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Knowledge Complexity and Collective Intelligence Development in Technology Based-Firms

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***Abstract*— This document addresses the issue of collective intelligence, complex knowledge, and complexity theory applied to technology-based organizations. For this, a review of the literature on the subject of complexity theory, complex knowledge, collective intelligence, and technology-based organizations is made. An analysis of four approaches to complexity theory that help improve the study of organizations from the consideration of turbulent and changing environments that require a high capacity for adaptation, innovation, and rapid assimilation of change will be developed. Finally, there is a need to innovate in the study of companies and to consider them epistemologically as independent entities that make up a complex adaptive system and that, in essence, are grouped together to consolidate their ability to adapt and adjust to market change and survival.**

Keywords—IT-Based Firms, Knowledge Complexity, Collective Intelligence

I. Introduction

The development of knowledge is presented from the emerging interaction of factors that evolve into an ecosystem composed of different elements that cause the emergence of new information and its interpretation [1]. This in turn causes the value of the goods and services offered to increase their appreciation among their users [2]. In an increasingly global, technological and fundamental environment in artificial intelligence to find technological structures and behavior patterns, it is important to consider other theoretical approaches to understanding the phenomenon of knowledge creation and its usefulness in organizations. Complexity is considered one of the approaches to analysis and problem solving that has recently generated the most interest [3]. The way in which organizational structures can be seen from a multilevel perspective, made up of elements and factors, makes their analysis comprehensive and the decision-making process more holistic. To this is added the issue of collective intelligence, which ratifies the complexity approach in the organization by considering that a company can be analyzed as a person is analyzed. This is possible because the members of an organization are ultimately part of the system that holds the company together [4].

In this document, an exposition of complexity theories is made as a foundation of study for organizations, it is extended towards the construct of collective intelligence, to consider each of the organizations as an independent entity that is analyzed from its structural singularity and the use of these concepts in the study of technology-based organizations is proposed

II. Complexity Theory

Complexity theory is a set of theoretical frameworks used to model and analyze systems within a variety of domains and with different levels of complexity [5]. This approach has proven to be a fundamental feature of a turbulent world that is not compatible with the traditional methods of modern science focused on linear analysis, and therefore, as researchers apply this approach in their different areas, such as computer science, ecology and engineering, it is possible to develop new sets of models and methods to understand its phenomena [6].

From these different approaches to knowledge a basic set of commonalities has emerged that has come to be recognized as a generic framework for studying complex systems abstractly. Complexity theory encompasses a wide and diverse set of models and methods, so far there is no unified formulation to structure and define this framework, so it is proposed to present it as a composite of four main areas that encompasses different perspectives on complex systems and their interpretation [7].

A. Systems Theory

First, systems theory is proposed, which is in many ways the origin of complexity theory. Before the formulation of complexity theory, systems theory dealt with the ideas of complexity, self-organization, adaptation, among others. Almost all interpretations of complexity depend on the concept of system [8]. In the same way that modern science can be expressed within the formal language of mathematics, the science of systems complexity can be formalized within the language of systems theory. However, systems theory is an abstract formal language that is difficult for most people to understand and is therefore used relatively little. Cybernetics is another area closely related to systems theory, it was also part of

the foundation of complexity theory, cybernetics during the mid to late 20th century studied control systems and provided much of the theoretical background for computer science. modern, and thus we can see how the interaction between computation and complexity science goes back to its origins, since the two have developed hand in hand [9]. Much of systems theory is associated with and has grown out of the entire area of computing. The areas of computer science and also information theory are areas that contribute to complexity theory in different ways, although systems theory is more than just computers, since it is composed of a complete formal language.

B. Linear Systems and Chaos Theory

Nonlinearity is an inherent characteristic and a major theme that runs through all areas of complex systems. Much of the theory of nonlinear systems has its origins in mathematics and physics. Some very counterintuitive phenomena have emerged from the study of certain types of complex equations, such as weather patterns, fluid dynamics, and particular chemical reactions in the form of the butterfly effect and the emergence of chaos [10]. Chaos theory, which is the study of nonlinear dynamical systems, was one of the first major challenges to the Newtonian paradigm in the main body of scientific knowledge. The modern scientific framework is based on linear systems theory, and this imposes significant restrictions on it, linear systems theory depends on the concept of a system that has an equilibrium and its behavior can be predicted, although it often works as an approximation, the fact is that many of the phenomena we are interested in describing are nonlinear. In addition to this, change processes, such as regime changes within ecosystems and society, occur outside of equilibrium and are governed by the dynamics of feedback loops and not by linear equations [11]. That is why trying to model complex systems using traditional linear systems theory is impractical, since the tool does not correspond to the problem. Thus, the areas of nonlinear systems and their dynamics are another important part of the complexity theory framework that comes largely from physics, mathematics, and the study of processes that are out of equilibrium.

