# THE ROLE OF COMPLEXITY, UNCERTAINTY AND IRREVERSIBILITY IN SOCIAL SCIENCES AND MODELS

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**Abstract**

Complexity, uncertainty and irreversibility are notions generated in natural sciences, where they have induced a change of scientific models, in spite of initial misunderstandings and rejections. Considering that complexity, uncertainty and irreversibility are characteristic for business activities and life in modern society, this paper, while using the insights of natural sciences, attempts to (re)construct their role in social sciences, especially economics and economic models. It is difficult to properly quantify these indicators, a fact which often led to explanations that treated them as anomalies, while they were excluded from scientific models. It is therefore not surprising that answers given to economic questions often did not contain these variables and were consequently often paradoxical. Complexity, uncertainty and irreversibility are indicators suitable for the information age, and were not utilized in the terminology and models of the industrial age and classical science. By generalizing and connecting contemporary insights of natural sciences with systems theory and chaos theory[1] it is easier to answer questions asked within social sciences, and especially economics.

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[1] One of the main postulates of chaos theory is: simple systems generate complex behavior. Complex systems are sources of simple behavioral patterns. Most importantly, the laws of complexity contain universality, disregarding the building elements of the system. Glick, J. "Kaos." Zagreb: Izvori, 1996, p.308.

## INTRODUCTION

Changes in science were always grounded in natural sciences. Due to greater possibilities of experimentation in natural systems (although it often seems that living in social systems means living in experimental conditions) and due to higher verifiability of the results, the scientific paradigms of natural sciences were modified and became paradigms of other scientific disciplines. For example: Newton's model of the universe based on absolute space and time, elementary solid particles, strictly causal natural phenomena and on the ideal of objective description of the world was for a long time generally accepted as the model of the entire scientific world. Similarly, numerous economic models, based on classical science, gave unexpected and even paradoxical answers to questions posed. The more practitioners and researchers tried to explain the situation, the sharper became the paradoxes. Using tightly structured models and strict determinism, social sciences more or less successfully resolved the problems of the industrial age. When, however, those same causal models attempt to answer the problems of the information age, the same paradoxical situation is created as the one the physicists found themselves in while trying to describe the atomic physics in terms of classical physics. This paper does not claim to teach about the scientific paradigm changes in natural sciences, but to demonstrate openness to the introduction of some of those concepts to social sciences even before the paradoxical responses coerce us into it. So when F. Capra states: «...we cannot decompose the world into independently existing smallest units. As we penetrate into matter, nature does not show us any isolated 'basic building blocks', but rather appears as a complicated web of relations between the various parts of the whole. These relations always include the observer in an essential way. The human observer constitutes the final link in the chain of observational processes, and the properties of any atomic object can only be understood in terms of the object's interaction with the observer. This means that the classical ideal of an objective description of nature is no longer valid",[2] it is difficult to believe that he is explaining the principles of quantum physics, and not those of economics. Therefore, if we want to learn to ask the right questions and get the right, and not paradoxical, answers, we must, just as natural sciences do, pay more attention to the notions of uncertainty, complexity, irreversibility, even when it is difficult to quantify and use them in scientific models.

[2] Capra, F. "The Tao of Physics." Fontana/Collins, 1976, pp.371.

## COMPLEXITY AND UNCERTAINTY - FROM STREAMLINE FLOW TO TURBULENCE

Even small differences in some of the key action factors[3] can induce sudden and important changes in the system behavior, which in the process changes from predictable through random to chaotic.

Due to their openness and dynamics, social and especially economic systems are susceptible to accelerated movement from the streamline (laminar) to chaotic flow. When the flow is laminar, small disturbances disperse on their own. But after the turbulence, as chaotic disorder in all measurements (small vortices within bigger ones), sets in, the disturbances grow to catastrophic dimensions. Turbulent movement, i.e. processes, is inconstant and random. In an economic system they create resistance and spend its resources. In order to understand a turbulence one should, first of all, understand complexity and change. Complexity is understood as the numerosity and diversity of the factors relevant for making business decisions, as well as for the numerosity and diversity of the connections between the factors. It is important to notice the existence of the internal and external complexity. Internal complexity is conditioned by the development and diversification process within an organization, while the external complexity is induced by social, economic, legal and political changes in the environment. Simultaneously with the increase in complexity rises the change dynamics of certain processes (the number and the speed of changes is increasing). Turbulence thereby brings fast and numerous changes and the growth of the internal and external complexity together.

