Integrating Big Data Analytics, Systems Thinking and Viable Systems Approach Towards a Shift from Individual to Collective Intelligence and Collective Knowledge Systems

STEFANO ARMENIA

s.armenia@unilink.it

Link Campus University

FRANCESCA LOIA

Francesca.loia@unina.it

University of Naples Federico II

Abstract

Purpose – The growing complexity of social systems and the faster technology evolution make central the role of the innovative information technology in complex organisations, geared towards collective intelligence processes among the various social actors and analytical tools. These are able to foster the participant knowledge, manage the feedback through a holistic approach and hence shift organisations from a plurality of voices to an interactive intelligence representing the ultimate identity of the organisation itself. In this regard, the aim of this paper is to offer a model for managing external and internal knowledge in order to support the viability of the organisation (system) in the longer term.

Design/methodology/approach – The paper adopts the interpretative lens provided by Systems Thinking, System Dynamics and Viable System Approach (vSa) to investigate the challenging domain of the knowledge and information management for complex systems as organisations. Therefore, a qualitative and interpretative approach is carried out to reflect upon Big Data approaches and Collective Knowledge Systems (CKS), embracing a system perspective.

Findings – The proposed conceptual model shows the crucial role covered by the holistic managing of the external and internal knowledge that permits to align the information variety of the organisation to the context and the entities that compose it in order to create harmonic relations. Leveraging on the concepts of vicariance, bricolage and exaptation, several advantages emerge that are correlated to the capacity of the complex system to reach a greater level of survival, by adapting and dynamically evolving itself.

Originality/value – The paper shows how Systems Thinking and Viable System Approach can provide deep insights into the field of information technology, evidencing the systems thinking contribution in analysing, understanding and managing dimensions and paths of social dynamics. A contribution to previous studies is provided with reference to themes as Big Data, information and knowledge management.

Submitted 30/07/2019 - Accepted 05/01/2021

1. Introduction

The last decade has seen growing attention devoted to social systems that are increasingly characterised by expanding complexity. Not only the rapid growth of the global economy, together with high population growth and the excessive exploitation of natural resources but also the ever faster technological evolution underlines the need of a new holistic approach able to comprehend the complexity of organisations in the post-growth era (Dominici *et al*., 2016). In such a complex and fragmented context, the shift from an 'objective rationality' to a lower level of the intended rationality (Simon, 1955) highlights the limits of human decisions in terms of restricted available information, its cognitive limitations, and limited time available.

Basing on the system thinking approach is possible to act wisely, by taking advantage of information feedback about the external context and, through this, redefine the decisions and the mental models established. Unfortunately, the feedback mechanisms are quite inadequate and ambiguous, and new approaches aimed to enhance the learning about complex systems must be addressed, considering new tools able to foster the participant knowledge, articulate and reframe external perceptions, and manage the feedback obtained by those perceptions through a holistic approach (Sterman, 1994).

In addition, the importance of information and knowledge in every economic and social process has led to the development of the so-called 'knowledge economy' (Powell and Snellman, 2004). Learning and knowledge creation are seen as qualitative relation processes that are sensitive and intellectual, creative and destructive, enabling and binding, and these considerations call into question the belief that organisational knowledge is essentially codified and centralised, highlighting instead that organisational knowledge is included in the relationships between a plurality of people inside the organisation and between the organisation and the context (Stacey, 2003). Therefore, the tacit knowledge of relevant actors in the organisation recovers always more and more importance in organisational learning and innovation processes, becoming the focus of considerable attention in the recent literature. However, it is missing a conceptual framework integrating micro-level learning activities (from the plurality of members) with organisational forms and macro-level (hence leading to a superior identity) societal institutions (Lam, 2000).

Thus, the need to manage the potential information coming from outside together to combine in an equal way the codified and tacit knowledge stimulates a new way of intending the information and knowledge management in the complex systems. Through the metaphors of exaptation (Gould and Vrba, 1982) bricolage (Lévi-Strauss, 1962) and vicariance (Reuchlin, 1978; Berthoz, 2013) can be considered new properties, both systemic and structural, able to guarantee a greater level of survival of the system in the context in which it operates. According to this, the growth of a system arises not only through an engineering activity but by process of collective intelligence (Lévy and Bononno, 1997), able to help the organisations to carry out a participatory logic that can guide towards a common purpose and increase the viability of the complex system (Barile and Saviano, 2011). With the aim to propose a conceptual model able to manage external and internal knowledge the paper adopts the interpretative lens offered by the Viable System Approach (vSa) and Systems Thinking and, leveraging on the concept of Collective Intelligence and Collective Knowledge Systems (CKS), offer a framework that permits to align the information variety of the organisation to the external and internal entities in order to create harmonic relations (Barile and Polese, 2010).

Therefore, system thinking, system dynamics and viable system approach act as the theoretical background, able to merge in a single model different key concepts and to explain the shift from individual to collective intelligence and collective knowledge systems. In particular, from system dynamics, the concept of feedback is essential for enabling the combination of the different types of knowledge in a synergic way by means of an improvement cycle (Iandolo *et al*., 2018). From the others hand, the Viable System Approach (vSa) underlines the importance to adopt a participatory logic that can guide complex systems towards a common purpose for increasing the viability of the system complex and dealing with numerous and changing entities of the context and internal.

The work is structured in four main sections. Firstly, it opens with the analysis of the theoretical background of reference, reporting the scientific evidence emerging from the literature dedicated to organisations as complex systems, the characteristics of these correlated to the metaphoric concepts of vicariance, bricolage and exaptation, and new challenges focused on new information technology. Continuing, the research path, structured by adopting the concepts provided by Systems Thinking and Viable System Approach, defines a new possible interpretative path with reference to the role of the external and internal knowledge in complex systems, by highlighting the crucial role of the Collective Intelligence and Collective Knowledge. Afterwards, the potential implications of the work are highlighted, from both a theoretical-scientific and a practical-managerial point of view and commented. Finally, within the conclusions, the limits of the work are underlined, and some suggestions for possible future research are offered.

1.1. Organisation and knowledge management as a complex system

Business organisations, typified by semi-autonomous organisational members interacting at many levels of cognition and action, can be represented by the generic constructs and driving mechanisms of complex adaptive systems theory (Dooley, 1997). Starting from the application of the complex system to the study of organisations and social behaviour, organisations are assumed to exhibit nonlinear behaviour and should be used to provide context-specific descriptions of organisational behaviour with more historical, longitudinal, and qualitative research methods (Svyantek and Brown, 2000). Complex systems face complex problems, and the human mind comes across different limits due to the restricted available information, its cognitive limitations, and the limited time available to take any decision. Hence, this context does not allow to achieve the ideal of ‘objective rationality’ (make the most optimal decision possible, given the information available) and is destined to a lower level of the intended rationality (Simon, 1955). Consequently, the performance and success of an organisation are governed primarily by the limitations of its members and depend on the organisational setting within which decision-making takes place (Morecroft, 1983).