C. Network Theory

Network theory is another important area of complexity theory [12]. Almost all complex systems can be effectively understood and modeled using network structures [13]. The study of networks is probably the youngest and most active area of complexity science, again fueled by the rise of computing. Its role in understanding phenomena has become fundamental since the advent of information technology. With the theory of networks and the availability of new data sources, real images are obtained of what some of the complex systems that make up the world look like. You can begin to see the connections within financial systems, or how the spread of disease spreads, the transportation of products in real time around the world, or the sociopolitical networks that influence governments. This is a new kind of science driven less by models and equations, but more by dense, real-time datasets. This means that you are no longer just looking at a model but can now be visualized to give you an intuitive and, in many ways, real sense of exactly what these complex systems are like. The main contributions to this area come from the area of mathematics called graph theory and information science [14].

D. Adaptive Complex Systems

The last major area of complexity theory mentioned in this section is that of complex adaptive systems and self-organization [15]. Complex adaptive systems are classic examples of complex systems so common that they are often used in parallel. These systems consist of many parts that act and react to the behavior of the other elements, such as a flock of birds flying together, the interaction of countries in spaces of international coexistence or also, companies in a competitive market [13]. All of these examples are highly dynamic and develop through a similar process. Self-organization theory addresses one of the main issues within complexity theory, that is, how things work together, how discrete components are integrated into a coherent functional organization but without centrally coordinating elements. Here we see how simple rule-governed agents synchronize their behavior with the emerging result of a self-organizing process. Researchers try to model complex adaptive systems by capturing these local rules and using computational tools like cellular automata and agent-based models to try to simulate how these systems are shaped by their interactions and evolutionary forces [16]. This is an area that has emerged from cybernetics and information science.

III. KNOWLEDGE COMPLEXITY

Knowledge arises when an entity achieves the perception that, based on its own experience and capacity, it manages to interpret data that it is receiving at a given moment and generates new information from them [17]. Knowledge derives from information, just as information derives from data. There is a direct relationship between data, information and knowledge. If the information is transformed into knowledge, then the intervention of a person or an intelligent being has occurred. Knowledge generation actions occur in human beings [18] at least until now, since Information and Communication Technologies (ICT) have increased their capacity for data processing and information creation, but they are still d they cannot create knowledge, this is only possible from the intervention of a human being [19].

Knowledge is presented as an alternative for the social development of individuals, which arises from empirical experiences, but which can later lead to its accumulation and give rise to new ways of understanding some known phenomenon, giving rise to the achievement of achievements that can, at a given moment, improve the quality of life of the men who make up a given society [20]. Every "observer" from society has in common historical, philosophical and cosmogonic antecedents that define everything credible and what is considered true

The theories on the “raison d'être” of knowledge and how it gives freedom to the individual, a long way has been traveled towards recognizing it as an active value of universities, companies, governments, or any other organization. who owns it [21] The importance of the creation and transfer of knowledge makes it important that it be managed efficiently and that it reaches all the actors that require it within a society [22]. Now, knowledge is considered a highly competitive value in organizations, and its efficient management an added value of the same[23].

Since the 1990s, the importance of management in business development has been established [19]. And it was Grant [24] who affirms that knowledge-based organizations emerge and transcend in the academic and business environment. Several authors have focused on this organizational vision, from Kogut and Zander, Spencer, Nonaka, Takeuchi, among others, have addressed the importance of managing what is known and more importantly, what is to be known by the organization.

Studies to try to understand the composition and importance of knowledge, as well as the relevance of its storage, transformation, and distribution, have included social analysis as a framework that allows understanding the individual elements that make up knowledge [25]. Ethnography explores mainly through the observation of the characteristics concerning a culture in particular, the ways of interrelating in those cores that generate knowledge and therefore help to understand its creation [26] .

