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Complex Systems and Networking

The aim of the paper is to present the role of system aaproach like a modern science phenomena and the paradigm of interdisciplinary research.The phenomena of globalization, the dominance of transnational corporation, the World system Theory, Scientific Word System are briefly reviewed. They can be recognized as an attempt of interpretation of the evolution to the networking paradigm. The theoretical and conceptual analysis is given on the basis of the European and American scientific literature.

Системный подход представлен как явление современной науки и парадигма междисциплинарных исследований. Приведен краткий обзор явлений, таких как глобализация, господство транснациональной корпорации, теория мировой системы, научная мировая система, которую можно интерпретировать как попытку эволюции, приведшую к парадигме сетевой организации. Дан теоретический и концептуальный анализ на основе европейской и американской научной литературы.

K e y w o r d s: globalization process, networking paradigm, transnational corporation.

System approach. The beginnings of the system analysis go back to times when researchers became aware of limitations of a reductionist way of thinking, deeply rooted from Cartesian times and the development of empirical research of physical process during Enlightment[1]. Cartesius in [1] states that one of stages towards discovering truth is to divide each examined phenomenon into as many components as possible required for finding the best solution. The consequence of the accepted method was derivation of the totality in relation to its components as well as linearity of phenomena and sequence of cognizance implying division of a problem into components and then its recomposition.

Systems sciences were developed relatively recently, in the second half of the 20-th century. Until then, particularly during heyday of modern sciences in 18-th and 19-th centuries reductionist streams dominated. Predominant concept applied in science was to investigate phenomena in eliminating conditions, sepa-

[1] One can point out at other previous accomplishments i.e. Leibniz et al., development of modern science though makes for a clearer understanding of system research.

rating phenomena from their environment. The goal of this approach was to find a «simple» description of the investigated phenomenon, most frequently by using a model or a mathematical formula. It was not earlier than in the 20-th century that a concept arose according to which complicated phenomena and complex objects cannot be analyzed partially and reduced to simple (partial) chains of cause and effect.

A natural scientist Ludwig von Bertalamffy is widely considered as father of a new approach in sciences. According to him, all kinds of phenomena should be investigated as mutually interacting systems not only inside them but also in relation to their environment. Together with an economist Kenneth Boulding they founded (1954) a scientific society named Society for General Systems Theory (later renamed into Society for General Systems Research) [2]. According to those researchers the general goal of systems research is to create theoretical concepts and tools for interdisciplinary research. Interest in systems research resulted in large part from a development of analysis and interdisciplinary studies started during World War II aiming at finding solutions to military problems.

Numerous works originating from different sciences have contributed to the concept of system approach. They may constitute strong inspiration for the development of this theory in modern research. Among most important works one can enumerate: social science (E. Durkheim), psychology (K. Levin), linguistics (N. Chomsky), anthropology (C. Levi-Strauss). The crucial research however was carried out in cybernetics, systems theory and philosophy of science (Norbert Wiener, Ernest Nagel, Herbert A. Simon, Arthur Koestler).

System analysis is an example of coming back to a holistic vision of the world, a concept known already in the Antiquity [2]. It can observe like evolution of paradigms from mechanistic to organic concepts (Table 1). At present it has became more visibly present in many research concepts[3]. Particularly one element of reality which is economy requires a holistic approach taking into account its complexity and impossibility to methodologically reduce its phenomena (see Table 1).

The system approach based on a postulate of Society for General Systems Research is one of the most distinctive features of development of sciences concerned with organization and management in the second half of the 20-th century. The integrative importance of the system approach is based on a postulate of a complex approach towards objects treated as open systems, that is interacting with the environment. Simultaneously, aiming at integration of various concepts through fighting interdisciplinary obstacles as well as using analogies and similarities to construct models [4] can be observed.

[2] Aristotle and a maxim attributed to him «a whole is more than the sum of its parts».