Today, the value co-creation process for organisations is not a supplier-centric process of production and delivery, nor is it customer-centric; rather, it is more complex and dynamic. By examining participants in the creative process, the value is created by and for all the actors through a choral win-win perspective. In fact, the involvement of several actors (such as customers, suppliers, and partners) makes value co-creation a complex process (Gummesson, 2008; Gummesson and Mele, 2010; Polese, Mele, and Gummesson, 2017). Therefore, the complexity of the systems in which we live grows, so do the unanticipated side effects of human actions, further increasing complexity. Effective methods for learning in and about complex dynamic systems are, for instance, tools to produce participant knowledge, articulate and reframe perceptions, and create maps of the feedback structure of a problem from those perceptions (Sterman, 1994).

In this direction, there is an increasing awareness by organisations that need to develop a capacity to grow their knowledge and to learn. This process needs to be improved in order for people to develop an understanding of the nature of their organisation, how it works, and the role of information and knowledge within it. This includes the creation of a sound understanding and practice of knowledge management (Alavi and Leidner, 2001). In particular, knowledge management can be defined as the creation of knowledge and its interpretation, dissemination and application, retention and refinement (De Jarnett, 1996). Often, it is seen as a critical source of competitive advantage (Allee, 1997), and it creates intellectual capital (Drucker, 1995). McAdam and McCreedy (1999) have explored a variety of knowledge management models, and one of the most interesting is that of Nonaka and Takeuchi (1995). Indeed, Nonaka and Takeuchi (1995) develop on their definitions of explicit and tacit knowledge to create what has become the well-known SECI model for knowledge creation. It derives from the idea that a mapping or conversion process occurs between tacit and explicit knowledge, resulting in four types of knowledge conversion, each of which is a process of knowledge translation. Another important aspect in knowledge management field regards the topic of information management (Laudon and Laudon, 1999, 2011). The relation between information and knowledge is essential to the organisation, and not only as a resource (Liew, 2007). Information is related to data in that the latter may be regarded as measurements of perceived phenomena (Frakes and Baeza-Yates, 1992). Information is manifested through structured methods of inquiry (both for structured and unstructured data), and in the systems' domain, there has been a great deal of exploration into methods that create information. Therefore, knowledge is a driver of organisational awareness and viability, and can occur as a transformation of acquired information from environmental phenomena, or virtually from communications with which members of the community interact.

Thus, it is through the manifestation of information and the creation of knowledge that complexity can be addressed, thus allowing organisations to develop the possibility of greater viability. Thus, the aim of the organisations is to manage complex situations and make their knowledge clear and less uncertain in order to survive in the longer term. Indeed, over the approach of knowledge creation cycle by Nonaka and Takeuchi (1995), based on a constructivist process through a positivist structure, a different critical approach for knowledge creation comes from viable systems, which does not see knowledge creation as a set of sequential steps, but rather as a set of phases that are constantly tested and examined through possibly complex feedbacks (Yolles, 2000, 2006). Therefore, the knowledge management fits in the larger context of systems thinking so that the influencing factors on its success or failure can better be recognised and understood (Rubenstein-Montano *et al*., 2001).

1.2. Complex system characteristics behind the lens of metaphors

Starting from the application of the complex system to the study of organisations and social behaviour, organisations are assumed to exhibit nonlinear behaviour and should be used to provide context-specific descriptions of organisational behaviour with more historical, longitudinal, and qualitative research methods (Svyantek and Brown, 2000).

In general, complex systems possess peculiar characteristics that determine not only their level of complexity but also their functioning. In her book *Thinking in Systems*, Donella Meadows (2008) describes these typical properties of complex systems and how they permeate complex systems of every kind and in every context. The properties mentioned by Meadows (2008), that is, self-organisation, hierarchy and resilience, if we want to make a parallelism, have strong points in common with three key concepts that could easily serve as a metaphor for the study of organisation management, which is, as previously said, full-fledged complex systems. The three key concepts are *exaptation*, *vicariance* and *bricolage*. They have a unique one-to-one relationship with the complex systems' properties mentioned by Meadows (2008), as shown in Table 1.2.1. The reason for these parallelisms lies in their definitions.

The *exaptation* (Gould and Vrba, 1982) is a particular type of evolution in which an evolved character for a particular function assumes a new function, independent of the primitive. The feathers of the birds, evolved from the dinosaurs presumably for purposes of thermal isolation and balance, have changed their purpose becoming fundamental for the flight. This is a perfect example of the self-organisation capacity that determines the process of evolution of species, which is governed by precise laws (Von Bertalanffy, 1952). These self-constituted laws emerge from the stimulus to the survival and adaptation of the biological system, which, as a complex system, evolves and adapts making its structures more complex and diversified and independently seeking the best possible structure to continue to exist.

The diversification operated naturally by complex systems has much to do with the concept of *vicariance*. In biological terms, the vicariance (Reuchlin, 1978; Berthoz, 2013) can be defined as the fragmentation of an environment as a factor in promoting biological evolution by the division of large populations into isolated subpopulations. Therefore, from a systemic point of view, the process of diversification and vicariance lead to the creation of a spontaneous organisation in systems and subsystems, according to a hierarchical order. Larger systems often coordinate smaller ones, which maintain themselves and the larger system, creating stable, efficient and resilient structures.

Finally, the concept of bricolage has something in common with resilience. As Lévi-Strauss (1962) states, the universe of available tools is limited for the *bricoleur*. For the *bricoleur*, the rule of the game consists in always adapting to the set of resources at her/his disposal, which are the contingent result of all the opportunities encountered to renew or enrich her/his resource stock, to find all the possible answers that her/his set can offer for resolving a specific problem. The ability to dynamically use resources to face problems and changes is typical of complex systems that regulate themselves and aim for a balance. The same balance that is central when talking about the resilience of a complex system that is the ability of a system to survive and maintain a balance within a variable environment by combining available resources and optimising their use.

Therefore, complex organisations should follow a conceptual model able to exploit these properties in order to achieve an advantage in the long run and encourage the value co-creation process.

