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Distributed Situation Awareness as a 'middleware' between the New Economic Sociology and Embedded Open Innovation

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Abstract: *Modern societies are comprised of open systems that their internal elements interact with their environment. In modern dynamic, digitalized, and decentralized environments Embedded Open Innovation is the new innovation paradigm. In order to develop a substantial amount of gravitational embedding force and knowledge, for commercial ends among others, both living and technical components are considered to be prerequisites. These diverse elements are integrated in multi-agent socio-technical systems exhibiting an open process of information fusion. As an indispensable system property, Situation Awareness impacts on knowledge creation, and signifies the awareness of the "exactly right" for the system as a whole. Thus, we argue that the combination of Distributed Situation Awareness and Embedded Open Innovation can contribute to change our view of collaboration, develop a holistic and systemic culture, along with models based on the socio-technical perspective. The notion of New Economic Sociology, which bears human-centered economic transactions, social motives, and shared interests for the social structure, offers the evidence that some of our assumptions and ideas seem to be rational and realistic. This grants us the confidence to claim that new open business models could be based in the future on the underpinnings of this paper.*

Key Words: ***Embedded Open Innovation, New Economic Sociology, Distributed Situation Awareness, socio-technical systems***

1. INTRODUCTION

Collaborative networks of users can solve complex problems the companies, and confined systems in general, are unable to solve themselves [1]. Along these lines, Open Innovation is *"...the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation respectively"* [2]. Open Innovation expands the space for innovation beyond conventional innovation processes [3]. In such a context, it is not a single customer that makes decisions or acts only by him/herself, but they are extremely socially and culturally interlinked [4], such as in local communities to support Local Open Innovation [5]. In this case, the market is no longer a target, it is more a forum [6] to *"tap into the knowledge of participants in the social ecosystem to create a freer flow of information, engage people more wholeheartedly, and enable richer, fuller stakeholder interactions"* [7]. Further, in such a complex system knowledge is unevenly distributed [8] and the direction of flows of knowledge and information cannot be predetermined [9]. Embedded Open Innovation is therefore a complex distributed form of Open Innovation falling under the scope of the New Economic Sociology. Specifically, Embedded Open Innovation displays the dependency of innovation from social inclusion and the **emergence of innovation from social interactions**. Accordingly, the notion of the New Economic Sociology argues that any economic behavior and/or action, such as information fusion, innovation etc, is embedded in networks of interpersonal relations, so that the assumption of atomized, i.e. individual, decision making is not valid [10]. The New Economic Sociology *"shows that the stability of the markets and organizations cannot be explained only by economic condition factors and by a natural inclination of the profit, but that it is enormously socially and culturally depended"* [11]. There are indeed solid links between Embedded Open Innovation and the approach of the New Economic Sociology, because the latter leads to a more **reflexive, embedded, and distributed notion of innovation**.

Hence, there seems to be an increasing demand for new 'open'-oriented paradigms in dynamic, digitalized, and decentralized innovative environments, where the most important and manageable **source of innovation is knowledge and understanding**, gained by trusted relations between communities, networks, and stakeholders that exchange data and information in a direct or even latent way. Such a new paradigm is the so called Embedded Open Innovation [11]. However, in the literature there are limitations [12], such as encountering coordination problems and neglecting the macro-social focus (see Subsection 4.1), that results from making Embeddedness the core concept of economic sociology.

Thus, in this paper, Distributed Situation Awareness and Endsley's three-level model of Situation Awareness are considered as **a conceptual stepping stone** to change our view of collaboration, and through this, to develop a holistic culture, and build new open business models in

order to tackle in the future, at least to an extent, some of the collaboration-related limitations.

