Strategies of Dynamic Complexity Management

Helena Knyazeva

Professor, School of Philosophy, hknyazeva@hse.ru

National Research University Higher School of Economics, 20, Myasnitskaya str., Moscow 10100, Russian Federation

Abstract

The modern theory of complex systems changes our view of historical processes and is accompanied by uncertainties, instabilities, and ambiguities. The knowledge of this theory allows us to master a system or holistic thinking to understand the laws of functioning and growth of not just structural but dynamic complexity. Uncertainties and chaotic elements that indicate any state of crisis are not only negative factors that we should be aware of and are not without fear for us. We can learn to manage them and use them to renew our social systems thus producing innovations. The strategic vision of complex system evolution becomes an effective tool for decision making and scenario planning based on our participatory activities with alternative futures. The article examines the case of Shell Corporation, which has been using scenario thinking technologies since the early 1970s, which has given it incredible competitive advantages and incentives for rapid growth and transformation into an international energy giant.

eywords: foresight; non-linearity; uncertainty; participatory futures; synergy; complex system; holism; emergence; scenario planning; alternative futures

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Contemporary complexity theory or systems science (systemics) [François, 1999] provides a conceptual basis for understanding the nature of complex dynamic systems that are defined by several characteristics. First of all, they have a large number of elements; for example, the human body consists of 230 cell types, the brain has 80-90 billion neurons. Another key factor is complex connections between the elements. A system with particularly complex interconnections may be more complex than another, even if it has fewer elements. The example of two people with different world outlooks trying to communicate with one another shows that their relationship is often more complex than crowd behavior, where individuality is lost. The next attribute of complexity is systems' behavior, their functioning modes, and transformation over the course of development. This allows one to view the system as dynamically complex, displaying non-repeating patterns, plasticity, ability to adapt, learn, and change behavior to increase its chances of survival and of successfully functioning [*Godfrey-Smith*, 1996; *Mitchell*, 2009]. In other words, complex systems are distinguished by their non-trivial behavior, emergence, unpredictability, uncertainty, ability to self-organize, cyclical causality, feedback loops, and the ability of small changes to generate dramatic consequences [*Erdi*, 2008; *Bakshi*, 2017; *Deaton*, 2018; *Kok*, 2018; *Nandram, Bindlish*, 2017]. A system's dynamism implies its changing over time and switching between different operation modes. One of the more important phenomena associated with the dynamics of complex systems' behavior is holism, which has the following properties:

- dynamic interactions, which ensure the wholeness and integrity of the system;
- synergy, i.e., the possibility of obtaining an evolutionary benefit from the correct, resonantly organized interaction of elements or subsystems;
- the system cannot be separated from its environment; there are input and feedback loops between it and larger systems, and ultimately the Global System.

In addition to the above features, complex social systems are characterized by the interconnection of intangible (mental, cognitive, etc.) and material (economic, etc.) components.

Simple Complexity or Complex Simplicity

Complexity and simplicity, chaos and order are perceived as opposites only in a simplified, abstract outlook. In reality they are intertwined with numerous subtle ties. There is no perfect simplicity or exceptional complexity in natural or social systems, just as there is no pure chaos (disorganization) or total order. Systems tend to feature dynamic (or deterministic) relative chaos coupled with a certain degree of order (organization). A turbulent flow is perceived as chaotic, while possessing a subtle, invisible, ordered structure. On the contrary, order and symmetry are accompanied by small random deviations and aberrations. According to Arnaud Spire, a completely symmetrical system is sterile and devoid of the ability to develop. What is devoid of symmetry and remains in a state which is far from equilibrium is fruitful [*Spire*, 1999]. To describe the combination of complexity and simplicity, uncertainty and certainty, neologisms such as "simplexity" and "perplexity" are used.

Edgar Morin offers an etymological clarification of the concept of complexity, pointing out that "complex" (from Latin complexus) literally means "that which is woven, knit together" [Morin, 2002]. Hence the first basic aspect of complexity, holism, is namely the combination of parts or elements leading to the emergence of a wholeness, which acquires new emergent qualities that are not observed in its individual parts. In his book "The Quark and the Jaguar", the 1969 Nobel laureate in physics Murray Gell-Mann presents a paradoxical vision in which the complexity of the microcosm and the living world structures are comparable. The world of quarks (the smallest components that make up elementary particles; the author made a personal contribution to the proof of their existence) has much in common with the world of a jaguar wandering in search of prey. The two poles of the world, the simple physical and the complex biological, are closely interconnected. The quark symbolizes the basic physical laws that rule the universe, while the jaguar symbolizes the embodiment of the surrounding world in complex adaptive systems. Thus, the quark and the jaguar express two aspects of nature, "simple" and "complex" ones [*Gell-Mann*, 1995].