In his book *Strategic Management*[4] Ansoff has identified following factors that contribute to the emergence of turbulences: *decreased predictability of change*, which is reflected in ever shorter time spans that are available for strategic reaction; *level of novelty of change*, as the measurement of immutability of existing organizational potentials that an enterprise can keep while taking control of the change, and *increase in the frequency of change* which indicates that we have to expect an increasing number of changes within ever shorter intervals.

[3] Sensitivity to initial conditions lies in the core of the chaos theory, while the unpredictability of the chaotic systems represents one of the biggest restrictions in scientific thought, which we inherited from the twentieth century.

[4] Ansoff, H.I.. "Strategic Management." London 1979. pp.50, as cited in: Osmanagić Bedenik, N.: "Potencijali poduzeća." Zagreb, 1993, p.34.

Liessmann[5] presented a good explanation of the influence of the environment (external complexity) on the development of turbulences using the following scale:

- *First level* of turbulence exists in a *cyclically repetitive environment,*
- *Second level* occurs in an *expanding environment,*
- *Third level in the environment of constant change*
- *Fourth level in the environment of sudden change*
- *Fifth level* of turbulence is associated with an *unpredictable environment*.

In the circumstances of Croatian economy the first two levels are improbable. Third, fourth and fifth levels are characteristic for our time and although it generates fear in many, turbulence is not always negative.

During the transition from turbulence to chaos autonomous use of random processes occurs, which results in saltatory development and a state of higher complexity. Such processes, recognized in nature, led to the development of the indeterministic theory of purposeful evolution, i.e. the theory of self-organization. According to this theory, the Second Law of Thermodynamics[6] is of importance only in the thermodynamics of closed systems. To open systems, such as all social systems, and thereby economic systems, followed by a high level of interaction with the environment, apply the laws of thermodynamics of real systems, therefore those who in science seek a general understanding of the habits of nature would be better served with the laws of chaos than the Second Law.

According to contemporary scientific interpretations, chaos that occasionally occurs in the behavior of complex dynamic systems, such as social systems, is fractal in its nature.

"The word *fractal* came to stand for a way of describing, calculating and thinking about shapes that are irregular and fragmented, jagged and broken up - shapes from the crystalline curves of snowflakes to the discontinuous dust of galaxies. A

[5] Liessmann, K.K "Strategisches Controlling als Aufgabe des Managements." *Handbuch Controlling.* Stuttgart: Poeschel, 1990, p.305-308.

[6] According to the Second Law of Thermodynamics, everything is inclined towards chaos. Every transition of energy from one form to the other loses something in the form of heat. *Entropy in the universe increases constantly, just as in any other hypothetical isolated system.*

fractal curve implies an organizing structure that lies hidden among the hideous complication of such shapes."[7]

The fractal character of chaos manifests itself as a trait of trajectories in phase space to shift from regular or periodic trajectories to stochastic ones and vice versa.

This causes the modern systematic thinking to reverse into its opposite. System behavior is unpredictable, and in more complex systems even chaotic. In the chaos that was generated this way we find stochastic attractors, points of stationary state, some sort of attraction force that brings regularity to chaos, while the recognition of these regularities can take the system to a higher-order state.

This is the reason why contemporary social and economic organizations (especially in Japan) cause "random" fluctuations, which through mutations (of the existing organization) leads to saltatory development and higher-order state. The creation of turbulence gives rise to entropy, which in turn brings forth the construction of information where there was none and thus the knowledge of the system is augmented.

Turbulent flows (processes) impose an intensive exchange of matter, energy and information on every level and in all directions. Some of these connections can be fatal, while others mean new quality, and even self-organization.

