Approach to the Organisational Complexity in Terms of Network and Intellectual Capital Concepts

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Abstract. *The viability of the systems depends on the way of adaptation of the internal complexity to the environmental complexity. Under structural aspect, any complex system represents a network. Complexity may be estimated on the basis of density and of the non-redundant character of the network. The capacity of the networks to create and diffuse knowledge is essential. Comparing the change speed of the environment with the knowledge processing speed in the system, we can determine the maximum complexity that can be absorbed. A close image of the internal complexity is the level of the human and structural capital. The external complexity may be expressed by means of the relational capital.*

Keywords: *requisite variety, endogenous complexity, exogenous complexity, network, intellectual capital*

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1. Introduction

Complexity has become a defining feature of modern reality. In an increasing manner, management has to administer structures and processes characterized by an increased degree of complexity. In this manner, management adds a pronounced constructivist touch to its epistemological profile of positive science concerned with the efficacy of the collective human action that of a science interested in efficient solutions to complex situations and problems. Gradually, management changes into a science of the use of complexity.

In this hypostasis, management needs paradigms and special analytical instruments, but that cannot be elaborated without a profound understanding of what complexity is, of its characteristics and properties, of how it is structured and functions. In this train of thoughts, we believe that the priority is the interception of the reticular nature of complex phenomena. The network represents the favourite structure of complexity. The emergent properties of the complex systems constitute the direct effects of the networks.

In order to survive and develop, the systems are compelled to adapt their internal complexity according to the level of the environment's complexity. It is a basic requirement of the complexity management. In essence, this approach takes into account the selection of the appropriate complexity – the complexity which the system is able to process efficiently.

The adjustment of the internal complexity of the system to its external complexity cannot ignore the close relationship between knowledge and complexity. We consider that they – knowledge and complexity – represent complementary and inseparable aspects: knowledge is stimulated and diffused by the complex structures, while complexity is, categorically, a problem of knowing the economical reality. This relation highlights the valences of the concept of intellectual capital as a diagnosis and management instrument of the complexity of economic systems. The motivation of this approach is simple: the intellectual capital is the expression of all the cognitive resources of the economic system (competences, processes, relations, attitudes, values, etc.), being, at the same time, a good measure for the levels of internal and external complexity.

2. Complexity, variety, redundancy

A viable system has not one regulator circuit, but many, corresponding to the different levels of organisation and parts (subsystems) of the system. In the absence of the variety in the adjustment of the system or in its relations with the environment, this falls inevitably in a state of inertia, risking even the disappearance. Ashby's theorem – the principle of the requisite variety – refers exactly to this aspect: *only variety can absorb variety.* Thus, in order to function in the presence of some high degrees of autonomy, there are necessary as many management levels (centres) as recursion levels exist (local feedback circuits integrated into the general circuit of adjustment of the system). True autonomy requires not few, but many levels of control. Thus, we see that if uncertainty expresses the background of the concept of complexity, variety (diversity) is that which gives it shapes.

Henri Atlan (1952, p. 85) observes that *„… in a direct manner the feeling of complexity arises from the encounter of a great number of different constituent elements"*. The measure of complexity is identified by the mathematician and biologist Ross Ashby (1947, pp. 125-130) with variety, and with the number of different configurations that can be composed by the elements of a system. This number of possible configurations, called variety, may record very quickly extremely high values and a higher variety and means a superior complexity.

There are, within the systems regularities or patterns of association of the elements, as some relations/relational configurations being forbidden, and other, compulsory. These regularities allow the recognition of some structures or stable shapes and not only the creation of some simple clusters of elements. The regularity of the associations is designated by the term redundancy (repetition). *The role of redundancy is to intervene in order to limit the number of theoretically possible configurations, counteracting, in this manner, the variety.* At limit, if within the system only one stable relational scheme is recognized, the redundancy is maximum and the variety is completely absent. The existence of redundancy reduces the variety within the system, although completely never eliminates it. Whenever there will be a certain degree of variety, which results mainly from the multitude of combinations and the abundance of the relations between the elements rather than their actual number.

Redundancy has the function to limit the variety, as some configurations are forbidden, and others are imposed under a repetitive form. If redundancy is maximum, the system is perfectly known and does not present for the observer any sort of complexity. But, if the redundancy is null, we have a maximum possible variety from the theoretical point of view. Thus, neither a structure, nor a stable form is recognizable within the system, which appears as a pure product of the hazard. The greater the complexity of the system, the less redundant the relational and functional configurations that characterizes it. Non-redundancy is a defining feature of complex systems.

Redundancy introduces elements of order in the system, allowing the recognition of some organisation and of a structure. Without a minimum of redundancy, the system is disordered, amorphous, having no true identity and any external impulse can annul it. Of course, if the redundancy is total, not only the structure is completely determined (most often in a trivial way), but also the movements of the elements of the system are entirely predetermined. Between these extremes, and between a redundant complication and a variety without any structure, between the “frozen” order and maximum disorder there is the hesitant path of complexity. Both extremes – rigid order and absolute disorder – are as dangerous for the survival and performance of the system.