Gell-Mann coined the term "plectics" to denote a new transdisciplinary subject area that studies phenomena from various fields through the prism of integrating the simple and the complex. Chains of interconnections between simple basic laws governing the behavior of matter and complex phenomena in their diversity, individuality, and development are considered [*Gell-Mann,* 1996]. The concept of plectics ("to fold" in Greek) clearly demonstrates complex systems' property to make the whole look simpler (a single object instead of many elements), forming an intricately woven fabric. Alain Berthoz develops the concept of simple complexity or complex simplicity, symplexité [*Berthoz,* 2009], based on the principles of selection and anticipation on the basis of probabilistic estimates. In this respect it is close to the approaches to constructing **scenarios of the future**. The principle of meaningfulness plays a special role, since meaning determines the choice of a development goal. Mastering the mechanisms of simple complexity (*symplexité*) allows one to function and develop efficiently, since by its very nature it assumes that the future is not predetermined [*Berthoz,* 2009]. Most of the modern techniques for describing complex systems reduce complexity and thus turn it into simplicity. Laws are established to "order" diversity and variability; the repetitive behavioral patterns in diversity are identified. Whenever possible, complex nonlinear functions are presented in linear terms, while process dynamics is extrapolated to the future based on the current state or past experience. Hermann Haken, the founder of synergetics as a discipline, developed the heuristic order parameters, cyclical causality, and subordination principle model [*Haken,* 1977]. For a complex system, it is enough to determine just a few order parameters which describe the behavior of the system as a whole in dynamics and are linked by cyclical causality: they are generated by the behavior of elements or subsystems, but having emerged, assume control over them. Unambiguous, deterministic behavior of the system at certain development stages arises as a result of the choice of a path at the bifurcation point, where small influences, fluctuations at the level of elements can determine the further course of the system's development as a whole [*Prigogine,* 1989, 1997]. Along this path order arises from chaos, unity from diversity, and remain in place until the next bifurcation point. The course of nature's and society's history looks like a cascade of bifurcations; therefore, the future is fundamentally open and unpredictable. The attractor structures model developed by Sergei Kurdyumov describes the relatively stable structured states that complex systems can reach over the course of their evolution [*Knyazeva, Kurdyumov,* 2001]. Seeing attractors as possible future states simplifies the description of a complex system. The spectrum of attractor structures is not arbitrary but discrete, determined by the intrinsic properties of a complex system. Therefore, not all paths to the future are possible, while having a knowledge of the attractor spectrum reduces uncertainty, since it helps one to understand which options are realistic and achievable.

Self-Organization of a Dynamic System as a Basis for Scenario Planning in Companies

To self-organize, a system must first be disorganized due both to random factors and deliberate impact [*Ashby*, 1958]. A necessary condition for self-organization is a variety of system elements. This principle also applies to business activity: the more diversified the activities of a company or the national economy are, the more resilient it is to shocks. Reducing system diversity increases the risks of decay. Accordingly, a focus on narrow specialization increases the likelihood of a company leaving the market in the event of the latter's radical transformation. The dynamic stability of an enterprise as a system means maintaining integrity and stability in development. This is achieved through continuous creative destruction practices, by consciously abandoning the old framework to gain a new stable foundation. To characterize this quality of complex systems, researchers proposed definitions such as "moving equilibrium" [*von Bertalanffy*, 1932], "order from noise" [*Prigogine*, 1997], "organising randomness" [*Atlan*, 1979], and " multiple unity "(unitas multiplex) [*Morin*, 1977]. In addition, Morin introduced the concept of "pluriverse" reflecting a conceptual shift in understanding the nature of the Universe: from a single, unique, and monotonous world ("universe") to a variety of alternative **development scenarios** ("pluriverse").

The above terms present from different angles the idea that a share of chaos, a variety of elements, and processes with a certain degree of freedom support the life of companies, sectors, markets, and economies as complex systems. "Complicated" and "complex" systems are distinguished. The first include computers, technical devices, and production systems (sets of equipment) created according to given algorithms. Their organization is determined from the outside and how they would function is generally predictable. The second type includes biological systems, economic and social structures characterized by dynamic complexity and unpredictable evolution. Self-organization gives rise to new forms, new types of ordered processes and structures. Randomness and elements of disorder, the measure of which is entropy, multiply diversity. Nonlinear relationships between elements lead to a rapid increase in the complexity of their organization. There are certain conditions for the self-organization of complex systems:

- *Openness*. The ability to exchange matter, energy, and information with the external environment. On the contrary, in closed systems disorganization and entropy increase.
- *Non-equilibrium*. Most of the processes in complex systems are subject to homeostasis: a return, with minor deviations, to the initial state of equilibrium. It looks like self-organization on the verge of chaos, when the risk of the system's destruction increases, but at the same time it opens an opportunity for multiple complications, the emergence of cascades of new forms and content.
- *Nonlinear connections between elements*. In a "linear" outlook, systems behave predictably, follow a univariate course, and their prospects can be predicted by extrapolation. However, in reality they most often pass through states of instability and bifurcation points, near which even insignificant events, deviations, and fluctuations can determine the further path. At such "forks" the system "chooses a path" from a wide range of possible trajectories. Nonlinearity also means the rate of systems' evolution changes

(from rapid growth to stagnation or decline, or vice versa); there are different modes of operation and systems are sensitive to fluctuations in their unstable states. Emergent phenomena become possible: the emergence of new, previously unobserved, complexly organized structures.