[3] Its sign may be a growth in interdisciplinary research

Table 1. **The paradigms of systems thinking** [3]

Paradigm characteristic	Mechanistic	Organic	Dynamic
Theoretical origins	Newton, classical physics	Von Bertalanffy's General Systems Theory	Chaos and complexity research, self-organizing and autopoietic systems
Research focus	Principles, laws, regularities, predictions	Feedback processes, relationships and interactions with environment	Spontaneous organization, continuous self-production and self-induced change
Operative interest	Predicting, controlling, preserving	Steering, sustaining	Opening up for natural evolvement, evolution and innovation
		S y s t e m	
Type	Closed, static, deterministic	Open, equifinal	Uncontrollable, emerging, self-organizing, self-producing
Main function	Efficient rule-like functioning, linear	Self-regulation, striving for stability and equilibrium, linear or cyclic	Continuous self-renewal and self-production, non-linear
State	Static, permanent, sustaining	Near equilibrium	Far-from equilibrium
		E n v i r o n m e n t	
Role	Non-existent	Causal chain of events that effects the system	Created by the system's self-reference
Boundary	Closed	Open	Open and (or) closed
Relationship	Systems as self-contained wholes	Adaptation to environment; open interchange with environment, inputs and outputs explained by feedback loops, interdependence	System must maintain a distinct identity and be self-productive; Systemic capacity for change is greater than environment's capacity for change
		C h a n g e	
Role	Catastrophe	Momentary disturbance	Necessity
Source	No change	Environment, adaptation to environment	Entropy, fluctuations, continuous process of self-production
Pace	Slow	Moderate, continuous	Sudden, bifurcative
Means of knowledge creation	Exploitation of existing knowledge	Information from environment is processed internally into knowledge	Self-referential interpretation of data from environment within the system, iteration of weak signals

System structure. The system analysis may allow to attempt description of the structure. Relations between elements of a structure can be described in the following ways: the whole dominates, roles of elements are secondary; integration constitutes a condition of mutual connections of components into the whole; parts set in order in the above-mentioned manner constitute an inseparable entity and if one part is altered the remaining ones are altered as well; the role of a part is seen in the context of a goal that the whole is trying to achieve; the position of a part results from the nature of its function; the whole as a defined system or complex reacts in a similar way as its parts; any action should start from the whole, which constitutes rationale, while parts and relations between them should result from those solutions.

Investigation of a process may take a form of extraction of its elements as well as definition of relations between those elements and with the environment. A formal representation of the system can take the following form [4, 5]: $S = S_i$, R_i, R_{ij}, where $S_i = \{a_{i1}, a_{i2}, ..., a_{in}\}$, denotes a set of elements, i.e. a subset of the system; $R_i = \{r_{i1}, r_{i2}, \ldots, r_{in}\}$ denotes a set of internal relations taking place in the set; $S_i R_{ij} \{r_{ij0}, r_{ij2}, \ldots, r_{ijn}\}$ denotes external relations between $S_i S_j$ elements, where S_j is a set of elements which do not belong to the system.

Another way of representing the system may be the one proposed in [6] where the system is described by four dimensions: a set of parts $C(s)$, set of objects which do not belong to the system but interact with its elements $E(s)$, structure of the system $S(s)$, understood as static and dynamic relations between elements, as well as objects which do not belong to the system and $M(s)$ denoting processes occurring inside the system and regulating its functioning: $s = <C(s), E(s), S(s), M(s)>$ [6].

According to the author, System Theory and system research can be counted among most explored theories in the contemporary science, including social and socio-economic sciences. It seems that such concepts as catastrophe theory, chaos theory, synergetic theory or fractal theory will constitute a strong inspiration for research in contemporary global world. The main common element of theses theories is that according to them, systems are non-linear and unstable complexes.