	Exaptation	Vicariance	Bricolage

Meaning	The shift of a trait in the function during the evolutionary process from both an anatomical and behavioural perspective (Gould and Vrba, 1982).	The substitution of a process with another process that leads to the same result. It is a fundamental tool for organisms because it offers them the powerful ability to create, innovate and interact with others in a flexible, broadminded, and generous way (Reuchlin, 1978; Berthoz, 2013).	According to Lévi Strauss (1962), the *bricoleur* is the one who uses the tools that he finds around him and tries to adapt them according to various attempts to his purposes. Furthermore, the author distinguishes between the *savant* (the scientist) and the *bricoleur* for the inverse functions that, in the instrumental and final order, they assign to the event and to the structure. In fact, the former brings to light the events through the structures; the latter, the structures through the events.
	Self-organisation	**Hierarchy**	**Resilience**
Complex system properties	The capacity to emerge over time in a coherent form and adapts and organises itself to guarantee adaptation without some singular entity capable of managing it or controlling it deliberately. Constant redefinition of the relationship between the system and its environment (co-evolution) (Holland, 1995).	The hierarchical structure maintains a certain degree of control but includes continuous internal reorganisation because the complex systems adapt their behaviour in relation to the changes that occur both internally between the agents that compose them, and externally, in the context in which they are inserted. The system evolves incessantly over time while maintaining its own coherence, the 'identity' of the entire system, without disintegrating (Levin, 1998).	The property of complex systems to restore functioning mechanisms by responding to stress phenomena. Resilient systems react by renewing themselves while maintaining the recognisability of the systems themselves. Resilience implies the restoration not of the initial state but of functionality through adaptation (Holling, 1996; Holling and Gunderson, 2002).

Table 1.2.1. Merging the complex system properties with metaphors of exaptation, vicariance and bricolage.[1]

[1] Source: authors' elaboration.

1.3. Big Data analytics as a competitive driver for complex organisations

Nowadays, starting from the problem of the limited information available in the decision-making process, the higher and quicker development of always better data management technologies in complex organisations have recently contributed to render cheaper and faster the activity of gathering and processing large amounts of data with reference to specific process and performance indicators. This new paradigm, represented by the Big Data phenomenon, is definitely exploding, representing a new era in data exploration and utilisation (Chen *et al*., 2012). The 'mass digitisation' (Coyle, 2006) connected to 'Internet of Things' interconnection (Ashton, 2009) led to a rapid expansion of large amounts of data, characterised by three dimensions: volume, speed and variety of generated data, as reported by the 3Vs model of Laney (Zikopoulos and Eaton, 2011; Beyer and Laney, 2012; Zaslavsky *et al*., 2013). Later, other concepts as veracity and value have been attributed to this model, with the aim to highlight respectively the quality across datasets and the capacity to generate useful output for industry challenges and issues (Uddin and Gupta, 2014).

Several techniques, technologies, practices, and methodologies are already being used in each sub-process related to a data-driven application, which comprises transmission, capture, storage, analysis, visualisation, and interpretation, to improve decision-making processes (LaValle *et al*., 2010; Chen and Zhang, 2014). Decisions will increasingly be based on data and analysis rather than on experience and intuition (McAfee and Brynjolfsson, 2012). In this scope, the data mining techniques permit to extract useful information from large datasets or streams of data (Fan and Bifet, 2013) and can reveal insights, supporting decision-making. Indeed, the data-driven model involves demand-driven aggregation of information sources, mining and analysis, user interest modelling, and security and privacy considerations (Wu *et al*., 2014). The purpose is, consequently, through data mining techniques, analyse structured and unstructured data and create information, becoming a strategic activity able to create knowledge and value for companies (Rowley, 2007; Cricelli and Grimaldi, 2008).

Thus, the proliferation of big data and the speed of analytics are significantly disrupting many business models, considering the information as an asset that will transform business and operating models (Armenia *et al*., 2017; Ciasullo *et al*., 2018; Troisi *et al*., 2018). Big data movement offers many unique opportunities for organisations considered as complex systems such as by benefiting of knowledge discovery and management process, by exploiting big data techniques, cloud computing, and semantic web in order to offer a broader spectrum of pervasive knowledge acquisition to enrich users' experience in learning (Begoli and Horey, 2012). In this regard, several organisations do not yet understand how best to use analytics to improve business performance and manage risk, because the skills are yet limited and strategic priorities are focused on other challenges, including legacy IT systems (Johnson, 2012). Structural and systemic management efforts will be needed to create a new performance culture for the organisation, including skills, capabilities, and infrastructure. Indeed, data analytics appropriately managed and implemented, can bring clarity to business decisions and improve business outcomes, by helping leaders to focus on the knowledge they need, derive insights and actionable intelligence from data and create, manage, and govern new business models (Prescott, 2014).

Hence, organisations considered as complex systems are facing new challenges focused on new information technology and are looking for ways to exploit the potentialities of big data to improve their decision-making processes, in order to take advantage from an evolutionary process in which the gradual understanding of the potential of big data and the 'routinisation' of processes play a crucial role (Janssen, Van Der Voort, and Wahyudi, 2017). Indeed, considering the exponential growth in data, enterprises must act to make the most of the vast data landscape, by applying multiple technologies, carefully selecting key data for specific investigations, and innovatively tailor large integrated datasets to support specific queries and analyses. All these actions flow from a value chain framework based on data that enables to manage data holistically from capturing to supporting decision-making and the variety of stakeholders (Miller and Mork, 2013).

This innovative information technology in complex organisations is oriented towards collective intelligence processes among the various social actors and analytical tools. These are able to foster the participant knowledge, manage the feedback through a holistic approach and hence shift organisations from a plurality of voices to an interactive intelligence representing the ultimate identity of the organisation itself. However, also the internal knowledge should recover a crucial role in the dynamic of knowledge of the organisations by contributing to the decision-making process and to improve the level of awareness regarding internal potentialities, limits and structural characteristics (Cohen *et al*., 1985; Ten Berge and Van Hezewijk, 1999). In this direction, by exploiting new information technologies for obtaining external knowledge and by taking advantage of the internal knowledge, organisations as complex systems can pursuit the viability in the longer term.

2. Methodology

Starting from the premises introduced in the previous section, the paper is based on a qualitative approach method in order to provide useful insights for managing the internal and external knowledge for complex systems. The choice to follow a qualitative approach is moved by the nature of the investigated field (Lincoln and Denzin, 1994). In fact, the analytical and reductionist approaches are restricted enough for the analysis of complex systems and this underlines the need of following a system approach, in order to highlight a whole set of phenomena and offer a clear picture about its structure and functioning. In order to fill this gap, the paper adopts the interpretative lens provided by system thinking, system dynamics and viable system approach for merging in a single model different key concepts. Indeed, from system dynamics, the concept of feedback covers a central role in the following model because it enables the combination of the different types of knowledge in a synergic way by means of an improvement cycle (Iandolo *et al*., 2018). From the others hand, the Viable System Approach underlines the necessary participatory logic that can guide complex systems towards a common purpose for increasing the viability of the system complex and dealing with numerous and changing entities of the context and internal. Subsequently, the concepts of Collective Intelligence and Collective Knowledge Systems are recalled as a first model in order to take into account the important role of the social web and build the viable framework for managing internal and external knowledge.