Dynamic Complexity and Emergence

Complex systems' development and self-organization are associated with the property of emergence [*Sartenaer,* 2016]. From an ontological point of view, "emergence" means the emergence of a new phenomenon, while epistemologically, it refers to the difficulty of understanding and predicting the behavior of a complex system. Emergence means the unpredictability of processes occurring in the system, for example, when events initially barely perceptible amplify to grandiose proportions and significantly affect the system's future (e.g., "black swans") [*Taleb,* 2010]. The unpredictability is due to unexpected turns in the system's development paths or a change in its functioning modes (from rapid growth to decline in activity, or vice versa). In this sense, emergence appears as an indeterminate randomness, the basis of an open future, complete with all the related problems associated with trying to foresee it. It has structural and procedural aspects which are inextricably linked. The structural dimension amounts to the newly emerged whole acquiring properties which have not been observed in its individual elements. In such a case one speaks of the emergent properties of the system that cannot be deduced from the characteristics of the elements. At the dynamic level, novelty emerges and the **holistic** effect becomes apparent, such as, for example, in properly organized executive teams, a well-coordinated orchestra, an adequately matched sports team, and so on.

According to the hierarchical principle, any system is an element of another, more extensive and highly organized system which also has emergent properties. Rising in the hierarchy increases the emergence. In terms of complexity, the more highly organized levels cannot descend to lower ones. But emergence also has the opposite effect: the emerging holistic structure transforms the elements in such a way that they begin to show properties they did not have previously. In this sense a part can be no less complex than the entire system. The integration of new elements transforms the system at different levels and the result of this transformation is not predetermined. The changes in the system are affected by internal and external factors, input and feedback loops connecting the organizational level in question with the higher and lower layers. The interaction of the system and the environment, the coordinated and interdependent emergence of both subjects' new qualities is called "dynamic co-emergence" [*Thompson*, 2007].

Managing Dynamic Complexity

New scientific knowledge about systems enriches our understanding of how dynamic complex processes can be managed and allows companies to effectively use *scenario planning* to flexibly revise development strategies, adapt them to the changing context and thus improve their prospects. This process is called "strategic reframing" [*Wilkinson*, 2014; *Ramírez, Wilkinson*, 2016]. Peter Senge recommends that companies and organizations master the systemic thinking principles as the "fifth discipline" [*Senge*, 2006], which does not fit into the classical disciplinary matrix and so goes to the interdisciplinary level. The merging of scientific disciplines leads to the emergence of a new culture of thinking [*de Rosnay*, 1975] and allows one to identify key conceptual transformations. There are numerous studies of approaches to managing dynamic complexity [*Gharajedaghi*, 2011; *Gonzalez,* 2013; *Hodgson*, 2020; *Jackson*, 2006, 2019; *Keatin, Katina*, 2019; *Nijs,* 2015; *Robinson,* 2005]. Here are the most relevant, in our opinion, provisions which can serve as a solid basis for management strategies.

New perception of chaos. Perceiving chaos as an undesirable element associated with high uncertainty and uncontrollability[1] still remains common. Since the days of Newton and Galileo, classical science looked at randomness as a form of ignorance. It was believed that a deep study of any complex phenomenon eliminates randomness and can produce its deterministic description. However, according to recent studies, randomness, variability, and volatility are deeply woven into the reality as objective properties of evolutionary processes [*Mainzer*, 2007a,b]. Variety is often achieved by randomly combining elements with unique characteristics. Maintaining it is considered a necessary condition for the balanced development of any system. A certain amount of chaos can be seen as complex systems' self-organization and self-building mechanism, which allows them to identify relatively simple attractor structures, development trends, and connect different elements or subsystems into a single whole. This, in turn, opens possibilities to adapt to changing environmental conditions, generate energy to overcome crises, and find ways out of evolutionary dead ends. The development rates of elements and substructures of a complex structure synchronize and new evolutionary wholes emerge. Elements of chaos

[1] Entropy is often seen as a measure of chaos and process disorganization in complex systems. However, the entropy approach has its limitations. The growth of complex structures and the system's structuring are typically accompanied by the emergence of order, macrolevel organization, and the maintenance of dissipation, dispersion, and microlevel disorganization processes.

serve as a mechanism for complex structures' and organizations' renewal and a source of innovation.