In order for the reader to grasp the concept presented herein, the direction of reasoning could be depicted in a rudimentary flowchart. Figure 1 illustrates the successive steps from the initiating concept of open systems to the emergence of properties in open collaborative environments. In brief, within a system, which continuously interacts with its environment or surroundings, i.e. open systems, the interaction can take the form of information, energy, or material transfers into or out of the system boundaries, depending on the system context. Within the context of multi-agent socio-technical systems, the principles of the New Economic Sociology introduce the distributed and embedded perspective of actions. Due to the limitations [12] that Embeddedness bears, there is a 'conceptual gap' -as regards the limitations of Embedded Open Innovation- between the New Economic Sociology and the application of Embedded Open Innovation that needs to be bridged. To be more specific, Open Innovation is embedded, and so Embedded Open Innovation takes into account New Economic Sociology. The aforementioned 'conceptual gap' derives from the limitations that Embedded Open Innovation encounters, under the notion of New Economic Sociology. These limitations may be reduced by the ideas that DSA introduces and the pre-models that this paper suggests.

For that reason, the paper proposes the concept of Distributed Situation Awareness, which could be otherwise characterized as the 'middleware' between the New Economic Sociology and Embedded Open Innovation.

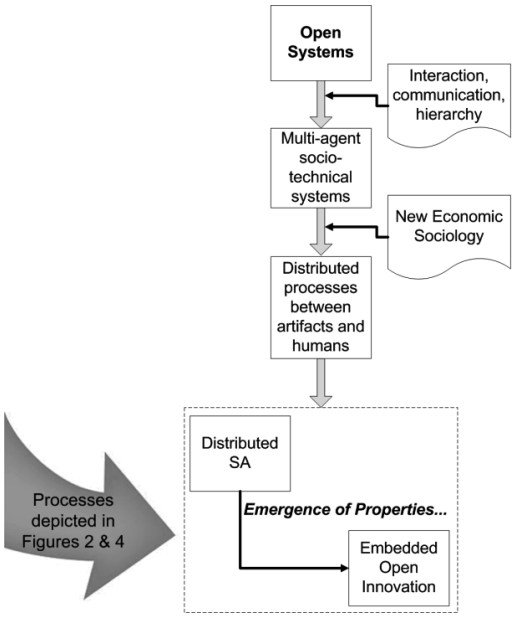

Fig. 1. The flow of reasoning that binds the New Economic Sociology, Distributed Situation Awareness and Embedded Open Innovation

The sections below are intentionally presented in a bottom-up fashion, relative to Figure 1. Before binding the three concepts of Distributed Situation Awareness, Embedded Open Innovation, and the New Economic Sociology together, one should first possess the basics of them. In this manner, we first include the definitions of Embedded Open Innovation and Distributed Situation Awareness and their conceptual connections (Figure 2), as well as an explanation of why they are characterized as emergent properties (Figure 3). After this, we combine them in a common framework, in order to show the processing from information and data to the embeddedness of Open Innovation (Figure 4). Following, we point out the common principles between the New Economic Sociology and Distributed Situation Awareness within the context of modern socio-technical systems, which exhibit open attitude towards joint venture and collaboration. Finally we discuss the contribution of the Distributed Situation Awareness approach to reduce the limitations of Embeddedness.

2. CORRELATING THE CONCEPTS OF EMBEDDED OPEN INNOVATION AND DISTRIBUTED SITUATION AWARENESS

According to [13] Embedded Innovation is *"the fundamental ability of a firm to synchronize organizational structures, processes and culture with* ***open collaborative learning processes*** *in surrounding communities, networks and stakeholder groups so as to ensure the integration of different external and internal knowledge, i.e. competences or technological capabilities, and to exploit this knowledge to commercial ends"*. Hence, the prerequisite of adopting Embedded Innovation is the existence of a *"****multi-agent system*** *to develop a substantial amount of 'gravitational embedding force' and significantly absorb and exploit knowledge for commercial ends"* [13].

Regarding multi-agent systems, they usually are complex socio-technical systems with both living and technical components, directly or indirectly bound together. More officially stated, *"the socio-technical premise can be articulated as: (1) the mutual constitution of people and technologies (and, specifically, digital technologies); (2) the* ***contextual embeddedness*** *of this mutuality; and, (3) the importance of collective action"* [14]. Here, the interaction between agents is neither linear nor predictable and the couplings between events and agents are dynamic. Namely, information and data penetrate individual, team, organizational and network layers, as well as every hierarchical level of the complex system -from the bottom to the top- and contribute to shape the picture of the 'new' innovation, i.e. product or service.