In the recent theory of organization of social systems, self-organization is revealed as continuous self-regeneration, new birth of organization[8] (on the higher level; author's comment). Dee Hock[9] brought attention to the harmonic combination of order and chaos by his "chaordic" (CHAos + ORDer) organization.

Unpredictability which is associated with turbulent and chaotic processes is typical only of human systems, therefore the necessary transfer of relevance from idolatry of the mechanic world order (industrial revolution) to the human model of action (postindustrial and information society) is unavoidable. Thus the self-creating ability of the people who represent the pillars of an organization becomes the fundamental criterion, as well as resource, of the overcoming of the complexity and uncertainty of the turbulent and even chaotic surroundings.

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[7] Glick, J. "Kaos." Zagreb: Izvori,1996, p.123.

[8] Jušić, B. "Sustavsko mišljenje", vol 3(3), 1994.

[9] Dee W. Hock. "Birth of the Chaordic Age." San Francisco: Berrett Koehler, 1999.

## GROWTH OF UNCERTAINTY FROM CLASSICAL ORGANIZATION THEORY TO MODERN VIEWS

From the antropological point of view, uncertainty represents the main characteristic of human existence. From the decision-making point of view, uncertainty could be seen as any situation in which there exists more than one form of behaviour, whereas a decision represents a choice between these possibilities. As J. Monod stated: „Human destiny and human goal are not written anywhere, and it depends solely on a human being what he or she will choose. A man always brings uncertainty into his or her choices...“.

In Croatia information uncertainty is very interesting regarding the relationship between a company-system and its relevant economic, legal and political environment. We cannot count on relationship between a situation of certainty, in which the future of an environment is unambiguously determined, whereas a system can be determined and can act towards it unambiguously (certainty equals 1) and optimally. There is a growing number of situations where the future is ambiguously determined and can be seen through two categories:

- Risk – when the ambiguity is known and likelihood is predictable, that is, it can be measuerd (likelihood is bigger than 0 and it summs up to 1).
- Uncertainty – when the ambiguity is of an uknown likelihood and it brings unsecurity and hazard. In situations of certainty an ability to judge relevant factors is needed for decision-making, wheras in situations of uncertainty evaluating outcomes and modalities occurs as a specific content of a decision-making process. Furthermore, decisions have a „routinized nature“ in certain instances and are chosen from a „programme“ that is at disposal, and which has been, for a huge part, already incorporated into the structure of a system. Uncertainty demands, on the other hand, making new decisions based on specific evaluations of multiple directions of acting and their possible outcomes.

Rational system behaviour demands a possiblity of behaviour forecasting and evaluating – of a situation, action and effect. That is why in risky situations one tends to anticipate and evaluate the likelihood of occurance of possible outcomes and their utility. When uncertain situations occur, exploring the future might be a strategy to employ, which decreases areas of uncertainty, as a result of which, uncertainty is transformed into likelihood and hazard into risk.

There is a need to be reminded that even Taylor and Fayol put an emphasis in the classic organization theory on an important, from today's point of view even overly emphesized, role of structures and functions in overcoming uncertainties. According to them, a structure and functions can eliminate every uncertainty and a need for a free judgement.

Later on, March and Simon, in theory of social systems and theory on adaptable and rational organizations, pointed to a crucial role of an organization structure in absorbing uncertainties.

The fraim for decision-making, according to this model, consists of an organizational structure, which, with its characteristics, either complicates or facilitates decision-making process, which regulates uncertainty.

The process of decision-making means, above all, use of standard operative procedures, which (are already determined by structure) almost automatically lead to a decision. As a result of it, one tries to incorporate into these procedures everything, which alleviates doubts and conflicts. The procedures can represent a result of a decision- making process, when bigger issues are not concerned.

However, a system is becoming more and more a part of a complex and extremley uncertain environment, which influences its choices and vice versa. The environment is considered to be that part of the surroundings, which determines requests for a system (i.e. a company) with regard to achieving its goals and with which it has to comply with. Finally, in order to fulfill dimensions of openess and dynamics as preconditions of its survival, the system meets one of the needs of its environment with its purposes. Vice versa, structuring parts of the environment will depend on abilities of the system to meet its environment's needs (and on the way it monopolizes those abilities), which are relevant or potentially relavant to defining and achieving goals of the system.