An “optimized” organisation does not entirely disposes of the necessary capacity to be able to absorbe more variety than the one intrinsic to the system. The signals of the future will be ignored or, at best, sent to the top of the hierarchy. The diversity, instead of being used, will be reduced or even rejected. *The internal complexity must be equal to the external complexity for the organisation to survive and evolve.* It seems a paradox, but this fundamental principle becomes operational through the property of redundancy. Among others, *redundancy may be understood as the aptitude of the system or of one subsystem to capture and treat, by means of internal and external connection and communication channels, a superior level of variety than the one strictly necessary for its normal functioning.* It results that redundancy may be seen also as a surplus of capacity over the one indispensable to the normal functioning.

In absence of minimum redundancy, the organisation does not have the capacity to create its future in a dynamic and diverse context. But, too much redundancy may become a serious obstacle to the adaptation of the system to a changing environment. That is why, to create the future means for the organisation, it should equip itself with the necessary redundancy at all levels of adjustment. In any case, *there is no exclusion relation between the efficiency (the quality of the performance) and efficacy (the quantity of performance), but one of creative contradiction.* Efficiency means to optimize what we do today, based on redundancy. Efficacy refers to the way we build today the conditions of the future, involving the creation of variety (complexity) by dissolving redundancy.

Thus, the definition of complexity adopted by us has in view the diversity of the elements that make up a situation: a whole composed of parts that interact, which, in their turn, relate to the environment. From this angle, everything is complexity. Undoubtedly, the complexity may be understood and defined in several ways, representing, in essence, a matter of knowledge or, more precisely, of positioning the observer: one and the same thing may be simple for one person and complex for someone else. It is the reason that determines Cornejo Alvarez (2004, pp. 17-33) to present complexity as a difference between the resources (intellectual, informational, material, financial, relational, etc.) necessary to confront a situation or a problem and the resources available to the decision maker. The greater the distance, the higher the degree of complexity of the situation. A complementary definition is provided by Hall (1996, p. 45), who affirms that, in general, complexity may be understood as the level of knowledge necessary to determine the appearance of some results in concordance with the function – aim of the system. Knowledge is necessary in order to monitor and control the behaviours of the variables that form the system. A system is complex when its steerage is difficult, because of insufficient knowledge.

Whatever the definition adopted, for a careful observer *complexity presents almost always the following essential characteristics:*

1. it is fluid and imprecise, its knowledge being always incomplete and relative;
2. it is unstable and subject to hazard, manifesting itself as a mixture of order and disorder;
3. it is ambiguous, the elements of the system behaving differently, according to the circumstances;
4. it is characterized by increased uncertainty and unpredictability, the complex systems developing autonomous behaviours, free of constraints and external determinism, following not regular paths, linear, but non-linear and discontinuous (what takes place in leaps or bifurcations).

The increase in complexity of the system determines, by virtue of Ashby's principle of requisite variety, the diversification, shading and enrichment of the organisational behaviours. To remain effective, the managerial system cannot be less complex than the organized whole that it steers or than the environment in which the system evolves. Determining the degree of complexity of the critical points of the system allows the establishment of the type of management necessary to each of them.

3. The endogenous and exogenous complexity

The complexity of a system can be delimitated by two closely interrelated areas – the endogenous complexity (internal) and exogenous complexity (external). Of course, the borderline that separates them is relative and fluid.

The endogenous complexity may be described, according to Mihaela Vlăsceanu (1993, pp. 70-74) using the following variables: 1) degree of differentiation, specialisation or division of labour within the system; 2) dimension of the system; 3) formalisation; 4) degree of centralisation; 5) coordinative intensity.

The exogenous complexity is given by the number and the variety (diversity of the types) of the relations which the system has with its environment. What also matters is the character of these relations, which may be equivalence (inter-dependence), subordination (dependence) or coordination (power and autonomy).

Perhaps *the basic idea of the complexity management is the followig: complexity cannot be entirely eliminated.* In many cases, the environment or the exogenous complexity imposes the increase of the internal complexity of the system. The complexification determined by the environment is appropriate for the systems capable to respond to the environment's expectations and, at the same time, to deal with efficiently, in terms of the costs of functioning, to some complex activities and relations, which multiply continuously. The lower cost of complexity management may constitute, in the case of these systems, an important source of competitive advantages and improvement of performance.

Everything that happens in a system consumes energy, and the energy cannot be used without discrimination, but selectively and gradually. To use efficiently and effectively the resources of the system means to have the capacity of adequate management of complexity. The aim of this management is the balance between the endogenous and the exogenous complexity.

The internal complexification should always be a reaction to the increase in external complexity. *The exogenous complexity determines the endogenous complexity and not vice versa.* The dependent factor is the endogenous complexity, conditioned by the exogenous complexity. Certainly, the variation in internal complexity, induced by the external complexity, rarely has a linear or unifrom character. But a situation of normality exists when the exogenous complexity attracts the increase in internal complexity. The internal complexification, without any justification from outside the system is noxious. However, sometimes the complexification is initiated from within the system, being the expression of the way in which it organizes and manages its own functioning processes. In most cases, this complexification is useless or even counterproductive and may be attributed to the following causes:

1. the incorrect evaluation of the exogenous complexity of the system by overestimation;
2. the inadequate management of the internal processes, which makes that, under certain conditions, the complexification not be opportune.

Avoiding the useless endogenous complexification is able to help to improve the functionality of the economic system.