As stated in the Introduction section, **innovation is a system endeavor** because it stems from system's interactions and this comes in lines with the emergent property concept. More precisely, a property is emergent when it cannot be detected on a single system element, but on the system in its wholeness. In systems characterized by intense social operations, there is *"something more"* [15] than just individual human and nonhuman elements, implying that there are in-between interactions that lead to the emergence of properties and overall behaviors. According to Von Hippel [16], **Open Innovation is distributed** and this is in close relation to what Situation Awareness researchers call **Distributed**

Situation Awareness (DSA), giving weight to network interactions and shared ideas.

In order to avoid misunderstanding, it seems purposeful to state that, although in the literature the most prominent researchers refer to DSA as an ergonomic methodology, they do not use the word 'ergonomic' in its strict sense. What they imply is that *"the systems ergonomics perspective places emphasis on the interaction between people and their artifacts in the world, to propose that situation awareness functions like distributed cognition. This means that the unit of analysis is the whole socio-technical system. Socio-technical systems theory allows exploration of the social and technical subsystems independently, which offers a theoretical framework for aligning the three views of situation awareness"* [17], i.e. psychology, engineering, and ergonomics. DSA is not limited to knowledge sharing but it integrates action sharing; that accords with [18], who define SA as: *"the combining of new information with existing knowledge in working memory and the development of a composite picture of the situation along with projections of future status and subsequent decisions as to appropriate courses of action to take"*. There are indeed serious arguments -some of them are made herein- that DSA is not that simple as some researchers who have just embarked on this new term and its subsequent concept may think.

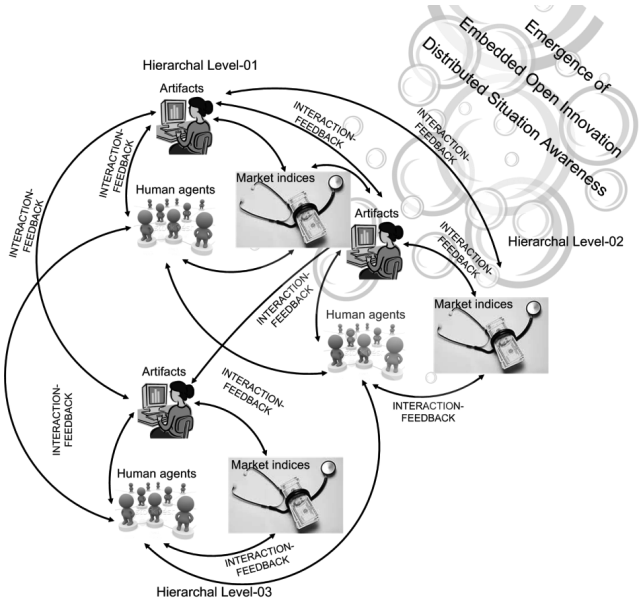

Fig. 2. DSA and Embedded Open Innovation as emergent properties

In the light of their notional proximity, Embedded Open Innovation could be adequately modeled by DSA. In an open process of innovation creation, DSA is an indispensable property that boosts knowledge creation, and keeps up with Von Hippel's [16] statement that to innovate, one should be aware of what the "exactly right" for him/her, as an individual, is. Apart from the individual awareness, innovation becomes distributed when the awareness of each and every stakeholder, i.e. the picture that each individual within the organization has in mind, and teams of stakeholders contributes to the embeddedness of Open Innovation, which is considered as a cooperative effort of a 'social ensemble' to innovate.