Globalization and systems. Some authors [7, 8], tend to connect the beginning of theoretical discussion, research and practical interest in the phenomenon of economic globalization with a paper written in 1983 by T. Lewitt «The Globalization of Markets». Although problems dealt with in Lewitt's article touched mainly marketing and market issues in a context of standardization of consumers' likings they constituted a beginning for larger interest in the field of broadly understood economic globalization, particularly in American and Japanese scientific and business milieus. In consequence, it is commonly taken for granted that the era of globalization and phenomena connected with it are associated

with the beginning of 90's of the 20-th century. While associating with this period «the birth» of globalization some point at geopolitical events such as the fall of the communist block next to economic events such as globalization of markets, sectors and IT technologies development.

It is more and more common though to see globalization as a process possessing a broader historical perspective [9] which started in fact together with the expansion of the Western civilization and the beginning of colonial period. Some [10] propose to see the globalization phenomenon in a perspective of two periods: first starting from 1450 to modern times and second from 1945 to present. The latter, from the end of World War II to present times, can be classified according to Kondratiev's theory of cycles, in which rising phase (*A*-phase) lasted from 1945 until 1967—1973 and the second phase (*B*-phase) started after the first came to an end, and lasted until present times. The period from 1450 may be analyzed on the basis of interpretation of classic economic cycles embracing growth, development and periodical crises of capitalist economy.

Some example of system approach to globalization is World System theory by Immanuel Wallerstein. In his works he investigated developing African countries, his main interests concerned social and economic changes that took place in these countries. His World System theory was also inspired by dependency theory [11] and historical determinism present in neomarxism.

Wallerstein's World System is defined as a social system possessing its own borders, structures, rules, legitimization of authority and internal coherence Furthermore, World System is defined as multicultural territorial division of labor in which production and goods exchange is necessary for its citizens [12]. The division of labor is treated as a global category. This leads to the appearance of two independent regions of the world: core and periphery. There exists also a category of semi-periphery, countries constituting borders of two regions in which mixed characteristics of both areas can be observed. In consequence, the main subject of research of the World System theory are relations of dependence between those regions. A differentiating category is above all technology – countries technologically developed and dominant in this respect constitute core, others are counted into periphery and semi-periphery.

Treating technology as a factor of global advantage in the world system implies far-reaching consequences. It results in a sort of technological determinism based on the fact that new technologies and innovations became most desired elements of today's world. From the social point of view technology and innovations become a form of economic expansion and stay in a large part out of social control, society does not determine technological innovations, it simply uses them [13].

In the process of globalization and shaping of the World System the most important role is attributed to activities of transnational corporations (TNC). Nu-

merous authors conclude that relations in today's world are parallel to those with nation-state pointing at TNCs' domination over state organization [14—16]] and marginalization of state institutions. Functioning of TNCs is based on activities carried out over national borders and in a large scale, without control from those states. A certain part of research on TNCs is carried out in the direction of analysis of the network aspect in functioning of corporations. Such research was carried out among others in [17, 18].

Ross carried out his investigations in the USA by analyzing city systems in the context of functioning of corporations. He referred above all to location of corporations' headquarters and their subsidiaries in American cities. He concluded that corporations through placing their subsidiaries in other cities than their headquarters gain a certain level of influence on the economy of the city where a subsidiary is installed. Ross investigated industrial enterprises thinking that such enterprises have bigger impact on local labor market, level of investments, energy consumption and relations with the natural environment. The result of this research was creation of an urban system hierarchy and definition of relations between headquarters and subsidiaries as headquarters-subsidiary networks.

Evolution of influence and role played in today's world by TNCs can be pictured on an example of branches and subsidiaries development. In 1692, 100 biggest industrial corporations possessed 1288 branches abroad. In 1998, 100 biggest industrial corporations possessed almost 10 000 branches in foreign countries [17]. This example illustrates how important it is to see globalization in the network context. Simultaneously, revenues of 500 biggest corporations constituted 15 % of the world's GDP to achieve 28 % in 1998 [17].