External organization vs spontaneity. In certain cases, systems, companies, or organizations which develop independently and spontaneously function better and remain more stable than structures built by external effort. In recent decades, a management model which considers companies and organizations as complex systems became more popular; it promotes self-organization, synergy, and diversity in order to find the best development paths.

Linearity vs nonlinearity. Rigid determinism is based on the belief in linear development. New scientific discoveries refute such an attitude, indicating that the world is organized in the form of complex systems which can go along multiple evolutionary paths matching their inherent nature. If it is possible to identify a limited set of viable development paths and create a mathematical model for them, the basis for scenario planning emerges. Also, the development of complex systems cannot be unidirectionally progressive; it is cyclical. Rapid growth and dynamic development are followed by periods of decline and stagnation, and sometimes degradation and simplification.

Entropy balance with external management. External management is not the only source of complex systems' sustainable development. It needs to be balanced with self-management, self-organization, spontaneity, and diversity. When the balance is upset in any direction, such as in the case of total domination of spontaneous market mechanisms, or, on the contrary, of state control, the risks of instability and crises increase. It is important to take into account that the shares of inner freedom and diversity (elements of chaos) must be regulated depending upon the evolutionary stage. In times of crises, they should increase to help the company as a complex system identify and take new development paths. Due to the nonlinear behavior of complex systems, extreme points inevitably arise along their evolutionary paths: singularities, or in other words, crises. In this context, crises are perceived as a natural component of complex systems' "life". Companies do tend to go through such periods from time to time, with the associated increased turbulence, chaotic movements, emergence of irrational social and cultural phenomena and processes. Understanding that it is inevitable helps one to proactively take such aspects into account in strategies and plan for creating new forms, structures, and various kinds of innovations.

Holistic thinking. Systems science emphasizes the importance of a holistic or systemic vision: the ability to see the whole behind the parts, recognize both the immediate context and remote configurations of possible developments, act locally on the basis of a global vision. A holistic view and scope are woven into the new rationality, becoming an intellectual and practical necessity. This cannot be comprehended with fragmented perception and thinking. Any informational facts acquire meaning only when placed in a certain context [*Morin*, 1999]. An equally important aspect of *holism* is understanding how to build dynamically stable holistic structures. The correct integration of parts into a whole leads to a situation where all elements begin to co-evolve (develop in a mutually consistent and harmonious way), which in turns accelerates the development of the newly emerged integral structures.

Small resonant impacts. The most relevant way to manage dynamic complexity is through small-scale but well-organized "soft management", which can trigger the necessary resonance at the right time in the right place. The nonlinear nature of the relationship between effort and effect should be taken into account. Major efforts can be fruitless, while on the contrary small and insignificant, but properly organized measures have the potential to be highly effective. The so-called "rule of leverage" [*Senge,* 2006] or "ephemerisation" [*Fuller,* 1997] works here, expressed as follows: "insignificant can cause significant, but great won't necessarily achieve something, even something small", which illustrates nonlinear relations between impacts and their results. Significant expenditures on managing a company as a complex dynamic system do not guarantee a proportional result. At the same time the correct and gentle influence applied at a certain point at the right time can "shake" the system and wake its dormant potential. Thus, it is not the force and intensity of action that play the decisive role, but rather its topology and "architecture". There are certain "situational configurations" in the company and other social environments under which small but targeted incentives are extremely effective. Knowledge of systems science helps one to act extremely efficiently, radically reduce costs, and generate the desired and (no less importantly) practical processes by making a resonant impact. Such actions tend to create synergies.

Instability as a resource. According to I. Prigogine, the way the system will go after passing the bifurcation point is not predetermined. This idea is presented in the study with the metaphorical title "To Die is not Cast" [*Prigogine*, 2000]. In turbulent times well-designed strategies play a decisive role. Playing on Einstein's metaphor of the "dice", Prigogine demonstrates the degree of chance's interference in evolution and the possibility of turning it into a targeted process. If according to Einstein all processes in the world can be perceived as deterministic if we reduce the probabilistic description to the one with no alternative outcomes, according to Prigogine randomness is deeply rooted in the world ontologically. As they develop, complex systems at different levels of the world's organization go through phases of instability and bifurcations when the choice of the further development path is made from a wide "fan" of possibilities and alternatives. It follows then that the future is not predictable in principle but is open. The new knowledge does not leave any ground for fatalistic beliefs and therefore the factor of "fate" remains a matter of individual perception but not a scientifically proven phenomenon. Complex systems' resilience depends upon their ability to pass bifurcations and identify new opportunities. Perceiving instability and randomness as assets helps one master the emerging new potential and turn the evolution in the preferred direction. A number of scientists believe that the course of time itself becomes nonlinear and has bifurcation points [*Dupuy*, 2010], which opens the possibility of choosing the future. By managing the instability near the bifurcation points, one can set the further development path. Passing through forks, the environment becomes sensitive to collective and individual actions that can lead to the emergence of new social, cultural, technological, and other patterns. At a new coil of the complex systems science, a strategic orientation arises based on the following premises:

- the future can be managed
- the future depends upon today's choices
- actions taken today are important for accomplishing a preferred vision of the future.