Figure 2 illustrates how DSA, as well as Embedded Open Innovation, emerge from the links, i.e. the interactions, among the different human agents, i.e. human-like figures, and artifacts, located at the same or different hierarchical levels. DSA, just like Embedded Open Innovation, is held by the entire system since no one system agent has a complete picture of any situation, but just a facet of the situation at any point in time [19]. What is more, it is also crucial for system elements to 'read' and 'interpret' indices. In a distributed environment, such as multi-agent systems (Figure 2), efforts for comprehension, knowledge creation, and decision making are not discrete or disconnected, but they change back and forth among the elements of the different hierarchical levels. The 'object' that the connection channels (between hierarchical levels, teams, and agents) carry and the different human agents study and comprehend is mainly information and data. Consequently, for Embedded Open Innovation to emerge, mutual, collective, and distributed cognitive and tangible actions are indispensable.

2.1. Endsley's Three-level Model Towards the Formation of Individual SA

If someone 'zooms in' on a single agent, within the complex socio-technical system (Figure 2), then he/she can recognize Endsley's three level model of Situation Awareness (SA) formation. She was the first who studied the concept of SA, in its simplest individual and cognitive form, and introduced the corresponding theoretical framework providing three steps of SA formation: (1) perception, (2) comprehension, and (3) projection. A brief explanation of each step is as follows [20]:

Perception (Level 1 SA): The first step in achieving SA is to perceive the status, attributes, and dynamics of relevant elements in the environment. Thus, Level 1 SA, the most basic level of SA, involves the processes of monitoring, cue detection, and simple recognition, which lead to an awareness of multiple situational elements (objects, events, people, systems, environmental factors) and their current states (locations, conditions, modes, actions).

Comprehension (Level 2 SA): The next step in SA formation involves a synthesis of disjointed Level 1 SA elements through the processes of pattern recognition, interpretation, and evaluation. Level 2 SA requires integrating this information to understand how it will impact upon the individual's goals and objectives. This includes developing a comprehensive picture of the world, or of that portion of the world of concern to the individual.

Projection (Level 3 SA): The third and highest level of SA involves the ability to project the future actions of the elements in the environment. Level 3 SA is achieved through knowledge of the status and dynamics of the elements and comprehension of the situation (Levels 1 and 2 SA), and then extrapolating this information forward in time to determine how it will affect future states of the operational environment.

We adopt Figure 3, made by Endsley, in order to explain how decisions about innovations are made. For this, it is important for an organization to shape the awareness of market situation, e.g. consumer demand, lack of products and services, existing or upcoming economic conditions etc., in the complex socio-technical environment in which an organization operates.

Although scholars argue that innovation occurs yet from the early stage of conception -which we acknowledge- to reach a satisfactory and feasible innovative product or service, an organization needs to read the 'signs' coming from the market, have the 'awareness' of what society needs, and project what society will acquire.

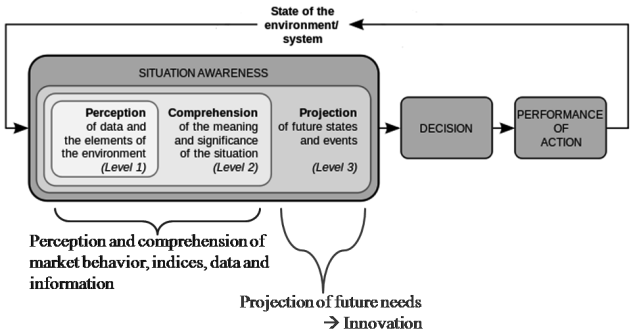

Fig. 3. The state of innovation in Endsley's three-level model of SA

In the first step, the organization perceives and comprehends data, information, behaviors around and within it, and economic, market, social and/or other kinds of indices. The next step is the comprehension, alternatively, the 'interpretation' of the message that information or data convey, and finally the projection of a future state of the organization itself, its operations, and/or situations that may possibly decide its future. In the case of an organization that innovates and collaborates systematically, innovation takes place at the stage of projection, since the organization, as a whole, should be aware and understand what is missing from the market, whether this refers to products or services.

Here, it is useful to complement the rough statement that innovation takes place in the level of projection with a small explanation; if we adopt the simplified innovation process (somehow valid for any other form of innovation, even for the complex ones, but on a distributed level), according to which innovation encloses conception, implementation, and finally marketing, the projection phase keeps up with the generation and evaluation phase. This roughly means that an idea is a projection of what the innovation will 'look like' and how successful the product or service is expected to be.