IV. Collective Intelligence and IT-Based Firms

A. Global IT Environment

The current global environment in the IT sector has managed to attract public and private efforts towards building conditions for the formation of a critical mass of companies. These processes not only imply a clear definition of public policies, but also the promotion of business behavior especially geared towards young people as a key driver of competition. The development of an entrepreneurial business is conditioned by a context that facilitates its performance, if tendencies towards bureaucratization appear, an environment that is not conducive to the creation of new companies that introduce creative and innovative products is generated. To this must be added the regional weaknesses in innovation processes that can hinder the construction of a favorable environment [27].

Consequently, for the emergence of an entrepreneurial business community that intensively uses knowledge and innovation, having an enabling institutional and regulatory environment is a key element. The IT sector is a good example of the processes described above; it is a dynamic sector sustained by the emergence of companies based on innovations that seek to strongly impact the market. When analyzing the dynamics of this sector in other countries, it has been found that they develop in a complex network of formal and informal relationships between the academic field, the state, and the productive sectors. This is a good example for the consolidation of the sector in Mexico, because it implies that within the national strategy it considers not only general aspects such as the promotion of R&D, but also the design of collaboration instruments to carry out joint investments in the public/private sector, and the training of human resources, and the development of strategies for very specific aspects [28].

B. IT Firm Environment in Baja California

Companies oriented to the IT sector in Baja California emerged mostly in the 1990s. Its growth has been maintained regularly from the second half of that decade to the present. They are mainly concentrated in Tijuana and Mexicali, as well as some in Ensenada and Tecate. Although average employment has grown in recent years, it continues to be, as in the rest of the sector in Mexico, essentially microenterprises with fewer than 15 employees. In 2001, when the process of creating the cluster began, companies in this sector had an average of thirteen employees. Now, more significant than the number of employees is the volume of sales. Only a fifth of the companies have annual sales above 500 thousand dollars. Half sell in a range of 100,000 to 500,000 dollars and almost a third are below the latter range. A defining fact is that all the companies are of national capital and essentially arose from personal savings. None had been developed under the cover of bank loans or risk capital. In this table, however, three companies follow differentiated dynamics from SMEs. These are Zentrum, Grupo Tress and Softtek

The development of economic alliances, commonly called clusters in Baja California, have become a recognized articulation mechanism for the development of companies from groups of related sectors. The case of IT is particularly recognized, not only for the boom in activities that it contemplates in the national and global environment, but particularly for having been the first that, in the case of Baja California, initiated a process of formation and formal articulation strategy.

There is a Cluster specialized in the Information Technology sector in the region. This body brings together more than 300 companies in this sector, including fifteen that have highly prestigious international certifications and that together have a population of more than 3,000 technology, software and hardware developers. Likewise, its strategic axes are: 1. Expand business opportunities at the local, national and international level for its members; 2. You develop the capacities of human capital to respond to the required technical requirements; 3. Establish infrastructure requirements to manage its development. In total, what is sought is to continue with the growth of 11 Information and Communication Technologies in Mexico (IT Baja, 2022).

V. IT-Based Firms Appications

To determine the process of application of knowledge in complex organizational environments such as in technology-based companies, the evolution of the company towards the use of strategies, technologies and tools focused on growth and permanence in the market is selected. For this, the study of this emergence is generalized proceeding from the approach of the members of the organization or intellectual capital and how, from them, the construction of proposals based on collective intelligence that together influences the decision-making process is reached. of decisions.

In these technology-based organizations, it is feasible to understand them as a complex adaptive system (CAS), which is contrary to the styles and types of traditional organization. These organizations are characterized by several of the factors indicated in the SAC, such as emergence, self-organization and evolutionary adaptation processes. This appreciation also implies organizational designs based on approaches and constructs that include limited instability, development of operations as a central controller and the restriction of the individual action of the agents in the system.

The organization must avoid the passivity of the extremes in the dynamic structure of the SAC, specifically not reaching

balance or chaos in its structure. Balance is a characteristic that is established and pursued from the traditional administration. However, the organization is considered as a biological organism where a stable state is ephemeral. This trend can deteriorate productivity and creativity in the company as well as impede the development of innovation; It is then a situation that must be avoided since the balance becomes a regulator of the ability to adapt to a changing environment and consequently to the disappearance of the organization (Miller, 2007).