Complexity is not just a source of costs and difficulties that burdens the functionality of the system. Complexity is also, by virtue of the action of the principle of emergence (the whole is something more than the mere sum of its parts), generating *system effects*, the most important being the phenomena of synergy, cluster effects, multiplication and training effects, scale and purpose economies, etc. The system effects or the emergent properties, created by the interaction or indetermination of the elements of the system, confers it new abilities, richer and insures to it, on this basis, an increased functionality. In terms of complexity costs, their evaluation is difficult, however, we consider that (Dumitraşcu, 2010, pp. 53-54), in the case of microeconomic systems, a fairly accurate representation of the external complexity can be obtained by analyzing the transaction costs and of the internal complexity, by estimating the agency costs. *The mission of the complexity management is to ensure a relation between the system effects and the costs of complexity in favour of the first ones.* Based on this criterion, we identify the following general situations:

1. Σ System effects > Σ Complexity costs; the system manages to adapt in an active and efficient manner to its environment;
2. Σ System effects = Σ Complexity costs; dynamic balance between the internal and external complexity;
3. Σ System effects < Σ Complexity costs; the system has problems of adaptation to the environment.

The capacity of the system to adapt its internal complexity as a reaction to the fluctuations of the external complexity is optimal when, by adequate exploitation of the emergent properties, relation (1) is fulfilled.

The problem of the complexity management is that, as it happens to most aspects of the complexity, *the system effects and the complexity costs do not condescend, but in a quite low proportion to quantification and rigorous economic calculation.* The capacity of the system to manage its complexity depends, therefore, widely on the intuition, experience and competence of its managers, but also on the quality of the organisational mechanisms and values (organizational culture) that characterizes it. *At each stage of its existence, the system can establish, even with approximation, an adequate level of its complexity.*

Most economic actors are forced to face and deal simultaneously with several levels of complexity and this by virtue of the pluridimensional and plurireferential character of the economic reality. *The economic system, for example, a firm, represents a mix of degrees of complexity, its different parts approaching different levels of the internal and external structural diversity, different levels of stability of the contexts of action, different degrees of certainty of the states of the nature in which it has to decide and function.*

However lower the endogenous complexity of the system is, this remains an open system, interacting more or less frequently and intensely with the environmental variables. *The need to ensure the survival and the efficiency of the system in an increasingly complex environment determines the flexibility and the complexification of its relations with the environment, which leads, implicitly, to the increase in endogenous complexity.* It causes the fluidisation of the borderlines between the "interior" and the "exterior" of the system, and the capacity to promote performance behaviours in the context of the exogenous complexity makes the preservation of an adequate level of the endogenous complexity absolutely necessary. In this way, *the exogenous complexity conditions the endogenous complexity, which must be dosed according to the first.* This is *a necessary condition of viability* of the system.

Another important consequence of the analysed relations is the fact that the viability (competitivity) of the system has, invariably, a layered basis as a result of the capacity of "rational dissipation" or at least "reasonable"attention, efforts and resources between processes and economic phenomena with different degrees of complexity. The competitive advantages of the system result from the quality of the *portfolio of complexities* for which the system under consideration opted for. A *"good" complexity* is *a sufficient condition of viability of the system.* We can define "good" complexity as that combination of objectives, conditions, elements, connections and processes of the system that ensure its maximum possible performance in terms of some reasonable adjustment costs.

For an economic system to be viable means: on the one hand, the achievement of a close correspondence between the endogenous and exogenous complexity and, on the other hand, the careful selection of the "complexities portfolio". This rule requires a rigorous, but flexible control of the behaviours and of internal and external relations through which the functioning of the system is ensured, a control that favours the qualitative aspects in relation to the quantitative ones.

4. The network as a structural expression of complexity

Complex systems unite the diversity and the multiplicity of their elements, structurally interconnected in a network of relations, which gives them the possibility to adapt to different contexts, to develop the learning capacity and to change according to the acquired experience. Any complex system develops a subjacent structure in the network. From the morphological point of view, complexity has a reticular character.

The idea of network implies a multitude of points (nodes) united through a series of connections that perform specific functions. In the economic world, the network of interactions and relations between the actors of the system is the condition that generates emergent properties. Thus, the system effects represent a collective phenomenon (group), a result of the cooperation between the elements of the system. Social networks, including the economic ones, have three distinctive characteristics:

- Within the network there is a positive identification as a group, which means that its members feel and know that they are part of a distinct whole, which assumes its own identity and image in which the participants find and recognize themselves.
- The members of the network have a common strategy, which requires mutual, complex and long-standing interactions and adjustments.
- At the level of the entire network, there are decision-making mechanisms, more or less formalised, but accepted by all the members, which ensure the coordination of the actions, conflict resolution, costs distribution, adjustment of the strategy etc.

A specific condition of the formation of the networks is the high degree of appropriability of the results: collective strategies focus on actions whose effects may be assimilated by the members of the network in such a way so as to motivate and justify the efforts assumed by them. The reason that underlies the emergence and crystallisation of the networks is as simple as possible: the integration of the actions or the cooperation between the members enables the achievement of some things that could not be obtained by individual action. The network enhances the individual capacities of the members, producing system effects. The complementarity between the competencies and the resources of the members of the network outlines an operational framework characterized by an overall functionality that exceeds the algebraic sum of the individual potential of the participants. According to Johannisson and others (2000, pp. 127-144), the networks of firms have as generic objectives either the optimization of the use of the individual potentials of the members through a better distribution of the responsibilities or the development of an element of novelty.