Building a Preferred Future

Leading experts adhere to a constructivist approach to understanding the world, stating that the external environment is not completely independent of our actions [*Le Moigne*, 1994; *Morin*, 1999; *Prigogine*, 2000]. The environment is created and transformed with the participation of people and reconstructed through interactions between objective reality and conscious creativity or projective action. The rule of objectivity, which remains a constant in scientific research, is supplemented by the prism of projectivity, i.e., different development directions are outlined and interpreted, and the probability of their implementation is estimated.

Constructivist epistemology involves not only discovery and learning, but also invention and creation. According to the constructivist approach, perceiving the future solely as an object of cognition looks unproductive. Building partnerships with it is much more effective. Constructing future scenarios implies making choices, and therefore "co-inventing" life. Constructivist practices are actively developing, moving into the mainstream and comprising various socio-cultural, socio-psychological, communicative, psychotherapeutic, and managerial tools, taking steps to strengthen security, making effective decisions in uncertain situations, and building development scenarios. Constructivism is currently understood not only as consciously constructing reality (including ordering and organizing society in accordance with the value preferences of the individual and collective subject), but also as promoting the creativity of social institutions, implementing and disseminating social innovations, managing development risks, going through crises and subsequently taking the desired development paths. Based on this understanding of complex systems, when they are unstable and possible development paths need to be identified, conscious attitudes and value preferences play a decisive role.

Instability can occur at two types of stages: bifurcation (branching of development paths), or extremum (culmination) of a complex structure's development. In both cases the system becomes sensitive to minor, microlevel fluctuations. Therefore, even a small impact can push it to one of the possible evolution paths, to a particular attractor in the spectrum. Resonant excitation of desired complex structures allows one to shorten the long and winding evolutionary path leading to a qualitatively new level. Having determined the parameters of complex systems' order, one can model, calculate, or qualitatively establish possible attractor structures for them, and using small but topologically correctly organized (resonant) impacts, turn the development process towards a desired path. It also becomes possible to actively intervene in the process of building complex structures from relatively simple elements over the course of their co-evolution, that is, joint, balanced development. One of the principles of evolutionary *holism* is a topologically optimal assembly of subsystems into increasingly complex, steadily evolving wholes in order to produce the necessary resonance, accelerate the progress of the emerged single complex structure, and achieve a preferred future. As a result, the new integrated system starts to develop at a higher rate than the most dynamic single structure did before the merger. The advantage of joint development is the saving of all kinds of resources. Furthermore, complex systems not only have a certain "memory depth" but can "attract" the future with the attractors inherent to these systems' internal properties. It becomes possible to constructively use the "attraction of the future" potential within the range of certain attractors.

Tools for Managing Dynamic Complexity

Achieving synergy. Synergy is the result of the **holistic** effect, when the emerging whole is greater than the sum of its parts. However, random connections between any system elements are not possible. Therefore, synergy is the result of a lucky self-organization. This phenomenon is a logical feature of evolutionary holism, regarded as a fundamental paradigm of the 21st century [*Laszlo*, 2012, p. 80].

In social terms, synergy becomes apparent in the emergence of integrity and cooperation, when 1 +

1 > 2, and in holistic individualization when the whole does not suppress or level the individuality but allows it to "flourish". In special forms of social holism, individuals' selfish actions paradoxically enhance social altruism and work for common interests [*Mandeville*, 1997; *Ruth*, 1961; *Luhmann*, 1987].

Synergy appears in the self-referential circle of human action: "I'll do what you want when you do what I want" [*Luhmann*, 1987]. Its social and ethical meaning reveals the "secret" of subjects' coming together in a social environment, when the division of labor or teamwork gives obvious advantages to a social group (or a state) and promotes it to leading market, political, or geostrategic positions. In optimal, correctly assembled high-synergy social structures the level of aggression tends to be reduced to a minimum, while the intensity of cooperation reaches a maximum. Such structures usually have a higher level of trust, internal diversity, decentralization, and responsibility. In the preferred social model based on self-organizing principles, each individual contributes to the collective behavior which acts as an order parameter. As a result, synergy mechanisms are triggered, involving ever more people in this process. Such models should be based on the responsibility principle broadly formulated by Hans Jonas [*Jonas*, 1984]. According to it, a self-organizing society would exist only to the extent that each member realizes they are responsible for the whole while carrying on with their individual activities [*Haken*, 1995].