On the other hand, the accelerated development of rules and behavior schemes tend to increase the possible states of the system, surpassing the absorption capacity and generating chaos. This situation can also develop instability in the organization and cause it to collapse. It is under the previous analysis that concerns arise that try to lead in a certain way towards the concentration of conditions that cause the technological organization to develop a scheme of limited instability, where sufficient absorption can be made to adapt to the new conditions of the environment. This from an application of innovative rules that have the capacity for change and adequate adaptability to remain in time as a company or organization [29]

Now, if we consider that the organizations that function as a SAC do not have a central specific controller, but rather the interaction of agents and their relationships define its proper functioning. So how do the board members of the organization participate? Questions emerge about how to avoid that being without a central controller can lead to chaos. On the other hand, by not having this centralized control, the question turns into where this order resides, it may be in the employees or in other stakeholders. When referring to a central control, it is considered the establishment of procedures, standards, plans, vision, mission, objectives, controlled scenarios and mechanisms that seek to limit individual action as much as possible and for this reason with few tools achieve the emergence of collective behaviors, such as innovation.

In the same way, it is important to distinguish the mechanisms that facilitate self-organization, it must be taken into consideration that SAC organizations require agents with internal models, connections between agents, as well as adaptive behaviors and everything that facilitates the system to self-organize. organize. In addition, all those communication processes that increase the interaction between agents of the same SAC must be included [30].

Finally, in technology-based companies, general concepts of SC and SAC can be proposed, which have in their nature the emergence, self-organization, evolution, and adaptability. For this consider the possibility of an organizational approach such as a SAC.

VI. Conclussions

Collective intelligence, knowledge and its complexity as well as complexity theory that includes the study of complex adaptive systems are found all around the interaction between individuals and between companies. In most cases, organizations can be considered to be an example of a complex adaptive systems and agents coexist and behave in ignorance of the final result of this organizational structure, but that does not prevent their contribution to the system. Companies require alternatives to model problems, types of organization, internal and external relationships, as well as social groups in the market and sector in which they operate; however, they are not necessarily models to predict what is going to happen.

This is why business organizations can be analyzed from a complex systems perspective, since their behavior is explained more in terms of interactions than the characteristics of the agents that compose it. In this way facilitating the understanding of the constructs of collective intelligence within the organization and the complexity of the knowledge that is used that can also be generated in it.

The interactions between the entities that make up the organization facilitate the emergence of new conditions that improve the situation of technology-based companies and develop better elements of adaptation and evolution in their environment; that is, the system not only adapts to changing conditions, but also transforms internally and in symbiosis with the external environment. In the context of the administration of these technology-based companies, the use of the term SAC is feasible to use when analyzing technology-based companies.

The SAC can be understood from the emergence, self-organization and evolution. Therefore, the search for balance that characterizes traditional management is no longer relevant for the study of technology-based companies that are usually highly complex due to the turbulent competitive environment in their sector. In his case, the levels of creativity and innovation, as well as the ability to respond to changing conditions in the environment, must be adaptable to change in an accelerated manner.

Instead, the traditional approach is usually exemplified in the bureaucratic structures of state-owned and public companies where fixed and immovable regulations are followed and prevent them from adapting their performance to the environment. An example of this are the public Universities that do not have the necessary speed to compete in an increasingly complex market and that require competitive strategies to sustain their own functioning and growth.

The activity of innovation, creativity and research in the technology-based companies analyzed as SAC can be approached from the study of connectivity between agents, centralization, limited instability and generation of novelties, as well as many examples. In any case, the understanding of the organization as a SAC projects lines of research around themes such as leadership, motivation, competitiveness and complexity, innovation in complex systems, decision making in decentralized organizations, strategy and complexity, construction of collective action in systems self-organized, among others.

There's also the need to consider that new entrepreneurs are facing with different complex issues than the stablished firms already in the market have. This raises the question about how this new enterprises can deal with this issues by applying in their strategies, human resources issues, negotiation skills, organizational behavior, innovation ambidexterity and other subjects related to their specific business reality from a complex, SAC, innovation and creativity approach [31][32[33].

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