Regarding the morphology of the networks, it can be described with the help of the following structural elements:

- Anchoring or locating the network, determined by the area occupied by the network in the gears of the super-networks in which it is integrated.
- Accessibility, defined as the extent to which the behaviour of one element of the network is influenced by the relations with the other elements and determined by the weight of the actors who can contact all the other elements and the numbers of intermediate elements that facilitate the relation between two elements.
- The rank or the degree represents the number of elements of the network with which a given element interacts directly.
- Centrality is the number of connections that reach a node, the overall centrality of the network resulting from summing the individual centralities of all nodes.
- The density is an overall characteristic of the network, indicating the number of effective relations in comparison with the maximum number of relations that could be generated within the network.

Among the foregoing criteria, density presents a special interest. We consider that the value of this indicator provides an overall idea on the degree of complexity of the system because it is the result of both the number of actors who form the network, but also of the configuration of connections that unite them. Density is a concept borrowed directly from the graph theory. In a network in which all the elements are related to the others, we will have a maximum density. In the networks in which some actors are linked only with certain actors, but not with everyone else, there will be areas with variable density. In the denser parts of the networks there are necessarily fewer intermediate steps in order to reach most of the other actors. The formula of calculating the density of the network (D) is equal to:

$$D = 2R/N(N-1) \tag{1}$$

where:

- *R indicates the number of relations established between the members of the network;*
- *N is the total number of members of the network.*

Density is a concept which influences in a decisive manner the quality of the relations within the network. The intensity of the relations (the value and the quantity of information exchanges between the members of the network), the frequency of the interactions (the average numbers of exchanges between the members of the network) and the stability of the network (average duration and volatility of the relations) are directly associated with the level of density. Therefore, the density of the network exerts strong effects on the speed and on the quality of the achieved communications, learning, acquiring and processing knowledge, as well as the exploitation of this knowledge in the processes of adaptation to the environmental conditions. In other words, the density of the network directly determines its capacity of self-organisation: the ability to explore solutions and new configurations as a result of the stimuli and challenges formulated by the environment.

Floyd and Wooldridge (1999, pp. 123-143) argue that the rapid diffusion and contagion of information, practices and knowledge represent essential characteristics of the economic networks. For this reason, Barabasi and Bonabeau (1997, pp. 50-59) show that their evolution has not usually a linear trajectory, but rather is subject to some exponential laws. The non-linearity of the processes conducted within the networks is due to the multitude of positive feedbacks, which often leads the system to explosive dynamics.

The density itself is influenced by aspects, such as: structural equivalence (elements of the network which fulfil similar functions); clusters (groups of elements densely connected); structural holes (interior areas in which the elements are not connected to the network); the E / I ratio (groups from inside the open network or closed to other groups); "small worlds" (small clusters with small distances between them).

The way in which these characteristics are combined determines the morphology of the network, generating an extremely wide variety of reticular structures from vertical or horizontal networks, with a relative complexity to the very complex „networks of networks", in which different networks connect to each other by means of some common (structural holes) points (nodes), forming „archipelagos" with a geometry equally extensive and kaleidoscopic.

The implications of the concept of network to ensure the viability of the microeconomics systems – the firms – are particularly active and may be summarized as follows:

- Competitiveness means less the better direct control of some essential competencies than the ones of the rival firms and more the capacity of finding quickly partners who have the required competencies.
- Competition takes place less between separate firms and more between networks of firms.
- The firm networks represent the “heart“ to generate the knowledge capital – by far the most important source of competitive advantages.

For the network’s efficiency the existence in the interior of its gear of the so-called *structural holes* is essential. The author of this concept Ronald S. Burt (1992, pp. 48-56) develops first the concept of *structural autonomy,* showing that an actor is autonomous to the extent to which his relations are not interrelated and, as a consequence, they cannot correlate in order to exert collective pressure on him. As a consequence, the actor is autonomous if he controls a maneuver space in its relations with the elements with which he comes into contact. The absence of the relations (structural holes) between the elements with which the considered actor enters into contact represent for him opportunities to control the flows of information and to coordinate the options between the elements separated by this holes. It results that the structural holes represent the “void“ between the non-redundant contacts. Two contacts separated by a structural hole may provide network benefits, which are cumulated by virtue of their non-repetitive, non-redundant character.

The diversity of the contacts of an actor multiply, by different means, its information benefits because, in this way, the relational network in which the actor integrates is richer in structural holes. In essence, structural holes represent sub-sets of non-redundant contacts and, regardless of the number of their members; they are unique sources of information. This happens because, outside the structural holes, the elements directly connected know, usually, the same things at the same time. Lazega (1994, pp. 79-86) shows that the non-redundant sub-sets provide a competitive advantage and, on this basis, the safety of the actor in being informed about the opportunities or the immediate crises. These are the so-called *access benefits.* Another category of advantages, *the synchronization benefits*, appears to the extent in which the non-redundant contacts are linked only through the considered actor, placed in the center of the network and which, by virtue of his intermediate position, will capture first the new opportunities created by the needs of one of the elements of the network and which can be satisfied with the resources of other elements. The third category of advantages, *benefits of opportunities allocation* results from the fact that the centre of the contacts network, with diversified links has, consequently, more chances to be taken into account in the allocation of the new opportunities. These types of benefits accumulate due to the fact that a dense and productive network in which an actor is integrated makes him, in the eyes of the others, more attractive in his position of possible contact and partner.