2.1. Systems Thinking and System Dynamics

One of the methodologies introduced in the definition of the proposed framework, at this stage of our study, is based on a qualitative modelling approach named Causal Loop Diagrams

(CLD). This is one of the basic tools in Systems Thinking, which in turn is typical of the initial qualitative design phase in the System Dynamics modelling and simulation approach (Sterman, 2001). System Dynamics (SD), proposed by Forrester (1961), is deeply rooted on the General System Theory (GST), proposed by Von Bertalanffy (1956) as well as from the theory of feedback control from systems engineering.

GST was developed by the need of making more 'scientific' the behavioural, biology and psychosocial sciences so that their concepts and theories could be appreciated as well as the ones of physics and mathematics (Von Bertalanffy, 1967). As stated by the GST, the basic condition to define a system, the one that makes it maintain its status of being a 'system', is that its elements interact with each other. More elements interact when one influences the other, for example, by exchanging energy during shocks, performing different functions, for example, in an electronic circuit, and exchanging information as in social systems. The stability of the system property is due to continuous interaction.

John Sterman (2012) describes System Dynamics as the founding element for the creation and design of a new systems science inside a fragmented academy and polarised world, hence also arguing that SD can constitute an 'Esperanto' for systems researchers in talking the same language.

Besides the fact that firms can be considered complex systems and, as such, they are good subjects for investigation by a systemic approach, the link between the SD approach and the general theory of the firm is marked. In fact, the SD approach was designed by Forrester in 1961 in his first seminal book *Industrial Dynamics*, where he was basically arguing how a company can achieve a sustainable growth only by considering the interdependencies between the economic and social systems. This implies putting what is called 'soft' variables (typical of human behaviour in decision-making) at the centre of a systemic and behavioural view of the firm. This, of course, is strictly connected to the important work done in the early 1960s at Carnegie Mellon on organisational theory (Cyert and March, 1963), from which Forrester later formalised the delay between information and action. Being also a simulation approach to the analysis of dynamic systems, SD often adopts a numerical rather than an analytic approach to the investigation of the systems' behaviour. This implies that SD escapes the rigidities imposed by the need of closed-form solutions, these latter implying simplified mathematical formulations amenable to analytical solutions. On the contrary, SD is not constrained by the limits imposed by closed-form solutions and can, therefore, adopt richer formalisations. Through simulation, SD allows investigating about the behaviour of complex systems (including the one tightly coupled with societal aspects/issues); furthermore, it deals with the decision-making problem in business, industry, economy, etc. (Sterman, 2000). The features of SD include the possibility to account (in the description of a system, or a system of systems) for aspects like nonlinearities, information feedbacks, time delays, interdependency between subsystems, and dynamic complexity (O'Connor and McDermott, 1997).

SD approach employs various tools for extrapolating information about complex systems and discovering hidden and counter-intuitive behaviours.

In this sense, the CLD approach, typical of the Systems Thinking approach, is heavily qualitative but is the starting point for the production of a quantitative model. Notwithstanding its qualitative value, the analysis of CLDs can introduce several important results. The first advantage in using this type of analysis is that it provides a vision that considers many themes inside a system as interconnected with each other, contrary to those past approaches where systems are analysed individually and on a sectoral basis.

The outcome of a CLD is a combination of causal links between variables. Links can be of two types:

1. Positive (S): when the independent variable (arrow tail) changes, then the dependent variable (arrow head) changes in the same direction;
2. Negative (O): when the independent variable (arrow tail) changes, then the dependent variable (arrow head) changes in the opposite direction.

There are two types of feedback loops: reinforcing feedback loop and balancing feedback loop (indicated by + and – inside the loop). Also, it is possible to indicate a time delay between the two variables (Figure 2.1.1).

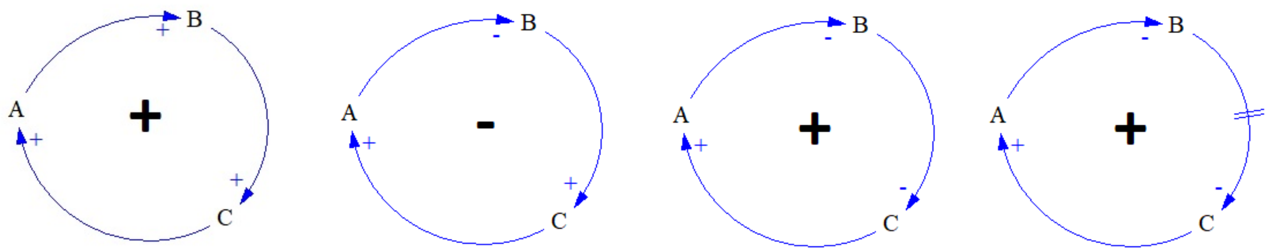

Figure 2.1.1. Starting from the left: Positive loop, negative loop, positive loop due to even number of negative links and delayed loop.

In a Reinforcing feedback loop, the effects of a small disturbance on one or more variables inside the loop cause an overall increase in the magnitude of the perturbation. This type of loop often produces exponential growth, increasing oscillations, chaotic behaviour or other divergences from equilibrium. Conversely, balancing feedback loop tends to promote a settling to equilibrium, reducing the effects of possible perturbations, which affected one or more variables inside the loop. However, the concept of feedback is essential for complex organisations, especially for enabling the combination of the different types of knowledge in a synergic way by means of an improvement cycle (Iandolo *et al.*, 2018).

Positive, negative, and delayed loops can give birth to a variety of systemic structures, named system archetypes, which can assist in taking a closer look at the problem displayed by a certain system and diagnosing the optimal solution (Mirchi *et al.*, 2012)

Systemic archetypes are modular structures that highlight a particular behavioural pattern. They can be used, individually or together with others, to infer a set of behaviours that can be found in the evolving observable variables of a system (Senge, 1990: 93):

> If reinforcing and balancing feedback and delays are like the nouns and verbs of systems thinking, then the systems archetypes are analogous to basic sentences or simple stories that get retold again and again.

Therefore, founding these types of patterns inside a system, it is possible to give a deeper explanation about its dynamics and performance (Armenia *et al.*, 2013).