While analyzing the World System phenomenon there appears one element that may draw one's attention. It is called Scientific World System. This system more and more often takes a networking form. This trend is clearly visible in EU's policy supporting scientific research (Framework Programs). One of specific characteristics of networks is a nonuniform distribution of knowledge (especially technical) and financial resources supporting scientific research. This is a crucial conclusion because it may be referred to network dependencies in the core — periphery setting.

Globalization of scientific research leads to the appearance of the following phenomena: promotion of wide institutional agreements and investigation of areas politically defined as important. In the 20-th century there was a visible trend to transfer main scientific centers and research networks from Western Europe to the USA. Scientific milieu is not an egalitarian one and researchers differ as to their skills, possibilities of carrying out research, level of financial support and, what is very important, as to possibilities of exchange of knowledge, thoughts and ideas.

Research centers with a proper atmosphere favoring scientific research tend to attract new scientists, thus becoming more and more powerful in knowledge and research potential, they become scientific centers. The term center refers to a sector of society in which certain activities which have special significance or function are relatively more highly concentrated or more practiced… [19].

It can be taken for granted that the center of science until 17-th century was located in Italy, then moved to Britain, France and Germany and finally in the 20-th century to the USA. 20-th century relocation of centers of science can be pictured by geographical location of Nobel Prize winners in chemistry, physics and medicine. This indicator is not perfect though since according to [12] in the beginning the Swedish Academy of Science tended to favor Scandinavian countries.

The above Table 2 presents a visible phenomenon of transfer of the center of science from Western Europe to the USA. Simultaneously, a growth of importance of the USA can be observed from 1920 i. e. ten years before a period of migration of German scientists of Jewish origin to the USA (in connection with Hitler's coming to power).

Networking. It has become more and more common to claim that the concept of innovations embraces everything that is connected with creation and application of new knowledge in order to win competitive advantage. In this respect innovations concern as well, apart from technology, economy, society and

Table 2. **Research for the Nobel Award** [20]

Place of research	Scientific center number at the period					
	1869	1900	1918	1934	1946	1970
USA	3	12	23	35	62	55
Canada	0	2	2	0	2	3
Germany	36	22	29	6	4	17
Rest of Western Europe	57	64	38	47	27	26
Australia, NZ, Israel	0	0	0	0	0	0
Eastern Europe	3	0	5	8	1	0
Eastern Asia	0	0	0	3	1	0
Rest of Asia	0	0	2	0	0	0
Latin America	0	0	1	1	1	
Africa	0	0	0	0	0	0
Contributions	30	42	49	30	85	26
Researchers	36	48	70	53	172	54

culture. A traditional approach applied by organizational and management sciences is not enough to explain and manage the development of enterprises. Modern economy recognized by P. Drucker as postcapitalist requires new approach to development challenges, where a single act of innovation is not enough. Innovation has to have a constant character. That is why in present times, the core of modern economy is characterized by network structure. One of characteristics of network dependencies being created is most frequently their spontaneous and chaotic character. In consequence, an important role is attributed to the environment of the administrative environment as a catalyst and participant of network cooperation.

Leaving behind a way of thinking that defines innovations as linear process: science (basic research) — innovations (implementation) — commercialization, towards a paradigm of continuous innovations (innovativeness) requires a different approach, very often a radical change of thinking. If innovativeness is: a constant process of flow and creation of knowledge, then certain factors defining effective functioning of network structure are of crucial importance.

Simultaneously, according to a new approach to innovativeness, creation of innovations depends on a complex approach. The word complex is vital since this approach should embrace the complexity of innovative networks as well as complexity of relations of cooperation and the whole network environment together with social context. Most frequently the innovative network environment is defined by means of the following elements: producers (creators) of knowledge; administrative environment; enterprises.

Network are comprised of three main elements: nodes, ties and flows. A node is a distinct point connected to at least one other point, thought it often simultaneously acts as point of connection between two or more other points. A tie connects one node to another. Flows are what pass between and through nodes along ties [21].