Structural goals are the result of the non-redundant contacts within the network. It is the argument which make us believe that the weight of the non-redundant relations in the total of the relations within the network may be regarded as a reliable clue at the level of complexity of the network. This is because, as we have seen, the complexity is driven by non-redundancy.

5. Indexes of endogenous and exogenous complexity

Although complex situations are very difficult to surprise with the help of quantitative methods, the necessity of some means, even imperfect to treat the complexity towards managing the systems is undeniable. We consider that, in the case of the microeconomic systems – the firms – the category of these instruments may include *the indexes of endogenous and exogenous complexity.* The hypotheses on which the elaboration of this indexes has been based are as follows:

1. The firm represents an internal relational network integrated into a wider and more complex network of external relations (with the environment).
2. The endogenous complexity is given by the extension and configuration of the internal network. The exogenous complexity is determined by the size and the consistency of the external relation.
3. According to the principle of the requisite variety (Ashby's theorem), to ensure the viability of the system, the level of its endogenous complexity must tend to the level of the exogenous complexity. This means that between the internal and the external network there must be a certain correspondence: it is necessary that the complexity of the internal network approaches the complexity of the external network.
4. A quite relevant approximation of the complexity of a network may be obtained by determining its density. Comparing the density of the internal network with the density of the external network, an overall evaluation of the degree of correlation between the two complexities may be realized.
5. The estimation of the complexity of the internal and external networks may be refined by taking into account the existing non-redundant relations relations

which emphasize and determine the appearance of the structural holes within the networks.

6. Following the co-evolution of the complexities of the internal and external networks, there can be decided structural and functional adjustments that lead to the compatibilization of the endogenous and exogenous complexities and, consequently, the preservation of the viability of the system.

Given these fundamentals, we propose the following general calculation relation of the Complexity Index (I_c) of the firm system:

$$I_c = P_{rnr} \times D, \quad (2)$$

where:

- *P_{rnr} is the weight of the non-redundant relations in the total relations R that characterize the network;*
- *D is the density of the network.*

Therefore, I_c appears as the density of the network corrected with the weight of the non-redundant relations R_{nr} in the total of the relations included in the network. Practically, I_c is a reduced density because in a network not all the relations are non-redundant relations.

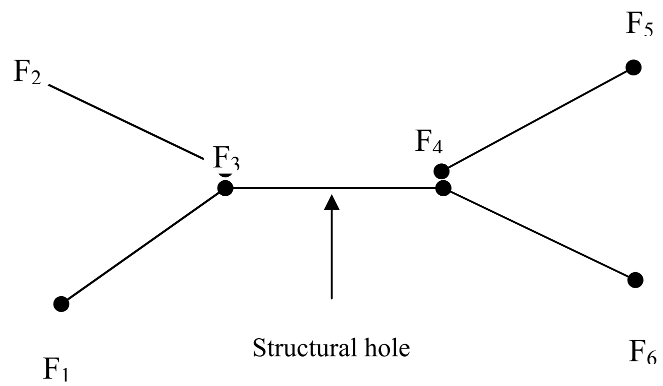
Since P_{rnr} is determined by comparing the number of non-redundant relations R_{nr} to the total number of relations R which form a network, and the density D is determined based on the relation (1), the formula for calculating the complexity index may be rewritten as it follows:

$$I_c = R_{nr} \times R \,/\, N(N-1) \quad (3)$$

The last relation clearly shows that the level of complexity of the system, estimated with the help of I_c is influenced to increase by the total number of relations specific to the network, but also by the quality of the configurations formed by these relations, quality materialized in the appearance of some non-redundancies and, therefore, of the structural holes. We recall that redundancy is given by the number of relations that can be eliminated without affecting the advantages of the access to information of a network node. Non-redundant relations, by the beneficial effects they generate, multiply, basically, the total number of relations, complexifying the network. At the same time, it may be observed that the number of elements or network nodes (N) do not act as a complexification factor, but rather as one of attenuation of the complexity. The conclusion is the following: a system consisting of a large number of elements is not necessarily a complex one, but rather a complicated one; the complexity is given by the structure of the relations established between the nodes of the network and the maximization of the structural holes. The complexity resides in the quality rather than in the density of the network.

Non-redundant relations that are at the origin of the structural holes act as a type of "bridge connections" between groups of elements or sub-networks participating in various informational processes. For example, if among three firms F_1, F_2 and F_3, which constitute a sub-network, only F_3 has direct links with the firms F_4, F_5 and F_6 which form another sub-network, it results that only this relation is non-redundant, showing, therefore, a structural hole (Figure 1). The networks that contain more structural holes or "bridge connections" convey richer information. The dimension of the network and the openings provided by the structural holes facilitate the generation of some benefits associated to the dissemination of knowledge, providing advantages derived from the capacities of mediation, contagion and diffusion.

Figure 1. Structural hole as a non-redundant relation



Source: Own elaboration.

Based on the exposed arguments, we consider that we may calculate the endogenous complexity index (I_{cen}) and the exogenous complexity index (I_{cex}) taking into account the calculation parameters specific to the internal network of the firm and, respectively, those of the external network of which the firm takes part. A numerical example of calculation is presented below (Table 1).