2.2. Systems Thinking and Viable System Approach

Recognising the limits of the traditional analytical-reductionist approach for complex systems, this paper follows a systemic approach, underlining the need for recovering a whole view of phenomena. In this way, the systems path appears as a bridge between a reductionist and a holistic approach (Barile and Saviano, 2011). Indeed, the Viable System Approach (vSa), re-exploring the contributions of system thinking to management, can be considered as a set of lenses for observing complex phenomena, focusing on the analysis of relationships among socioeconomic entities in the context, which seek viable interacting conditions (Barile and Saviano, 2008; Golinelli, 2010). Given the complexity for organisations, the vSa can support the process of decision-making (Barile and Saviano, 2018) by basing decisions on a participatory logic that can act as a guide towards a shared goal. In particular, considering the survival as the primary purpose of a system ('system viability') (Barile *et al*., 2012), the system in order to survive tries to be aligned (i.e., consonant) with its relevant supra-systems (i.e., other systems that retain critical) (Polese, Mele, and Gummesson, 2017). The concepts of consonance between two systems (individuals, social system, etc.) can be analysed by means of the model of information variety (Ashby, 1991), which accounts for the symmetry of information varieties among the involved entities.

The information variety, as shown in Figure 2.2.1, has the following three dimensions (Barile, Saviano, and Polese, 2014):

- information units, which is the number of single units of data detained by a system (the structural knowledge of the system);
- interpretation schemes, or the cognitive schemes according to which the information units are assembled and understood (the knowledge 'shape' of the system) based on the context;
- categorical values, which are the basic values and strong beliefs of the system (the resistance to change) that influence the way in which the interpretative schemes are used.

The role of the categorical values is particularly relevant because they are responsible for allowing and directing interaction, the degree of system openness, the information sharing process and the outcome of the interaction. In sum, the categorical values finally decide the overall degree of consonance (Barile, Saviano, and Polese, 2014). Thus, in order to reach a greater level of consonance, the system should consider the variety of expectations of external systems considered relevant, allowing for greater awareness of the interventions that could be aimed for reaching a greater level of consonance and ensure viability in the reference context. To this end, incorporating the social community into the decision support systems processes (Wu *et al*., 2018) can help the organisations to carry out a participatory logic that can guide towards a common purpose and increase the viability of the system complex. Therefore, it is necessary to look for solutions that can support the decision-making process, which finds itself dealing with numerous and changing entities of the context in conditions of complexity, in an attempt to harmonise the interests of the various actors and to converge towards a joint evolutionary direction, towards the context consonance (Barile and Calabrese, 2011). In this direction, the technologies can be considered as a strategic driver that allows users to communicate in order to align their information variety and improve the context consonance and the viability of the system (Barile *et al*., 2018).

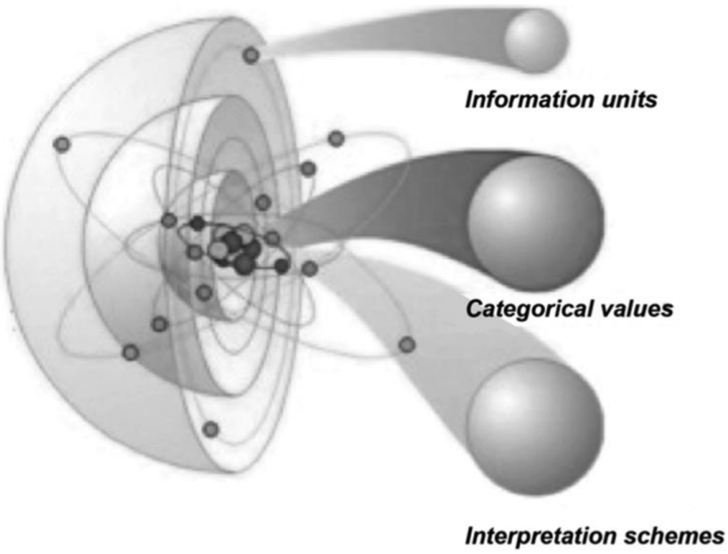

Figure 2.2.1. Representation of information variety (Barile, Saviano, and Polese, 2014).[2]

2.3. Collective Intelligence and Collective Knowledge System

Starting from the theory of the knowledge creating (Nonaka and Takeuchi, 1995), the cognitive systems (individuals) can have an impact on the development of a social system (as an organisation) which, in turn, can influence their beliefs. In this direction, the Collective Intelligence (Lévy and Bononno, 1997) is understood as different micro-contributions to the understanding which can be provided in order to multiply instead of summing the intelligence of singles. When one system provides to the other its ability to solve complexity, both the knowledge of each system and the collective knowledge are increased. According to Wise, Paton, and Gegenhuber (2012), the concept of CI encompasses and surpasses many of the recent conceptualisations (such as open innovation, crowdsourcing, and wisdom of crowds), by representing the human tendency to do seemingly intelligent things in a collective manner (Malone, Laubacher, and Dellarocas, 2010). Above all, this concept takes on importance with the advent of the Web 2.0 era, by leveraging the collective power of user contributions, interactions, and feedback is the key to market dominance. A new category of techniques enables the discovery of the patterns, interrelationships, and individual profiles locked in the data, which people leave behind as they browse websites, by posting on blogs, and interacting with other users (Alag, 2008). Furthermore, based on the CI concept, the Collective Knowledge Systems (CKS) (Gruber, 2008) are able to solve user problems thanks to collective intelligence phenomena based on ICT tools (analytics and research engine, etc.) (Gaeta *et al.*, 2010). The CKS are specifically a kind of system in which small groups of proactive users produce information artefacts that can be searched by other users that need information. In such human-machine systems, both humans and machines actively contribute to the resulting intelligence.

[2] Image used with the permission of aSvSa. Available online at http://www.asvsa.org/ (last accessed: November 12, 2020).

