is observed with the discretization of matter and the quantification and the structuring of processes. This leads to a very common question:

Beyond the Real, is "Instant Time" a very consistent situation?

Let us try to understand what can either be done or planned within a reduced framework involving only one "code", for example, the code of matter. In physics, to sum up the situation, it is commonly agreed that there are two kinds of laws from two disjoint fields to describe and govern the evolution:

– *Quantum mechanics*, which describes the relations between the elementary particles in the infinitely small world (which is assigned to "the code of matter").

– *The general theory of relativity*, which is the geometric theory of gravitation. It explains and controls the relations between masses and assemblies at large, macroscopic, and at infinitely large scales. It also addresses the space-time curvature (which directly related to energy and momentum).

From a logical point of view (this can also be done with some other "codes" such as the code of life, of thought, etc.), it is possible to lean on the underpinning mechanisms of each code and to transpose these in the sustainability domain. In the following, we address the well-known quantum energy phenomena, by showing how we could establish a possible link between a quantum entanglement and wormholes.

– Works of Albert Einstein, Boris Podolsky and Nathan Rosen in 1935 were used to develop a paradox (also called "EPR link"): this EPR paradox (EPR standing for Einstein–Podolsky–Rosen) is an experiment, whose first goal was to challenge the Copenhagen interpretation related to certain properties of quantum physics: this has led us to consider the role of the entanglement to maintain several particles connected together, whatever the distance that separates them.

– The general theory of relativity describes the space-time dynamics and explains how massive objects (and, more generally, any form of energy) can curve it. Einstein and Rosen, at the same period, had the idea that extremely compact and arbitrarily distant objects in the Universe, black holes, for instance, could own a kind of tunnel to connect them (such a fold in the network of space-time). This shortcut, or "wormhole", is called an Einstein–Rosen bridge or ER bridge.

As can be seen from Figure 1.4, the distance traveled by light between two points located on both opposite sides of the "wormhole" is much shorter than that which follows the external path on the fold of the space-time surface. More recently, Juan Maldacena (Institute for Advanced Study – Princeton, New Jersey) has shown, by considering a pair of black holes and a particle–antiparticle pair, that it was possible to connect two phenomena relevant to either the general relativity or quantum physics. Thus, any entanglement corresponds, in fact, to a wormhole or a channel to communicate very fast in the space-time universe.

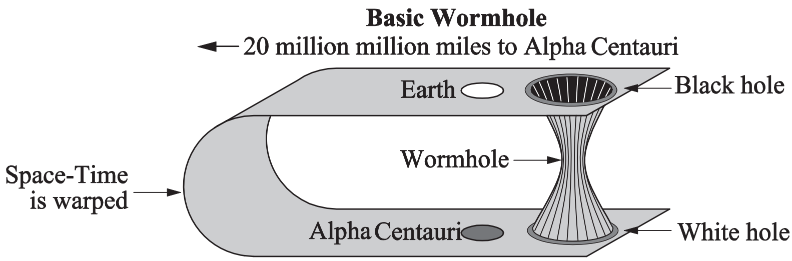

Figure 1.4. *Wormhole in the Cosmos [BAL 05]*

1.6.4. *Application*

1) This result is useful: it overcomes the difficulty (principle of locality) which states that no signal can travel faster than light. The notion of quantum entanglement associated with a wormhole seems to violate this principle. Thus, the entanglement can be described as a space-time tunnel effect, that is to say, a short path, in a fifth dimension, which would connect two points of the universe simultaneously, such that any action that affects one equally affects the other. Each particle is associated with a fold of the universe, bringing two remote areas just to make one, in one place. Interpretation of this result is of key importance: it enables the connection of two particles or agents across space; the two entangled particles would be in fact as a unique one, as if we were at the entrance of the channel.

2) Application example of a wormhole. Here, the wormhole becomes a hole, or passage burrowed by a worm. This hypothetical structure of space-time envisioned as a long thin tunnel connecting points that are separated in space and time (Earth and Alpha Centauri). It is then a short pass between two far away places in space. In Figure 1.4, for instance, a kilometer-long wormhole through the hyperspace replaces 20 Tera kilometers between the two structures; this enables us to save years and years of space traveling to join the two neighborhoods.

3) Here again, we can quote a very well-known game called Q-craft. It is a "mod" (improved modification of a video game) that brings the principles of quantum physics to the world of Minecraft. QCraft is not a simulation of quantum physics, but it does provide "analogies" that attempt to show how quantum behaviors are different from our everyday experience, allowing players to create structures and devices that exhibit Minecraft versions of quantum properties such as observer dependence, superposition of states and

particles entanglement. This also enables us to provide retrocausality: it is a hypothetical phenomenon that reverses causality, allowing an effect to occur before its cause. Here, it is of key importance to note that retrocausality is just a complementary concept of “causality” that we commonly use in our mode of reasoning. Thus, real life and quantum physics have to be merged, as for an ambivalence, in our thoughts.