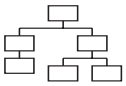
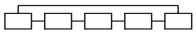
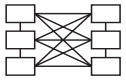
One of the most spectacular example of network structure is a cluster. Inside a cluster of enterprises one can find three kinds of networks: production, development and innovation. The above networks are characterized by different structure and functions that they perform in relation to information. Those functions are identified with basic processes concerning knowledge and information i. e. its creation, transfer and application.

In a production network, flows between participants are connected with manufacturing of a product and thus embrace mainly physical products and cash flows. Inside this kind of network the sales process takes place. All information transferred inside a network concern production, for example stocks. Such network may be dominated by one participant occupying a central position in it while other partners included in the exchange process may not even know each

other. Thus the structure of this network possesses a hierarchic character. To ensure its effectiveness, production network requires application of clear and coherent rules and regulations. That is why important information circulating inside a network should take a codified form to ensure that it reaches all units. It is sufficient that information circulates in one direction from up to down since any discussion or new thought may lead to modifications, which are not desired in this kind of network and may constitute an obstacle for its effectiveness.

Development network (Table 3) is characterized by horizontal structure and can be applied to join enterprises in a regional clusters framework, also in case when they do not cooperate in productive functions. Participants of such network can be competitors who agree to share certain information that constitutes a source of individual profit for them. Flows in a development network possess by nature an immaterial character. It can be for example information concerning production methods or know-how knowledge. Enterprises through learning best practices from others can achieve higher levels of effectiveness. From the perspective of regional activities, a network orientated for development may boost results of its participants in acquiring high-risk capital. The most important feature of this type of networks in undoubtedly orientation towards sharing knowledge and information. A constant development of network is based above all on silent knowledge, bi-directional flow of knowledge and mutually dependent relations of all participants. Relations that one deals with in the network possess a reciprocal character and at their base one will rather find trust instead of formal agreements. In a development network there is no dominant unit, however a coordinating entity supporting the process of knowledge and information diffusion sharing may be established.

Table 3. **Characteristic features of three kinds of networks of knowledge system** [22]

Category	Production network	Development network	Innovation network
Graphic model			
Structure	Vertical	Horizontal	Diagonal
Function performed in relation to IC	Knowledge implementation	Knowledge transfer	Knowledge creation
Flows between participant of the network	Material (products, payments); immaterial (information concerning production)	Immaterial (transferable specific information concerning enterprise, know-how)	Material (innovative products, payments), immaterial (research knowledge, experimental knowledge, know-how)

Taking into account realization of knowledge and information processes, the most advanced network in this field is innovation network (see Table 3), in framework of which new knowledge is created as well as new solutions needed to deal with specific problems are found. These solutions are worked out consciously and in cooperation with other members of the network. Flows in such network concern the process of innovation, for example product patterns or research knowledge of experimental character. Structure of relations in an innovation network is diagonal which means that its participants are recruited from different sectors and production chains. In this type of network various public and private institutions may cooperate with enterprises. Innovation network has to master the process of knowledge and information creation, which should be new to all participants of the network.

Conclusion. In the reality of network economy and society, system approach can be use for explain the complexity of the contemporary time. System approach can be the tool for scientific research and study of networking attributes:

a shift in capitalist economies from an industrial to an informational base;

the organization of economic activity globally on the network model;

reorientation of the temporal and spatial organization of human activity in response to technologies that enable real-time communication across vast distance;

distribution of power based on access to networks and control over flows;

escalating productivity of technology sectors and technology intensive industries;

increased technological mediation of commercial and financial activity;

restructuring of work and employment in response to the imperatives (possibilities) of information technology;

growing digital divides between those who are positioned to take advantage of network technology and those are not.

Системний підхід подано як явище сучасної науки та парадигму міждисциплінарних досліджень. Наведено короткий огляд явищ, таких як глобальізація, панування транснаціональної корпорації, теорія світової системи, наукова світова система, яку можна інтерпретувати як спробу еволюції, що призвела до парадигми сітьової організації. Дано теоретичний та концептуальний аналіз на базі європейської та американської наукової літератури.

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