In order for a system to succeed, it is not enough to know the certainty level of an incoming information from the environment, but one should also know certainty of effect of decision makers‘ activities – a system.

To more fully understand the system behaviour with a regard to the level of the environment's certainty[10], it is good to check some of the dimensions which determine such a behavior.

**Table 1:** System behavior regarding the level of the environment's certainty

| SYSTEM | ENVIRONMENT | | |
|---|---|---|---|
| | CERTAINTY | RISK | UNCERTAINTY |
| PROBABILITY | Unambiguous situation, certain S1<br>w=1 | Ambiguous situation with known likelihood S1-Sn<br>0<w<1<br>∑w=1 | Ambiguous situation with an un known likelihood S1-Sn<br>w=? |
| ANALYTICAL METHODS | Deterministic | Stochastic | Heuristic |
| PREDICTABILITY | Forecast | Forecast | Projection |
| RESEARCH | Past (trend) | Past (regression analysis) | Future<br>(decreasing uncertainty, scenarios) |
| PLANNING | Programming | Programming | Strategy, strategic games, scenarios and simulations |
| SOLUTION | One optimum | One optimum | More conditioned suboptimal solutions |

Methods that are to be used while making decision in the given three situations of the environment's (un)certainty depend on time (how early new phenomena are anticipated) and range of information and their significance for the analysis and perceiving of changes.

In accordance with it, data collecting systems for early warning have been developed throughout many areas, which are also known as radar or alarm systems.

Predicting in risk and security conditions was based on knowing the past and present, which was enough for creating forecasts and extrapolation of the future.

[10] According to: Masse, P. Le plan ou l anti-hasard, Gallimard, p.188-200, the table has been modified because of this article

Nowadays, forecasts lose its importance since the relation between achieved and planned results is mostly inadequate.

For forecasting, stable objects of observation are required, as well as linear time, which makes it inapplicable in conditions of great complexity and rapid changes. We do not live in times when in the focus of our attention were immobile phenomena. Our primary interests are not stabile situations and perseverance anymore, but rather development, crises and instability. We do wish to research both phenomena that remain constant and phenomena that change, evolution of growth, genesis and mutation of the norms of social conduct.

Real life as well as science shows a creative role of irreversibility nowadays, which enables processes of spontaneous organization. We live again in the world of coincidence where reversibility[11]and determinism are just rare cases, whereas irreversibility and indeterminism are becoming the rule. The notion of classic science that treats irreversibility as an illusion or as a result of a superficial description is in conflict with the new concept, according to which irreversibility is a source of order, creator of organization. Irreversible processes cease to be just approximation of reversible processes, and the growth of entropy is not synonymous to losses any longer, but it also represents a spontaneous evolution of the system.

Uncertain future cannot be anticipated based on the past and present, but only by exploiting uncertain future by creating scenarios of the environment in the range from optimistic to pessimistic, and by simulating possible behavior of a system. Forecasting is giving way to projecting or even anticipating, which is why there are no more unambiguous goals or unambiguous and optimal solutions. In an environment where only a change and complexity are certain to happen, strategic management is becoming more important. We do not talk about or use "or … or" strategies, but rather "and … and" strategies, which describes a dynamic play of the system with its environment. Within the play of order and chaos, decision-making is not associated with long-term plans and conservative strategies, but with a pure feeling of utility and healthy principles, with a help of which a number of

[11] Irreversible (lat. irreversibly): irrevocable, unalterable, unrepeatable, can happen just in one direction, one-sided
Economic processes are irrevocable in time; it is impossible to go back to the time when one was preparing or making a decision by trying to "fix" the wrong one. Once a decision has been made, resources have been used, which may cause durable consequences to the system and the environment, and so changing preconditions for the future.

individual and short-term goals (which are understood and which lead to the desired goal) are created.