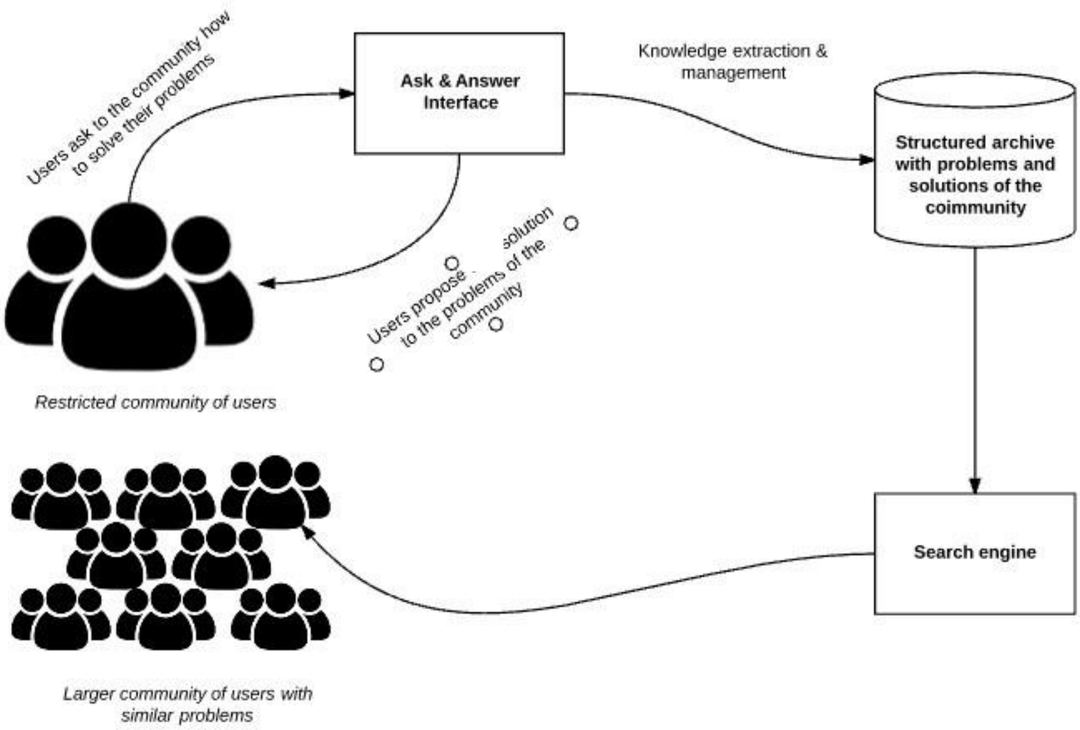

Figure 2.3.1. Example of a Collective Knowledge System.[3]

The CKS, as shown in Figure 2.3.1, consists of three subsystems:

1. A social system supported by information and communication technologies, which formulate a problem that can be solved by means of discussion in the community;
2. A search engine, capable of finding questions and answers in the contents generated by the social system;
3. Intelligent users, capable of formulating problems by means of queries for the search engine.

Therefore, one of the key characteristics of the CKS is the presence of user-generated contents. The system is also able to make inferences from the user-generated contents, by means of knowledge extraction approaches, thus producing answers and results that cannot be found explicitly in such contents, which represents emerging knowledge enabling the shift from gathered and individual intelligence to collective intelligence.

3. A conceptual model for managing external and internal knowledge based on big data analytics and CKS: advantages and implications

Starting from the considerations above, seeing the organisations as complex systems focused on the goal of managing and developing their knowledge, and according to the view of Viable System Approach and Systems Thinking, a conceptual model for managing external and internal knowledge based on big data approach can be presented.

[3] Authors' elaboration from Gruber (2008).

In particular, the model, depicted in Figure 3.1, is composed of two sections:

1. 'Humans users', regarding human-human interactions;
2. 'Machine processes', dedicated to automated activities carried out by software and hardware components.

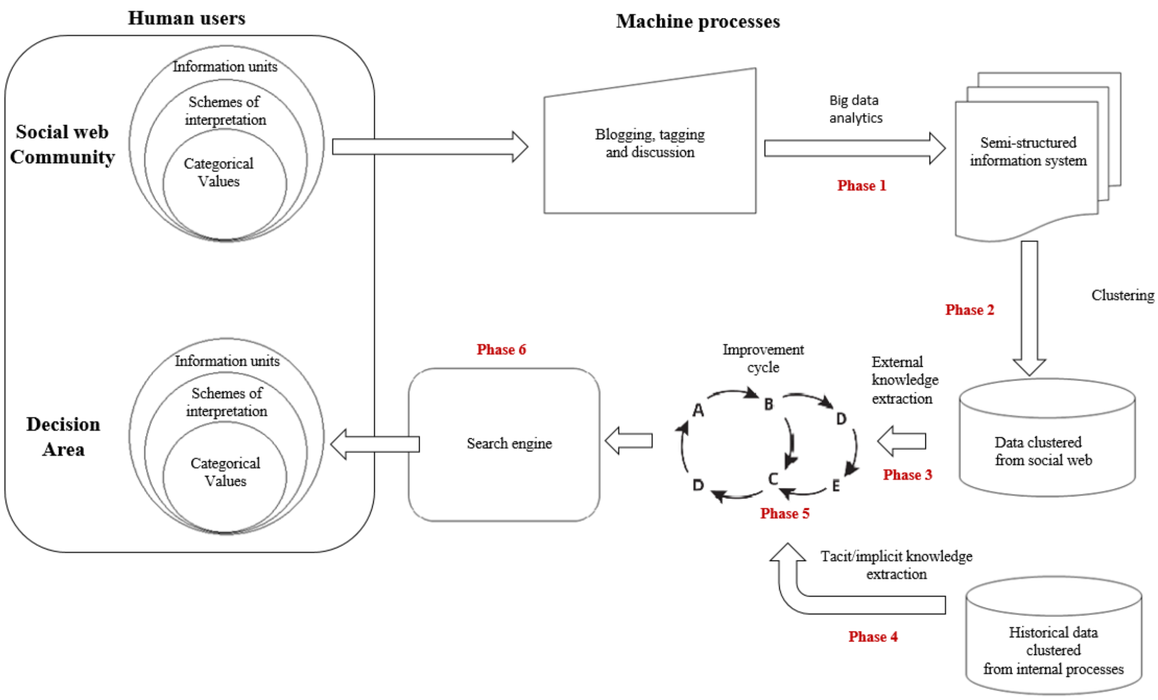

Figure 3.1. A viable framework for managing external and internal knowledge based on big data analytics and CKS.[4]

In this model, regarding the external knowledge and according to Gruber (2008), an important role is covered by the communities of the social web, characterised by a determined information variety composed by information units, interpretative schemes and categorical values (Calabrese, Iandolo, and Bilotta, 2011). In order to interpret and set up effectively the relationships with the multiple entities present and active in the environment and create context consonance, the organisations try to exploit new forms of interaction, collaboration, and knowledge sharing (Barile and Calabrese, 2011) with the social web community (Gruber, 2008) through leveraging the collaborative dimension of social software.