Table 1. The calculation of complexity indexes (example)

Indicators	Internal network	External network
R_{nr}	1	3
R	10	12
N	6	9
I_c	I_{cen} = 0,333	I_{cex} = 0,5

Source: Data figures are hypothetical and selected by authors to illustrate the operation of the model.

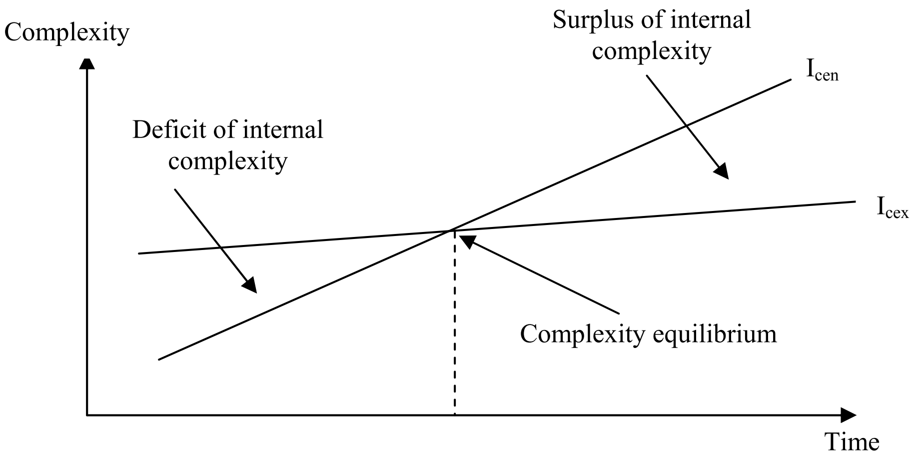
We observe that $I_{cen} < I_{cex}$. What conclusions may be drawn besides that the level of endogenous complexity is significantly lower than the level of exogenous complexity?

6. The interpretation of the complexity indexes in terms of the theory of dissipative systems

The theory of the dissipative systems provides the conceptual framework necessary to interpret the values taken by the indexes of endogenous and exogenous complexity. This is because the complexity of a system is similar to the force of the field of informational energy that irrigates it. According to Prigogine's (1982, p. 11) the theory of dissipative systems, in order to survive and evolve, a system far off the equilibrium captures and, at the same time, releases (dissipates) energy from and within its environment. Any system, at any time, represents the result of these transactions between the internal and the external energy field.

Obviously, the force (complexity) of these energy fields differs. An internal energy field more powerful than the external energy field means that the system releases or dissipates more energy than it captures (absorbs) from its environment. When the difference between the forces of the fields is high, this energy release may take place very quickly, explosively: the system disintegrates into its environment. But if the internal energy field is weaker in comparison with the external one, the system attracts or takes over from the environment more energy than it can release (dissipate). When the difference of force is significant, this process of accumulation of the energy may take the shape of the implosion: the system is crushed by its environment. This processuality is shown in Figure 2.

Figure 2. Complexity equilibrium



Source: Own elaboration.

Returning to the internal and external complexity indexes, we may identify the following situation-type:

1. $I_{cen} < I_{cex}$. The internal complexity is insufficient to deal with the external complexity. The system suffers in the interior from an energy deficit that does not allow it to stop the inflow of energy from the exterior. The appearance of

some functional blockage is possible due to the overload or to the "suffocation" of the system as a result of some pressures and external stimuli that fail to process properly. The system needs more internal complexity to deal with the assault of the external complexity.

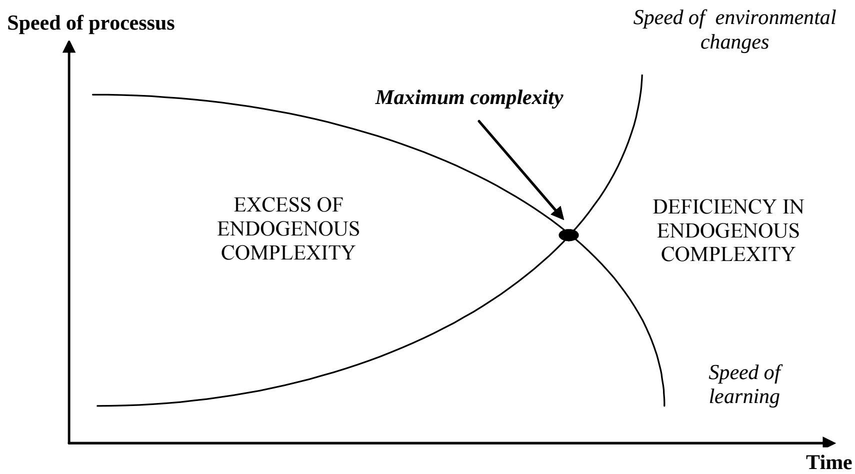
2. $I_{cen} = I_{cex}$. It is an equilibrium point. The internal complexity succeeds to completely absorb the external complexity. The system releases in the environment exactly as much energy as it captures. The internal network is properly integrated and adapted to the conditions of the external network.

3. $I_{cen} > I_{cex}$. Surplus of internal complexity in relation to the level of external complexity. The system contains more energy than it is necessary for a successful adjustment to the environmental conditions. In the interior of the system useless surpluses or "excrescencies", appear which burdens its functioning. The system accumulates in the interior more energy than it is required by the adequate adaptation to the environmental conditions. The system must get rid of this ballast in order to approach again the equilibrium point.