## MODELS, THEIR BOUNDARIES AND USE IN NEW CONDITIONS

Decision-making in new conditions is opposite of static decision-making in an orthodox economy. Neither of classic methods of projection is satisfactory. When control services compare ex post results with the anticipated ones, disappointments appear frequently. People involved with statistics, economy or social accountants have been trying to hand in compatible reports, which could be capable to, at least, partially determine the direction of actions. To put it more precisely, projections with changeable objects should possess a certain level of coherence, but all the phenomena they try to show, occur in irreversible time, and for none of them there have been any tested dynamic regularities, or likelihood coefficients that could be used. Linear projections do not include fluctuations. Exponential projections depend on the choice of exponents and have the same disadvantage. Logistic projection is based on a notion of a long evolution as a known fact. For a long time the only "cure" for unsatisfactory projections were "audits" that were performed in continuously shorter intervals. The term "projection" has lost its meaning in that way, so a good anticipation may even be better than a classic projection.

Hence, many questions arise frequently, such as if the new decision-making will have problems with quantifications, mathematizations or, more broadly, quantitative analysis; if it points out to difficulties that economics deals with since it is preoccupied with narrow theories and market analyses, and detached from historical dynamism or human resources. Are formalizations and mathematizaitions, applied to economics, not on the way to qualitative progress, accepting neglected variables and relations, some of which are a part of new idea of development?

In any case, it can be said, that the less irreversible time, complexity and uncertainty are taken into account, the harder it is to integrate into one model all the variables which may affect the functioning of a system or to choose, without any arbitration, the variables whose effect is crucial. It does not mean that we must give up that model, but rather that we must work on their operationalization.

Analogy and an inspiration for that could be the model of a constructive-dispersive structure, simplified by I. Prigogine[12] and the Brussels school's theory.

The main idea of that school is an evolution that may lead into metastabile forms of things and energy, farther from the positions of balance. Under the condition of neglecting plain verbal transpositions, it may show a way to researchers of physical, biological and information entropy-negentropy and to learning about their consequences in the economical and social systems. Such formulations are completely different from mechanical balance and inert objects; they are used in order to reproduce nets of goals and active systems at different levels in a more suitable way.

The latest models do not refer solely to units (individuals brought to simplified sequences of comparative statistics), but they also use instruments, with which one can achieve a combination of units and sectors (matrix), their interconnections (transient matrix) with asymmetries being included (diagonal matrix), and placing (according to one's needs) matrices of successive data into vector spaces where they are being deformed.

## CONCLUSION

By changing the object and methods of research, modern science is leaving the illusion of its exterritoriality and the notion of itself as an integral part of the culture in which it develops. Metamorphosis of science means inevitable search of models of fitting scientific work into the society, in order to make science more or less useful, and not deaf to the needs and demands of the society. Science is becoming an object of buy-and-sell agreements and a tool of global competition, and exactly that science, which will know to ask the right questions, and so it will get the right answers, is the science which can understand and change the world. In social sciences, changes of paradigms occur more slowly than in natural sciences (which have a greater possibility of performing experiments, and results of which are more susceptible to control).

However, noone prevents social sciences to include the notions and insights of natural sciences in a more creative way, e.g. when such occurrences happen that on asked questions, only paradox answers are repeatedly received.

[12] Prigogine, I., Stengers I. "Novi savez", Zagreb: Globus, 1982.

Physicists also received paradox answers when they tried to ask questions from atomic physics with a language of a classic physics[13]. Since questions and answers are related to systems, insights of natural sciences can be very easily transformed into social sciences – especially economics. We may even be able to better understand unexpected answers that life offers in the areas of the employment, stock exchange, energetics, ecology, industry, public sector, law and politics if we could understand and take into account the role of complexity, uncertainty, irreversibility of the world we live in. Although such phenomena are hard to quantify, we should not give up and we should insist on putting them into models, but we should also work on their operationalization.

There are no perfect systems for measuring and by gaining new insights, some parameters will be neglected, some new will be used, and as more complex they get, the greater is their importance for us. The goal of the model is, and it should be forgotten, to explain and not to simplify a condition, and what is the most important (the most truthful), will in time become the most simple.

The orientation of economic (but also social) systems directed towards achieving certain goals appears as an attractor, the focal point, which enables absorption and reduction of complexity and uncertainty.

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