Therefore, in phase 1, starting from intelligent users that interact on social web through activities of blogging, tagging and discussion on internet contents, it is possible to extract useful information from a large amount of data through big data analytics. In particular, it is obtained by clustering a semi-structured information system that can be managed in order to compose a repository of data clustered (Fan and Bifet, 2013) (phase 2) Thus, from this repository, it is possible to manage and exploit the knowledge derived from the environment (phase 3).

[4] Authors' elaboration.

In addition, in order to consider and manage the internal knowledge strategically, the implicit knowledge and the explicit knowledge within the organisation have to be considered (phase 4). In this regard, the extracted or extractable knowledge composed from the data by the information systems of the organisations can be exploited and connected to the explicit knowledge. In particular, the 'procedural knowledge base', comprised of the knowledge derived from information systems on business processes, connected to a 'declarative knowledge base', instead formed by unwritten rules and procedures that influence the organisational level, can contribute and support decision-making activities, enriching a greater degree of awareness about internal organisation's potentialities, limits and structural characteristics (Cohen *et al*., 1985; Ten Berge and Van Hezewijk, 1999)

Therefore, with reference to these three different types of knowledge, respectively the 'social web', the 'procedural' and the 'declarative' knowledge, our approach will consider them in a synergic way and combine them by means of an improvement cycle, with the aim to support the decision making processes, considering both external and internal information (phase 5).

After, a search engine (phase 6) is capable of finding questions and answers in the data clustered, generated by the social web community (Gruber, 2008) and by internal processes, and offers these outputs in order to support and improve strategic decision-making activities, characterised by a high level of complexity. Consequently, this approach is able to derive inferences from user-generated content, by means of knowledge extraction approaches, producing information that cannot be found explicitly in such contents, which represents emerging knowledge enabling the shift from gathered and individual intelligence to collective intelligence. In addition, the offered framework is able to consider the internal knowledge, composed of rules, procedures, but also implicit information regarding the organisation's structure (Nickols, 2000). In this way, the decision-maker can align his information variety to the external entities, represented by the social web, and to the internal components that constitute the organisation, in order to reach a great level of consonance, which represents potential harmonic relations, and to ensure a greater possibility of vitality for the complex system considered (Barile and Polese, 2010).

Considering the properties of the complex systems, this approach can offer several advantages:

- Regarding the self-organisation, through the proposed approach the system considered, leveraging by the influences coming from the same elements that constitute it, can benefit from the internal knowledge (phase 4). By using the search engine (phase 6) on contents about the internal knowledge, the system obtains answers able to highlights the organisational traits from changing and support the strategic decision-making processes. In this regard, the exaptation metaphor highlights that the knowledge extractable from the historical data of the organisation connected to declarative knowledge based on procedures can contribute and support the viability of the complex system, enriching a greater degree of awareness about the inner organisation's strengths, critical issues and structural characteristics;
- With regard to hierarchy, the identified mechanism of collective intelligence takes account of continuous internal reorganisation due to process of adaptation in relation to the modifications that are needed for both inside and outside reasons by leveraging on the obtained internal and external knowledge. In this way, by exploiting the new awareness achieved, the complex system substitutes the processes for better them and evolves

continuously, in order to increase the ability to interact with others information varieties in a more consonant way. Therefore, the vicariance concept underlines the need to align the information variety to the context, represented in this case by the social web, and to the internal components that constitute the organisation, in order to establish potential harmonic relations with the different actors.

– Continuing with the resilience, the system, exploiting the framework proposed, tries to adapt itself by considering multiple perspectives (both internal and external), with regard to uncertain environmental conditions and structural characteristics. As a *bricoleur*, it tries by responding to stress phenomena by adapting its information set according to its various purposes and strategic projections. Only through the phases of learning, diversifying and evolving, it is possible for the system to pursue the viability and ensure its continuation.

4. Conclusion

In a context characterised by growing turbulence, the complex systems seek the viability by balancing a plurality of sub-components that react in unison with external or internal information. They are coupled with the environment they occupy and are also susceptible to very small environmental variations. Through the concepts of vicariance, bricolage and exaptation, the need for a holistic approach is more evident. In addition, the innovative technological approach starting from the Web 2.0 can break new ground in this field. These metaphors, applicable in multidisciplinary fields (sociology, psychology, neurosciences, and biology), addresses new aware perceptions in order to deepen the changeable nature of social systems and their complex evolution.

Accordingly, the paper shows that effective management of the internal and external knowledge of an organisation requires a holistic perspective, also able to clarify the role and contributions of new technologies and big data. In the same direction, the paper underlines the existence of multiple perspectives, which the decision area of a complex system should consider. This consideration highlights the need for adopting multi- and trans-disciplinary approaches with the aim to effectively provide a clear picture and framework to systemically consider the external information and the organisational structural aspects by integrating a plurality of contributions into a final unique identity of a collective intelligence/knowledge.

Reflecting upon these research streams, some implications can be derived both from theoretical and practical points of view. It is possible to state that, from a theoretical point of view, the paper merges the Viable System Approach and the Systems Dynamics with the concepts of Collective Intelligence and Collective Knowledge System, in order to combine the systems thinking, the interpretative lens of the reality, with different research streams and perspectives related to new trends in information technology. At the same time, from the managerial point of view, the work shows a framework that can be a valid support for managing the external and internal knowledge with the aim to make the decision-maker more aware on the interventions and strategic policies to carry out.

Recognising the validity of the proposed concept, some possible future lines of research can be tracked with the aim to enrich the framework proposed and deepen it through a possible case study related to the identified problems. Therefore, the reflections herein are only directed towards outlining a possible conceptual path in which borders and boundaries require a better definition because of the multiple connections and influences that can be traced among the identified concepts. Specifically, more studies should be developed to effectively understand the relation between internal/external vs single/collective knowledge correlated to the concept of resilience and how this connection can affect the viability of complex systems.

Keywords

Big Data; Systems Thinking; Collective Knowledge Systems; Collective Intelligence; Viable System Approach

References

Alag, S. (2008), *Collective Intelligence in Action*, New York (NY): Manning.

Alavi, M., and Leidner, D.E. (2001), "Review: *Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues*", *MIS Quarterly*, 25 (1): 107–136.

Allee, V. (1997), *The Knowledge Evolution*, Oxford: Butterworth-Heinemann.

Armenia, S., Carlini, C., Onori, R., and Saullo, A.P. (2013), "Policy Modeling as a New Area for Research: Perspectives for a Systems Thinking and System Dynamics Approach?", in *Proceedings of the 13th European Academy of Management (EURAM) Conference*, Istanbul, Turkey: EURAM 2013.