Holistic and creative thinking as the basis of sustainable positions in the future. The abilities in highest demand increasingly often include creativity, "soft" innovation, visualization, narration, and holistic thinking. Today, against the background of constant bifurcations, a transition is taking place from the extensive consumption-based model to an intensive one, which relies on cohesion, communication, and awareness [*Laszlo*, 2012]. The arrival of the conceptual age is also mentioned [*Pink*, 2005] to replace the information one, with a radical shift in emphasis and a revision of values: from the dominance of purely analytical, linear thinking to nonlinear, visual, and symbolic. Cognitive skills such as holistic vision, intuition, emotional intelligence, and so on are of particular importance. Companies with access to a talent pool like this gain an edge. There is growing demand not just for professional abilities, but also for structuring and design skills. In addition to the ability to accumulate information, being able to critically comprehend it through the prism of holistic thinking is valued. Objective arguments alone may not be enough to substantiate one's position; it is important to present cases from personal experience. A serious attitude toward work must be combined with a gameplay approach [*Pink*, 2005]. High-tech skills are gradually giving way to "high-concept" ones (the ability to conceptualize) along with "high-touch talents" such as understanding aesthetic subtleties, immersing into narrative plots, adapting, and being tolerant of other cultures' ethical norms. Understanding complex systems allows one to flexibly adapt to change, successfully go through periods of turbulence and bifurcation points with a positive attitude, and take advantage of newly opened opportunities to turn the vector of development in a new direction. Large companies master the competencies in, and knowledge of, complex systems and set the trend for medium and small businesses by using the appropriate tools to operate in an increasingly complex and variable context through **scenario planning**.

Scenario Planning Practices

According to various estimates, in recent years scenario planning became a successfully mastered practice for 65% of companies [*Wilkinson, Kupers*, 2013]; it is being constantly updated and enriched with new approaches, which allow one to work with dynamic complexity and handle tasks on several levels while taking into account the global and local contexts with complex, multi-layered configurations. Scenario planning implies nonlinear, rolling coverage of possible prospects and effective "cooperation" with the future. The tendency to go beyond linear thinking can be detected in almost all fast-growing companies since linear thinking involves cognitive distortions (emphasis on familiar processes or neglecting weak signals with the potential to evolve into dominant trends and initiate a new development vector). Understanding that a complex system becomes susceptible to weak signals in instability states of two types, approaching a bifurcation point followed by the forking of possible development paths and in a state of culmination (maximum growth or decline), is crucially important. When a critical point (singularity) is passed, the regime changes: growth is replaced by decline, or, conversely, decline is followed by a rise, a recovery.

There are five approaches to perceiving the future: retroactive (focused on the past), inactive (focused on the present), pre-active (predicting the future), proactive ("creating" the future), and interactive, which implies collective "cooperation" with it [*Ramírez, Wilkinson*, 2016]. A shift in these attitudes is now taking place, from proactivity to interactivity. Predicting the future is difficult due to the complexity and disarray of economic and social processes. Therefore, the constructivist approach based on carefully working with trends turns out to be the most relevant one. Weak signals are taken into account, which might imply the emergence of new strong trends. Scenario planning is carried out through multiple iterations of probabilistic forecasts based on deep expert knowledge.

The World Business Council for Sustainable Development (WBCSD): case study

How the provisions of complex systems theory project on production processes can be illustrated by the example of the major project WBCSD Vision 2050 being implemented by the World Business Council for Sustainable Development (WBSCD) [WBSCD, 2010]. This association brings together about 200 leading companies from 36 countries specializing in 22 industries. The project's goal is to develop a set of measures that companies need to jointly implement to switch to a fundamentally new development model by 2050.

The measures were identified through scenario planning based on the complex systems theory. A strategic document "Vision 2050: The New Agenda for Business" [WBSCD, 2010] was produced with input from 29 leading international companies operating in 14 industries. Scenarios were used in combination with building a preferred vision of the future, retrospective analysis, and modeling, which allowed for preparing a roadmap specifying decision-making timeframes for large companies. Problems with expert evaluation arose over the course of research and the production of the document due to the still widespread linear approach to perceiving reality. These issues hindered the combined application of different methods and widening the focus to holistically cover and interpret global, regional, and industry-specific contexts. They were overcome by conducting retrospective analysis which allowed one to mentally move back in time, from the desired situation in 2050 to the present. As a result, 40 measures were outlined to advance to a new development level, along with more than 350 points on the roadmap implementation timeline.

The combination of scenarios allowed for rethinking the current situation and the traditional consumption-driven growth model. Typical linear projections of global megatrends for 2050 were identified at first followed by discrepancies with the planet's actual resource potential to support such development. Thus, the current views of growth prospects, barriers, and risks have been adjusted according to the actual state of affairs. As a result, nine areas for parallel implementation were identified, along with new "systemic" solutions based on intersectoral collaboration such as the transition to a **new waste-free** economy model, circular recycling design, and promoting cities' transition to sustainable development.