To conclude, the three basic stages depicted in Figure 2 are the structural components of DSA, but what SA needs to become 'distributed', i.e. DSA, is the iterative and collaborative execution of these three steps. DSA is differentiated from the 'simple' SA three-level model (see Figure 3) by means of being an emergent property of socio-technical systems [19].

3. AN ABSTRACT CONCEPTUALISATION OF EMBEDDED OPEN INNOVATION FROM THE AWARENESS PERSPECTIVE

From the definition of Embedded Open Innovation and the statement that knowledge is the key source of innovation, one can spot the close connection between **innovation and information**. Besides, according to [21] modernization, as well as innovation are reflexive phenomena, thus the same happens with Open Innovation in a sense that growth is created by positive feedbacks. Under this view, feedback loops describe systems that grow and at the same time change the dynamics of their own growth.

In terms of the three-level model, knowledge is the product of perceiving, filtering, comprehending, and assessing information and data. It is therefore necessary to provide the organization with the appropriate information fusion channels, feedback, and control mechanisms.

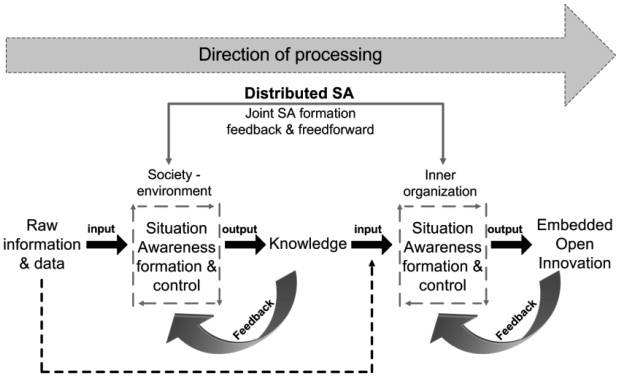

Fig. 4. An idnicative DSA framework for obtaining Embedded Open Innovation

From Figure 4, raw information, together with data, enters the system which, as considered herein, consists of the organization itself and its near surrounding environment, since an innovative organization is not a confined sum of elements but an open collaborative system. In Figure 4, everyday needs as well as global market trends play the role of raw information and data that together with individual, sophisticated -why not unique- needs render society aware of what its needs are on a macro-level, i.e. not individually. Thus the unit of society, as a sum of individuals, knows what to acquire from the given organization. Apparently, constraints such as cost, time, feasibility of application and other practical issues determine the appropriateness of this needs, e.g. think for example how crowd-funding platforms work.

As a next step, these targeted societal needs, i.e. the knowledge from society, enters the organization, and combined with raw information and data (dashed arrow that bypasses society-environment) the organization reassesses the market situation and reaches a conclusion about the necessity and adequacy of the characteristics that an innovation should possess. Feedbacks represented by arrows on the figure, are of high significance because they render the whole procedure distributed.

It is crucial to focus on feedback loops, where knowledge and innovation 'move a step back', in order

to be reassessed and/or updated. Furthermore, because the challenge is to conclude with a 'collective' innovation, there is a loop (Figure 4 the upper bidirectional arrow) representing the interchangeable data between society-environment and the inner organization, which represents the collaborative formation of SA, i.e. the DSA, as the previous step before opening the way to Embedded Open Innovation. This part of the framework is the most challenging one in its application, since its roots run deep into the societal and organizational culture. This argument gives a reason for changing our perception over collaboration and innovation by apprehending them, correspondingly, as the means and the emergent property, i.e. the 'outcome', of a complex socio-technical system.

This framework does not demote knowledge to awareness, contrariwise, awareness is something more than knowledge, it is the *"continuous extraction of environmental information, and integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing future perception and anticipating future events"* [18], such as new consumer demands and innovations. What is more, *"SA is acquired based on the integration of knowledge that is derived from recurring situation assessments, where situation assessments are the process of perception and pattern matching"* [19].