Corollary: Complexity management represents an oscillation around the equilibrium point of the complexity through the periodical review of the endogenous complexity (through the alternation of the solutions of complexification and internal simplification of the system) so that its level should be closer to the level of the exogenous complexity.

The power of an informational field influences the propagation speed of the changes in its interior. Therefore, a powerful external informational field of energy materializes in high speed of the changes that occur in the environment. A powerful internal informational field of energy translates into high speed of the learning processes, knowledge processing and communication specific to the system. This also means a higher potential of self-organization that the system has access to. The maximum complexity that a system may absorb is limited by the learning speed, the development of knowledge and the communication that the respective system is capable of (Figure 3).

Figure 3. The maximum complexity that can be absorbed



Source: Own elaboration.

The maximum complexity expresses that point of operational and decision-making saturation beyond which the system cannot adjust reactively and proactively its functions: feedback and feed-forward derange rapidly, the system losing its capacity of self-organization. The calculation and the analysis of endogenous and exogenous complexity indexes are useful for the prevention and management of the announced risk.

The problem is how to determine the speed of the changes in the environment, on the one hand, and the speed of communication, learning and management of knowledge, on the other hand. This is because the calculation of the complexity indexes reveals only the general tendency of movement of the system or, more precisely, the way of evolution of the complexity that characterizes it. Although very important, this aspect suggests, however, few things about the real capacity of the organisation to process (absorb) the external complexity through internal self-organisation.

7. Speed estimation based on the intellectual capital

There are resources that can be obtained and mobilized only by means of relations. Knowledge belongs to this category of resources. Knowledge circulates through the connection networks, infusing them according to a function of logistic type, as Anderson affirms (1999, pp. 216-232): first of all, an initial phase of entry, followed by an exponential expansion phase, extremely fast and active, which impregnates most part of the network, then, a maturity phase, that is spreading more slowly, and the process ends in a phase of saturation and decline.

Stewart (1991, pp. 44-50) defines the intellectual capital as the framework of the knowledge held by the members of the organisation and which confers it competitive advantages. Subramaniam and Youndt (2005, pp. 450-463) gives a very similar definition of the intellectual capital. And Nahapiet and Ghosal (1998, pp. 242-246) sustain that the size of the intellectual capital is given by the totality of knowledge and the capacity to acquire new knowledge from the communities to which the organization pertains. There are many other more or less related definitions, all suggesting the same thing: the intellectual capital is not the sum of the acquired theoretical knowledge, but the consequence of knowledge capitalisation, that is, its transformation into concepts, competences and connections full of advantages.

The intellectual capital represents the synthetic expression of knowledge acquired and exploited by the organisation. The measurement of the speed of creation of the knowledge may be, therefore, achieved by determining the pace of accumulation of the intellectual capital, more precisely, of those components of the intellectual capital that delineate the human capital and the structural capital. Since the firm is part of an "ecosystem", to which it is connected by a multitude of links (external network), we consider that the changing speed of the environment is reflected in the evolution of these relations. In terms specific to the intellectual capital theory, the counterpart of the environment's speed of change is the accumulation rate of the relational capital.

Guthrie and others (2004, pp. 282-293) present the following explanations for the components of the intellectual capital:

- Human capital consists of knowledge (tacit and explicit, individual and collective) that the individuals and the groups within the organisation have, as well as all the available capacities to generate this knowledge.
- The structural capital is defined as the totality of the intangible resources, capable of generating economic value, which resides in the design and structuring of the firm. This component of the intellectual capital results in the configuration of the processes, the systems and infrastructure used by the firm, knowledge being systematised, disseminated and accessible. This is everything that the formation, development and capitalization of the human capital may allow.

- The relational capital may be defined as all knowledge incorporated into the organisation and in its members, as a result of the value of the relationships established with different components of the environment. The relational capital is, thus, the consequence of the interactions and exchanges which the firm realizes with its environment.

We consider that the sum of the human capital and of the structural capital constitutes a credible image of the internal complexity, while the relational capital may be a good measure of the external complexity of the firm.

One such method of measurement has an indirect character and involves the following steps:

1. The measurement of overall intellectual capital of the firm, as well as of the specific components – human capital, structural capital and relational capital. The measurement will be made for at least two consecutive periods.
2. The determination of the accumulation rate (increase) of the sum of the human capital and of the structural capital, expressing the learning speed, processing of knowledge and of communication within the firm, ra_{cus}.
3. The determination of the accumulation rate of the relational capital, expressing the speed of change of the firm's environment, ra_{cr}.
4. Carrying out the comparison between the two rates in order to evaluate the position of the firm with regard to the point of maximum complexity.

Therefore, calculating the ra_{cus} and the ra_{cr} we can draw the necessary conclusions about the speeds to which we have referred earlier. If ra_{cus} tends to exceed ra_{cr} we can affirm that the learning, knowledge processing and communication speed is superior to the speed of production of changes in the environment. The firm develops its capacity of self-organisation, being able to successfully resist to the processes of growth of the complexity of its environment. If, however, ra_{cus} remains behind ra_{cr} we deal with a delay of the capacity of self-organisation in relation to the rapidity of the changes occurred in the firm's environment and the capacity of absorbtion of the external complexity decreases.