1.7. Extensions of the concept

This concept modeling provides interesting and sustainable advantages: it helps in understanding and reviewing some theoretical advances, in presenting interpretations in the field of “synchronized events”, and in giving a possible explanation to such phenomena. For example, it is argued that culture, or a telepathy-like effect, is connecting two human beings: they may have the same reactions and the same reflexes when faced with an uncertain event, regardless of the distance separating them.

When one of them disappears, knowledge and skills are transferred to the other, as with a legacy. We see the same type of situations with twins. Is it telepathy? Thought connectivity?

1.7.1. *Comments*

Nothing is proved but we have to propose a possible explanation to the concepts of entanglement and telepathy. Many people feel that instinctively. Of course, we come up against the limits of the speed of light, and we have to open the doors of a new paradigm.

Referring to the previous example, the principle of conservation of information, in a closed system, as for the reversibility over time, can thus be perpetuated. In terms of energy, or heat, there is no dissipation: the entropy does not increase. Any radiation, or dissemination of information, is not a messy or disordered signal. In addition to energy, we can carry information back to the whole environment.

It is the same comment we can interpret, when experts in information systems say that the new industrial informatization is based on a “brain workforce” and is negentropic, i.e. it generates a negative entropy. Indeed, negentropy has been used by biologists as the basis for explaining some purpose or direction in life, namely cooperative, moral or instinct.

In this way, returning to the quantum theory principle, everything happens as we could be in a three-dimensional universe model, governed by gravity, and associated with a two-dimensional surface on which a particle and its field follow quantum laws. Thus, as explained in this section, two theories can talk to one another. In contrast, this new opportunity requires some changes in terms of mechanisms implementation: here, some equations of relativity have to be canceled at the border of an object issued from these equations.

1.7.2. *Life sciences: power laws, evolution, life and death phenomena*

First, it is useful to recall some approaches and practices used to study any industrial system (intended to produce finished goods and services), and to see if they are satisfactory, and adapted to the new environmental circumstances of our planet.

In all well-known activities such as industry, government, economics, services, etc. it is customary to base data analysis, the interpretation of results, and the development of a decision, on descriptive and inferential statistics. The statistical science is useful as it allows several basic types of linear and nonlinear analysis such as:

– aggregating and synthesizing data and situations, as a simplified image of a reality (multivariate analysis);

– classifying, data clustering, partitioning, etc.;

– screening, with discriminant analysis and sorting;

– ordering and ranking;

– time series analyzing and predicting, etc.

This approach has achieved great progress: now, it has evolved to incorporate multivariate spaces. However, this approach has its limitations because it is based on interesting but too restrictive mathematical techniques (mathematics is perfect for abstract problems, to learn how to model and understand complex systems, but they are limited in terms of problem solving).

What is usually performed is to think in terms of data clustering and aggregation. This approach, issued from group technology, provides the advantage of reducing the interrelationships complexity (a simplexification process). Then the influence of the interdependencies, which is a source of weaknesses and dynamic instabilities at the level of local and almost stable equilibria. This, also, simplifies data manipulation and makes sometimes simplistic our intellectual processes (because of reductionism). For example, in a population:

– The concepts of mean and standard deviation are used to represent a distribution, in a simple way.

– They may represent the evolution of a situation unless it is a linear continuous curve in a two-dimensional space.

This approach, however, has some drawbacks. There is no:

– consideration of singularities, therefore, no disruptive phenomena;

– flood phenomena, underestimation of distribution tails;

– compatibility with self-organized dynamic processes, etc.;

– possibility to manage unpredictability, volatilities of scalable systems, etc.

In terms of sustainability, we can point out the incompleteness of the statistical models: because of our reductionist approach, we are led to model an oversimplified reality. This leads to a computable solution, but to only performing a partial optimization on a small neighborhood. Hence, the risk of convergence to a suboptimal solution, in a warped space-time basin, is quite high. Elaborating a more complete model may lead us to consider a more complex convergence path: instead of traveling along a curve or path, we are evolving among a surface called an area of convergence. Thus, optimization is like a ball moving toward a less energetical hole. Figure 1.5, relevant to studies of roughness, is similar to the one we have in optimization: the surface is that formed by all the different possible paths of convergence. Roughness in 3D surfaces and porosity in volumes are important factors able to represent the complexity of a structure or of a surface solution. Mathematician Benoît Mandelbrot established a relationship between surface roughness and its fractal dimension.