4. THE NEW ECONOMIC SOCIOLOGY IS DOMINATED BY AKIN PRINCIPLES AS DSA

In the New Economic Sociology, Embeddedness is the core concept indicating a sociological approach to the economy [12]. What a sociological approach offers are statements of how and why particular facts about the social world are related. They range in scope from concise descriptions of a single social process to paradigms for analysis and interpretation. Some sociological theories explain aspects of the social world and **enable prediction about future events**, while others function as broad perspectives which guide further sociological analyses. The prediction of future events presupposes cognitive perception and comprehension, there is thus a latent but strong connection between the sociological approaches and the awareness of situations. In the examined case, 'situations' are economic or market related, but the process is the same as depicted in Figure 3.

The New Economic Sociology carries some characteristics that exhibit similarities with the those of DSA in socio-technical systems. The characteristics of the former are presented below [14]:

(1) An economic transaction is done **by and for people**. As such this transaction reflects sociality in the ways it is conducted, in the sets of assumptions regarding the behaviors of the participants and the behaviors of the non-participants, and the roles that these transactions play in **the larger social world** (their structuring potential).

(1') SA in complex socio-technical systems, i.e. DSA, is also done by and for people. Although most of the time socio-technical systems bear a plethora of technical artifacts, their focus and efforts are human-centered. Humans are monitored both on an individual level and in teams in terms of their shared ideas, information, and data that flow within (sub)systems and hierarchical levels. What is more, the general impact of information possession and understanding, by the different system elements, is important for the formation of DSA for the system as the unit of analysis.

(2) The motives of the participants are influenced by their **social relations, norms, and structures**: participants are **social agents**.

(2') In socio-technical systems, mental models, operational and hierarchical constraints affect communication and interaction between the elements of the system, i.e. the organization. The most important elements within the system are agents, who correspond to the group of system elements that possesses reasoning mechanisms and demonstrates a capability to influence other agents or situations. They also carry mental models and cultural characteristics that affect the outcome of any communication or operation.

(3) The importance of institutions and their construction as sets of **shared interests and social relations** that are so important to the **structuring of society** that these interests and relations are often encoded as laws and regulating social norms.

(3') The corresponding shared interests and social relations exist in all kinds of systems which include the human factor. Within the boundaries of an extended, dispersed, and diverse environment, the clear statement of individual roles is vital. That is, ambiguity in role definition can adversely affect DSA [15] because it may lead to confusion over who knows what, at what times, and who possesses what information. This clear picture about individual as well as team roles, in combination to system's objectives and organizational culture, shape the structure of the system, the corresponding communication channels, and the points of high interest, regarding systems operations.

From the above, it is seems that there is a common context, within which SA and the New Economic Sociology were developed over the years. Either one refers to SA or to the New Economic Sociology the system under consideration is always a complex organizational work design that recognizes the interaction between people and technology in workplaces. The socio-technical system also refers to the interaction between society's complex infrastructures and human behavior. In this sense, society itself, and most of its substructures, are complex socio-technical systems.

4.1. Rethinking the Limitations of Embeddedness Under the DSA Concept

Embeddedness is becoming the central concept of the New Economic Sociology and refers to the degree to which economic activity is constrained by non-economic institutions. In the New Economic Sociology, network structures, rather than social action, become the explanatory variable [22]. Beckert [12] explains that the meaning of Embeddedness is twofold: On the one hand,

markets are limited by institutional regulations and the moral fabric of society. On the other hand, Embeddedness is not only an analytical term, but also alludes to the political or social reformist task of stabilizing a (democratic) organization of society through the institutional regulation of markets. Hence, the reference point of Embeddedness is not the economy as such, but *"the larger social systems in which all economies are located"* [23]. Beckert [12] has also detected two limitations concerning Embeddedness. These limitations are:

(1) Actors in economic contexts must **resolve coordination problems**, which Beckert [12] has identified to be the problems of value, competition, and cooperation.