The relative difficulty lies in determining the size of the intellectual capital. The widest awareness was gained by the models of evaluation of the intellectual capital Skandia, developed by Edvinsson (1997, p. 18) and Intellect, elaborated by Euroforum (1998, pp. 24-39). Most of other models have substantial similarities with these ones. However, the model of evaluation of the intellectual capital proposed by the Spanish Nevado and Lopez (2004, pp. 163-182) deserves attention. The distinctive element of this methodology is that it tries to determine the monetary value of the intellectual capital by combining two categories of indicators: absolute indicators of the intellectual capital (C), expressed in monetary units and efficiency indicators (i), of the nature of some rates, expressed as percentage or as coefficients. In this model, the intellectual capital has its well-known tripartite structure, emphasizing the human capital (due to the people), the structural capital (due to characteristics of the organisation) and the relational capital (due to the quality of the relations with the environment). For each of these categories of intellectual capital absolute indicators, but also efficiency indicators are selected. The monetary value of each category of intellectual capital is established by multiplying the absolute indicators with the efficiency indicators. If more than one absolute or efficiency indicator is selected, in calculations their average values will be used. The overall monetary value of the intellectual capital of the firm is obtained by adding the monetary values of human capital, structural capital and relational capital:

$$\text{Intellectual capital} = \Sigma(C \times i) \tag{4}$$

Table 2 presents an application (for example, a hypothetical company), which illustrates the way of functioning of the model Nevado-Lopez (to simplify calculations, we selected only one absolute indicator and one efficiency indicator for each category of intellectual capital). We will use the results obtained to determine ra_{cus} and ra_{cr}.

Table 2. Determining the value of the firm's intellectual capital based on the Nevado-Lopez model

Indicators	Year 1	Year 2	Year 3	Year 4
1.Investment in staff training	5800	6350	6700	7450
2.Qualified employees in total employees	0.6	0.63	0.7	0.74
3.*Value of human capital*(1×2)	3480	4000	4690	5513
4. R & D investment	6100	6850	7500	8250
5. New products in total products	0.35	0.4	0.43	0.51
7.*Value of structural capital* (4×5)	2135	2740	3225	4207
8. Investment in marketing	6000	7100	8300	10500
9. Annual growth in market share	0.27	0.35	0.48	0.61
10.*Value of relational capital* (8×9)	1620	2485	3984	6405
11.Global value of intellectual capital (3+7+10)	7235	9225	11899	16125

Source: *Data figures are hypothetical and selected by authors to illustrate the operation of model.*

Next, we will determine the annual growth rates of the human capital and of the structural capital, on the one hand, and of the relational capital, on the other hand (Table 3).

Table 3. Calculation of rates ra_{cus} and ra_{cr}

Indicators	Year 1	Year 2	Year 3	Year 4
1.Human capital + Structural capital	5615	6740	7915	9920
2.ra_{cus}	-	0.2	0.174	0.253
3.Relational capital	1620	2485	3984	6404
4.ra_{cr}	-	0.533	0.603	0.607

Source: Data figures are hypothetical and selected by authors to illustrate the operation of model.

We can observe that, throughout the analysed period, the levels recorded by the ra_{cr} rate are substantially higher than the levels of the values of the ra_{cus} rate. This means that the accumulation speed of the changes in the firm's environment categorically goes ahead the learning speed, communication and processing of knowledge from the interior. The firm's environment rapidly becomes more complex (the exogenous complexity increases) compared to the level of the endogenous complexity, which, although it also increases, cannot keep the pace. If there are not proper interventions, probably the firm will soon exhaust the capacity of absorbtion of the external complexity by self-organisation. To refine the analysis, it is necessary, in our view, to trace the dynamics of the main indicators of performance and profitability of the company.

8. Conclusions

The concepts and modern managerial systems are not yet able to steer and to valorise adequately two dimensions, inextricably linked to the modern business organisations – complexity and knowledge. The acceleration of the pace of changes, combined with the objective process of multiplying the interdependencies and interactions resulted in the unprecedented development of complexity. The organisational fields are increasingly invaded by complexity and irrigated by knowledge. The multiplication of complex phenomena and the complex and hipercomplex evolutions is a real challenge for management.

The understanding and exploration of knowledge as essential economic resource represents the gateway to the modalities of "taming" the complexity. The organisational knowledge, summarized in the concept of intellectual capital, currently provides the strongest competitive advantages for companies. The increase in speed of communication and the explosive development of knowledge represent decisive factors in modelling the organisational spaces, forcing a radical review of the balance between the tangible and the intellectual capital.

The increase in complexity of the economic world determines the rethinking of the politics, strategies and practices of management in terms of intellectual capital. Complexity management is inseparably associated with the management of organisational knowledge. Managing the organisational knowledge and managing the organisational complexity merge in an unified approach to identification of some common paradigms and instruments.

Also we consider as a possible "bridge connections" between the epistemological paradigm of knowledge and the complexity the concept of network. Both, knowledge and complexity is organized as a network. Structural peculiarities of the network determine their adaptation and evolution capacity.

In fact, the mentioned peculiarities define the rate and quality of intellectual capital accumulation by complex economic systems. Intellectual capital is an essential component of self-organization potential of complex economic systems. The argument is simple: intellectual capital is knowledge in action, applied knowledge to solve concrete problems of the system. The level of complexity of economic organization can be described using controlled elements of intellectual capital.

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