The WBCSD Vision 2050 strategy highlights approaches and practical tools suitable for application in an increasingly complex world, which helps one avoid problems by combining different solutions, involving a wide range of participants and widening the reach of all possible perspectives.

Valuable lessons from this case study include engaging experts who adhere to different viewpoints and applying a wide range of interpretational frameworks to build plausible scenarios. This allowed for exposing the fallacy of the existing beliefs in the linear nature of external changes and the possibility of maintaining continuous linear growth [*Wilkinson et al.*, 2013].

Building scenarios based on intuitive logic allows one not only to better assess the actual evolutionary potential of the extraordinarily complex world, but also to develop strategies for adapting to it to achieve a preferred future. Three types of complex systems need to be simultaneously addressed to accomplish this objective [*Spangenberg*, 2020]:

- *mental model (perceived reality)*: applied to understand the reality and build recommendations on this basis;
- *computerized model (virtual reality)*: allows one to quantitatively assess the assumptions generated by the mental model;
- *extraordinarily complex world (actual reality)*: disrupts the design of the first two systems by demonstrating unexpected behavior.

To prepare effective scenario recommendations, all three system types need to have a comparable complexity level. If this condition is not met, confusion and misperception of probability, uncertainty, and ignorance concepts arise, so the resulting scenarios and the recommendations based on them will be erroneous and misleading or, at best, useless for decision-making. Thus, ensuring that the mental models applied by developers of scenarios, strategies, and roadmaps adequately match the nonlinear development of the world is a key success factor in working with the future [*Spangenberg*, 2020].

Shell's Lessons

Many WBCSD member companies have used Vision 2050 to develop their corporate strategies. One of them is Shell, which has more than 50 years of unique experience in building scenarios to remain competitive and design the future. Shell perceives the future not as an object of research, but as a "partner" with whom it "interacts" in a participatory format [*Ramírez, Wilkinson*, 2016].

Shell's road to success began in the late 1960s when the company was regarded an outsider in the energy industry [*Laudicina,* 2012] and strived to find solutions to make a breakthrough to a new level. Shell was one of the first to pay attention to the results obtained by the leading research organizations RAND and the Hudson Institute, in particular the scenario planning technique [*Jefferson,* 2012]. The correct choice of strategic tools and their consistent application allowed it to survive the global shocks and crises (such as price fluctuations and the collapses of oil markets caused by geopolitical shifts in 1973, 1979, 1986, and 1991) with minimal losses and identify new opportunities.

Drawing on knowledge of complex systems, Shell applied this conceptual grid to scenario building, which allowed it to understand and interpret weak signals, identify critical uncertainties and non-linear turns in business cycles. Pierre Wack, the founder of Shell's scenario building practices, named the following key steps in this activity [*Wilkinson, Kupers*, 2013]:

- identifying the most important trends and breaking them down into predictable and unpredictable ones;
- identifying sources of uncertainty with the greatest impact upon the course of events;
- drafting a set of possible plots and their outcomes with an in-depth analysis of any scenarios whose credibility cannot be refuted by logical reasoning;
- iteratively refining the scenarios, with a focus on weak signals and wildcards.

The approaches to and emphases upon applying these principles were not always the same. At the early stages, in the 1970s, scenario building was based on iterative re-perception and seeing of the future: designing interpretive frameworks for decision-making. The success of scenario planning was predetermined by the fact that from the very start, scenarios were inbuilt into all organizational processes: strategy development, risk management, promotion of innovation, and the development of a leadership culture [*Wilkinson, Kupers,* 2013]. In the last decade, this activity was primarily focused on "seeding the future": selecting tools to support decision-making involving a wide range of specialists in different fields. Scenarios correlate with quantitative models and are coordinated with other corporate processes including the development of innovation strategies [*Wilkinson et al.,* 2013]. Scenario building at Shell has a number of specific features: scenarios remain unfinished ("open stories"), go through multiple iterations during discussions [*Bentnam,* 2014], and are sensitive to weak signals. This process is accompanied by unique staff training methods.

The nonlinear approach allowed Shell to accurately predict the fall in oil prices in the early 1980s and develop effective countermeasures. After the energy crisis of 1973 the company developed the "Boom & Bust" scenario which provided for the possibility of "vigorous recovery containing the seeds of its own destruction" [*Wack*, 1985]. Shell displayed a degree of flexibility that was rare at the time. Without trying to predict when the overall crisis will end and recovery will begin, the company chose to develop a set of preventive measures. The recovery in oil prices after the 1973 crisis occurred very quickly and was called the "released spring effect". Certain economies, including the United States, grew by 11-12% in 18 months, which is similar to an economy the size of Britain's springing up from scratch. Such a rebound does not mean outstanding achievements, but only reflects the depth of the "dent" the global economy received in 1973-1975. Positive feedback was the basis of this rapid nonlinear growth, when the initial increase in economic indicators contributed to the further acceleration of their growth. In the theory of complex systems such processes are called peaking regimes, when growth occurs not exponentially but even faster, according to the hyperbolic law. Actually, such surprises are not uncommon in business cycles [*Wack*, 1985].