Suggestion (1') This work intentionally suggests DSA (and not any other form of SA - for more see [15]) because coordination and communication are indispensable behaviors for the system to attain its hyper goals. When awareness is distributed, so does information and knowledge as well. Owing to the fact that operations and procedures are distributed by nature, coordination and communication cannot be absent from the information-knowledge-innovation equation (see Figure 4).

(2) Taking Embeddedness as a foundational concept, it directs research in **economic sociology to the meso- and micro-level** and **neglects processes of macro-social** change which were paramount in the investigation of economic phenomena by classical sociologists.

Suggestion (2') The two crucial characteristics of socio-technical systems, i.e. hierarchy and emergence, indicate that a change at a micro-level fetches changes at a meso-level and triggers changes on the systems as a whole or even on the hyper-system, i.e. macro-socially. Systems thinking has been applied to complex problem solving, by 'viewing' problems as parts of an overall system, rather than reacting to specific parts, outcomes, or events and potentially contributing to further development of unintended consequences. Systems thinking is not one thing, but a set of habits or practices within a framework that is based on the belief that the components of a system can best be understood in the context of relationships with each other and with other systems, rather than in isolation. Systems thinking focuses on cyclical rather than linear cause and effect procedures. Since systems thinking 'lends' its principles to the DSA approach, it is inevitable to consider the examined system not only in its wholeness, but in correlation with other systems which directly or indirectly interact with each other.

5. DISCUSSION AND CONCLUSION

Until now, researchers have acknowledged the need to perceive Open Innovation as an embedded process, however, there seemed to be no sufficient theoretical background to reflect upon the course of events from data and information, to knowledge creation, and finally to Embedded Open Innovation. Besides, the reasoning presented herein, facilitates readers to grasp the differentiation between innovation, Open Innovation, and Embedded Open Innovation.

This paper provides evidence that Embedded Open Innovation is indeed a complex distributed form of Open Innovation falling under the scope of the New Economic Sociology. Besides, in this paper, there is a one-by-one mapping between the characteristics of the New Economic Sociology, as stated in the literature, and the DSA in complex socio-technical systems.

The socio-technical perspective, and, in particular, the principle of mutual constitution, speaks directly to the complex and dynamic interactions among technological capacities, social histories, situated context, human choices and action. All in all, the socio-technical premise implies that technologies are socially situated. In this context, Embedded Open Innovation constitutes an emergent property of complex socio-technical systems, dictated by the gradually increasing human needs and interactions with sophisticated technologies, along with the corresponding newly introduced theoretical and practical aspects, such as Systems thinking and the New Economic Sociology, which were briefly described previously.

To conclude, in this paper it was considered important to explain that Open Innovation is embedded and emergent to demonstrate the limitations of the existing models. Hence, the novelty of this paper lies in the integration of the concept and collaboration principles of DSA to overcome the limitations of Embedded Open Innovation. Shaping the awareness about the situation of the market, as a prosperous field of co-creation, serves to understand how the human (i.e. individual understanding over a situation) and the 'market' (i.e. collective action and understanding of many distributed humans aided by infrastructure) cognition work together, in order to reach an innovation, whether in its simple or in its open embedded form.

Concerning future work, since DSA is an emergent property of complex socio-technical systems, it seems that it could be a suitable conceptual model that will help scholars move a step forward in developing new open business models and adequately answering the aforementioned limitations. For this reason, and in order to provide researchers with grounded suggestions and evidence, regarding the combination of DSA and Embeddedness, we offer some theoretical underpinnings for the examination and handling of those limitations.

All in all, when there is shortage and inadequacy of concepts and models, a way to deal with it is to try to change the paradigm, i.e. the 'worldview'. In order for one to persuade him/herself, there is a plethora of scientific works (e.g. [15, 17, 19, 24, 25, 26]) explaining how the concept and the principles of DSA have answered to critical questions in aviation, aeronautics, safety and security, and in other sectors, less critical for the safety of the human elements and the system as a whole.

5.1 Further Research

The paper in hand may sound theoretical, but it is theoretical only in the sense that we do not have yet the scientific tools to prove the gravity of our conceptual statements in the sector of innovation.

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