Here, we will use such surface modeling to point out how we can get an optimal solution. The minimum energy levels relate to sinks; they are deep depression (in dark). Light depressions (lightly shaded) are almost stable sinks, called suboptimal attractors. Thus, to achieve a global optimum, we need to move over this surface, leaving small sinks, crossing mountain passes and ridges, in the sense of Boltzmann, that is to say, accepting a temporary degradation of a state, to reach a deeper cavity, then to better improve a comprehensive and sustainable solution.

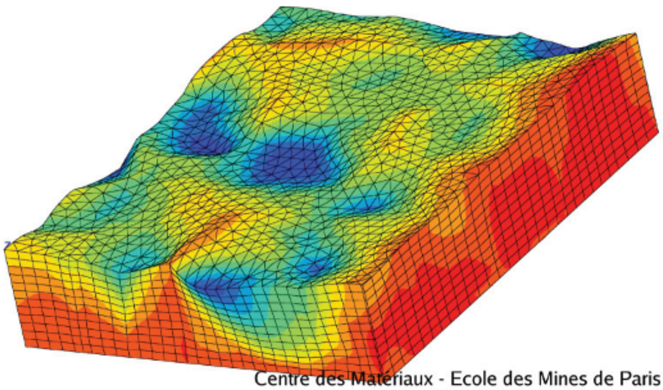

Figure 1.5. *Distribution of potentials, and optima, along solutions' surface [ENS 14]. For a color version of the figure, see www.iste.co.uk/massotte/sustainablity2.zip*

Ill-structured problem resolution is often issued from a trial-and-error approach. This trial-and-error approach is the one used in nature through what we call simulated annealing, or genetic algorithms. Anecdotally, the simulated annealing is a particular case of the genetic algorithm, and it is a satisfactory result since exceptional circumstances are much more frequent than expected or predicted by usual and conventional theories.

In practice, it is always possible to deviate from a predetermined path, against our will, because of the interactions and feedback existing in the networked system; as already stated, most of the future events in a complex are unpredictable. Indeed, when progressing (along a trajectory) on an energy potential surface (as in a curved space), it is difficult to predict whether we will be attracted to a shallow crater (weak attractor), or whether we will escape it and later reach a better solution (more in-depth nest-holes of energy). In decision-making, where modeling is not easy, "regenerative" methods are useful and sustainable: great difficulties are encountered to process the various, exceptional and transcendent cases to converge better. Indeed, we often experiment with difficult situations where the modeling of statistical data sets incorporating exceptional facts is a problem. This has been described to question about the sustainability of statistical sciences: indeed, exceptional situations are much more common than conventional statistical laws generally predict. The exception and uncertainties in a complex system are a common occurrence, so we have to change the way we think, represent or model the world to provide greater consistency.

1.7.3. *The power laws*

As often stated, industrial, economic and social systems are not linear; they obey to power laws. The challenge is to integrate this concept into our models. The power law is a mathematical relationship between two quantities x and y. For example, if "x" is a quantity or the frequency of an event, and the other "y" is the size of an event, then the relationship between y and x is a distribution given by the power law: one variable increases or decreases very slowly, while the other one varies in an invasive or pervasive way.

A "Power Law", expressing the relation between two quantities X and Y, is modeled as follows:

$$y = ax^k$$

In this equation, the variable "a" is a constant of "proportionality", while "k" is another real number, called the "exponent" to represent the power, index or degree of the power law.

1.7.3.1. *Applications*

Power laws are observed in many areas of life (physics, biology, psychology, sociology, economics, industry, logistics, etc.). They make it possible to describe all phenomena that exhibit an invariance of scale leading to a singularity. Changes in a financial stock market follow a power law (Mandelbrot); the firm size is one of the areas where power laws apply remarkably well: in companies, their size is measured either by the gross income, the number of employees, the balance sheet, revenues from sales or stock market capitalization; in each case, we get a distribution in the form of power law.

1.7.3.2. *Change of coordinates*

Here, we address either an orthonormal or scaling transformation. It consists of changing the scale of a variable (standard shift) to obtain another type of image about the real world representation. With logarithmic coordinates, the graphic curve of a power law is a straight line. Indeed, the above relation can be written as a linear equation:

$$\log(y) = k \log(x) + \log(a)$$

Let us define: X = log x, and Y = log y. We then find the equation of a linear function like: $Y = \alpha X+\beta$, where the slope α is equal to the value of the exponent k, and intercept β is the logarithm of the constant of proportionality. Such scaling does not correspond to a change in core values as it is done in data analysis, that is to say, in multivariate statistics, where the new axes of a reduced hyperplane are defined as a linear combination of several variables.

A study of the variation of the axes and curves can be done with different values of “k”. In Figure 1.6, several curves are drawn; they are related to different values of k | $Y = X^k$, that is to say with a constant a = 1.