The complexity theory points to the need to pay attention to the harbingers of radical change. When a certain value begins to change so that the cycles become increasingly shorter and the amplitude of change increasingly larger, this heralds a turning point: a crisis, a change in the development regime. Processes of this kind took place in the economy in the 1950s, when phases of increasing amplitude and decreasing duration were observed. From the outside, the state of the system still looks the same but its swing indicates increasing instability and the imminent arrival of a turning point in its development.

Shell's approach to solving the mental models problem is remarkable: overcoming decision-makers' indifference to information in the scenarios. It is not enough to simply paint a picture of uncertainties, outline a spectrum of possible development paths, and present model calculations. These results will not be recognized if they are not adapted to the recipients' mental models [*Wack*, 1985]. Therefore, the mental "soil" needs to be prepared for "seeding" nonlinear knowledge. For scenarios to be taken into account in decision-making, they must transform people's reality perception patterns, taking into account their personal cognitive characteristics. Shell has developed a phenomenological approach which explores the perception of reality through the prism of personal experience. Scenario planning is complemented by a critically important aspect: working with recipients' individual perceptual, mental, and practical experience using narrative methods which imply creating realistic future plots referencing personal experience and a strategic vision of development paths. This allows one to critically rethink the existing images of the future and the strategies based on them [*Cornelius et al.*, 2005]. This approach proved to be more effective in changing perceptions than simple comparative analysis of scenarios and working with digital data.

Another technique is "deep listening" to decision-makers during structured interviews. It allows for identifying the respondents' key problems and approaches to adapting their perception at a later stage.

Shell's exclusive toolset helped create a unique corporate climate with the right constructs, promoting freedom of discussion and acceptance of an "open-ended" future [*Wilkinson, Kupers*, 2013]. It is based on an approach which sees the company as a living organism whose development can be blocked or, on the contrary, facilitated by the environment. The environment created by Shell fosters the rapid development of skills required to capture weak signals, construct new trends, and develop a culture of synergistic discussion.

Another important problem is the fact that the external world (actual reality) is always more complex and unpredictable than the attempts to adapt mental and computerized models (perceived and virtual realities) to match it. The element of uncertainty and unexpectedness is invariably present in the objective reality and, moreover, it is very significant. Therefore, despite its colossal long-term scenario building experience, even Shell does not always manage to catch the changes in the outside world in time. At least three major events were not envisioned in Shell's global forecast models, namely the 2008 financial crisis, the shale gas boom in the United States, and Germany's decision to accelerate the transition to renewable energy after the Fukushima nuclear disaster [*Wilkinson, Kupers*, 2013]. Nevertheless, Shell managed to find ways out even of these situations with relatively small losses, thanks to a timely and well-thought-out response policy.

Shell is currently developing scenarios not only until 2050 but also until the end of this century. Based on the latest advances in the development of evolutionary, holistic, systemic, and network approaches, and on the need to have knowledge of a wide cultural context for doing business effectively, the company builds scenarios not only for the energy market, but also for the economy, geopolitics, environment, and resource conservation. Geopolitical confrontation is currently increasing on various levels along with the pressure on oil companies due to the need to solve environmental and social problems. Taking into account the present and emerging challenges, Shell strives to make its business more flexible and customer-oriented, responsive to the social and cultural changes taking place in the world, and environmentally friendly.

Conclusions

The effectiveness of strategic foresight and scenario planning practices is due to their focus upon the advances of systems science. Representatives of this discipline show varying degrees of optimism about the future. Their positions are based on two key arguments. An individual with the appropriate competencies can consciously influence the choice of further development paths during periods of instability when passing bifurcation points. Fluctuations, minor changes (in historical terms, the actions of individuals) can become significant and turn the course of events in a new direction. The degree of optimism about the future may differ from one scientist to another, but there is hardly any doubt that one can actively participate in its creation. Experts describe such a model of the future using four main characteristics: possible, probable, preferable, and participatory future, or more generally, 4P futures. Shell analysts point to the need to radically change the attitude toward the future. Scenario building is not an attempt to predict the future, but to "cooperate" with it. The future can be "grasped" only through joint action, participatory activity, perceiving a plausible scenario as a personal experience embedded in global context. Long-term development options can be calculated and choosing the path to the most favorable vision of the future, designing trends in accordance with humanitarian values is the responsibility of each member of society.

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