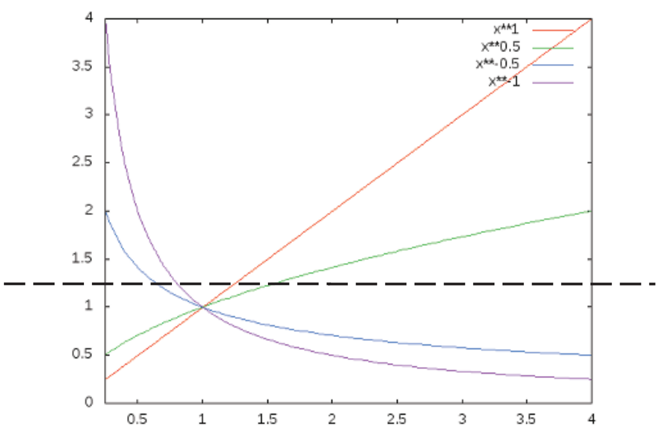

Figure 1.6. *Distribution of Mandelbrot power laws according to the value of the “K” exponent. For a color version of the figure, see www.iste.co.uk/massotte/sustainablity2.zip*

– For K = 0, the curve is “flat” (dotted line). The output remains equal to “1”: there is no transformation.

– For K > 0, and K < 1 (green curve), it has an increase in biological or performance type. Phenomena are amplified in a nonlinear manner: it is the case, for example, of the variation of the weight of an individual, with respect to its size, which follows, in a first approach, a power law.

Similarly, Galileo showed that the strength of the yarn-beams, or even small girders, which support the floor of a building, varies in proportion to the size of their section, so as the square of its width/height (surface), whereas the weight of the structure varies as the cube of its length cubed (volume). Thus, the force does not vary linearly with weight of the floor, but according to a power function, with an exponent of 2/3 (=0.66): the strength of a yarn-beam grows “slower” than its weight (while, in the minds of many people, the rate of the exponent would be equal to 1). It is the kind of exponent we find when we compare either several fractals structures or economies of scale. Also, we find this ratio in the subdivision of traffic flows: transportation vehicles on roads, blood in arteries, etc.

– For K = 1, (red curve), there is a linear type of proportionality between the input and the output (examples abound).

– For K > 1, but entire value, we fall into amplifications of second, third ... degree. This creates instabilities, flood phenomena or runaways due to the feedback loops we have in an interconnected system.

– For K < 0, (blue curve), we get curves widely used in economy and finance to explain, for instance, how the density of the firms is distributed according to their size, or, how resources or revenues per employee are distributed according to the size of the population involved, etc.

The first consequence is related to the occurrence of exceptional (abnormal) events. In the field of conventional statistics, these events are seldom or very rare, according to their amplitude (e.g. intensity of an earthquake, or number of earthquakes, change over time of a market value, etc.). This is explained through the standard deviation mechanisms that tend to underestimate the distribution tails (e.g. blue curve in a binomial distribution). In Figure 1.7, we see that as a distribution (e.g. the defects rate over time, the density of unexpected events, the customer satisfaction survey, etc.) is to be modeled by a “power law”. The probability of occurrence of unusual events located in the tail of the distribution curve can be much higher than predicted by using a so-called "normal distribution". Fortunately, we can partially correct this deficiency with the Weibull distribution. This is the reason why, in advanced IBM technologies, we used to base our forecasts and analysis on James Stein's estimators [MAS 06]. It is the most appropriate way to get consistent information in the area of sustainability.

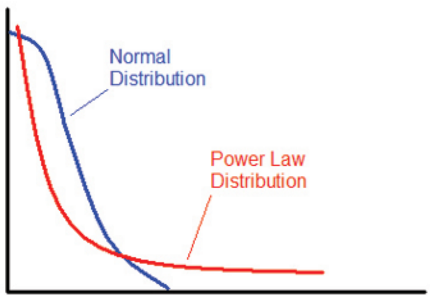

Figure 1.7. *In high technologies, normal distribution is an exception [MAS 06]*

In the following chapter, we mention different examples relative to the evolution over time, where such results apply:

– inventory in an industrial process. This example is issued from IBM's electronic industry. In 1987, an IBM Europe study to highlight the phenomenon of fractal chaos in the assembly lines of thermal control module (TCM) was conducted;

– social networks, when observing overreactions in collecting information on a given subject matter (say e.g. through hashtags). This affects either demands or market needs, or market retraction (i.e. the over-reduction of contracts or acceptance of a new service by a population). The planning system is then submitted to unexpected and amplified disturbances.

The factor k is >1 or >>1 each time. The main results, as roughly described here above, were summarized in an IBM Technical Report [MAS 06].They can be useful to better appraise the sustainability of any complex system.