Armenia, S., Ferreira Franco, E., Mecella, M., and Onori, R. (2017), "Smart Model-Based Governance: From Big-Data to Future Policy Making", in F. Nonino, S. Armenia and G. Dominici (eds), *Model-based Governance for Smart Organizational Future: BSLab-SYDIC International Workshop, Rome, January 23-24* (Book of Abstract), 44–53. Available online at http://bslab-symposium.net/BSLab-Sydic-2017/Book-Abstracts-BSLab-Sydic-2017-final.pdf (last accessed: November 12, 2020).

Ashby, W.R. (1991), "Requisite Variety and Its Implications for the Control of Complex Systems", in G.J. Klir (ed.), Facets of Systems Science, 405–417, Boston, MA: Springer. DOI: 10.1007/978-1-4899-0718-9_28.

Ashton, K. (2009), "That 'Internet of Things' Thing", *Radio Frequency Identification (RFID) Journal*, 22 (7): 97–114.

Barile, S., and Calabrese, M. (2011), "Business Design and Context Consonance (Business Design e Consonanza di Contesto)", *Social Science Research Network (SSRN) Electronic Journal*, 1–26. DOI: 10.2139/ssrn.2053618.

Barile, S., and Polese, F. (2010), "Linking the Viable System and Many-to-Many Network Approaches to Service-Dominant Logic and Service Science", *International Journal of Quality and Service Sciences*, 2 (1): 23–42.

Barile, S., and Saviano, M. (2008), "Le Basi del Pensiero Sistemico: La Dicotomia Struttura-Sistema", in S. Barile (ed.), *L'Impresa come Sistema: Contributi sull'Approccio Sistemico Vitale (ASV)*, 63–81, Torino: Giappichelli.

Barile, S., and Saviano, M. (2011), "Foundations of Systems Thinking: The Structure-System Paradigm", in S. Barile *et al*. (eds), *Contributions to Theoretical and Practical Advances in*

Management: A Viable Systems Approach (VSA), 1-25, Avellino: International Printing Srl Editore.

Barile, S., and Saviano, M. (2018), "Complexity and Sustainability in Management: Insights from a Systems Perspective", in S. Barile, M. Pellicano and F. Polese (eds), *Social Dynamics in a Systems Perspective*, 39–63, Cham, Switzerland: Springer.

Barile, S., Saviano, M., and Polese, F. (2014), "Information Asymmetry and Co-Creation in Health Care Services", *Australasian Marketing Journal (AMJ)*, 22 (3): 205–217.

Barile, S., Fulco, I., Loia, F., and Vito, P. (2018), "Un Modello di Supporto alle Decisioni Territoriali tra Analisi dei 'Sentiment' e Consonanza Sistemica", in C. Baccarani *et al*. (eds), *Transformative Business Strategies and New Patterns for Value Creation: Referred Electronic Conference Proceedings*, 257–273. Available online at https://www.sijm.it/wp-content/uploads/2018/11/FULL-PAPER-VENEZIA-COMPLETO.pdf (last accessed: November 12, 2020).

Barile, S., Saviano, M., Polese, F., and Di Nauta, P. (2012), "Il Rapporto Impresa-Territorio tra Efficienza Locale, Efficacia di Contesto e Sostenibilità Ambientale (The Firm-Territory Relationship between Local Efficiency, Context Effectiveness and Environmental Sustainability)", in S. Barile, S., Saviano, M, Polese, F., Di Nauta, P. (2012), "Il Rapporto Impresa-Territorio tra Efficienza Locale, Efficacia di Contesto e Sostenibilità Ambientale", in *Referred Electronic Conference Proceeding Convegno Sinergie "Il Territorio come Giacimento di Vitalità per l'Impresa*, 387–402.

Begoli, E., and Horey, J. (2012), "Design Principles for Effective Knowledge Discovery from Big Data", *2012 Joint Working IEEE/IFIP Conference on Software Architecture and European Conference on Software Architecture*, Helsinki, 2012, 215–218. DOI: 10.1109/WICSA-ECSA.212.32.

Berthoz, A. (2013), *La Vicariance: Le Cerveau Créateur de Mondes*, Paris: Odile Jacob.

Beyer, M.A., and Laney, D. (2012), *The Importance of "Big Data": A Definition*, Stamford, CT: Gartner.

Calabrese, M., Iandolo, F., and Bilotta, A. (2011), "From Requisite Variety to Information Variety through the Information Theory the Management of Viable Systems", in E. Gummesson, C. Mele and F. Polese (eds), *Service Dominant Logic, Network & Systems Theory and Service Science: Integrating Three Perspectives for a New Service Agenda*, Online Proceedings of the 2011 Naples Forum on Service, Naples: Giannini.

Chen, C.P., and Zhang, C.Y. (2014), "Data-Intensive Applications, Challenges, Techniques and Technologies: A Survey on Big Data", *Information Sciences*, 275: 314–347. DOI: 10.1016/j.ins.2014.01.015.

Chen, H., Chiang, R.H., and Storey, V.C. (2012), "Business Intelligence and Analytics: From Big Data to Big Impact", *Management Information Systems (MIS) Quarterly*, 36 (4): 1165–1188.

Ciasullo, M.V., Troisi, O., Loia, F., and Maione, G. (2018), "Carpooling: Travelers' Perceptions from a Big Data Analysis", *The TQM Journal*, 30 (5): 554–571. DOI: 10.1108/TQM-11-2017-0156.

Cohen, N.J., Eichenbaum, H., Deacedo, B.S., and Corkin, S. (1985), “Different Memory Systems Underlying Acquisition of Procedural and Declarative Knowledge”, *Annals of the New York Academy of Sciences*, 444 (1): 54–71.

Coyle, K (2006), “Mass Digitization of Books”, *The Journal of Academic Librarianship*, 32 (6): 641–645.

Cricelli, L., and Grimaldi, M. (2008), “A Dynamic View of Knowledge and Information: A Stock and Flow Based Methodology”, *International Journal of Management and Decision Making*, 9 (6): 686–698.

Cyert, R.M., and March, J.G. (1963), *A Behavioral Theory of the Firm*, Englewood Cliffs, NJ: Prentice-Hall.

De Jarnett, L. (1996), “Knowledge the Latest Thing: Information Strategy”, *The Executives Journal*, 12 (2): 3–5.

Dominici, G., Roblek, V., and Lombardi, R. (2016), “A Holistic Approach to Comprehending the Complexity of the Post-Growth Era: The Emerging Profile”, in Ş.Ş. Erçetin (ed.), *Chaos, Complexity and Leadership 2014*, 29–42, Cham, Switzerland: Springer.

Dooley, K.J. (1997), “A Complex Adaptive Systems Model of Organization Change”, *Nonlinear Dynamics, Psychology, and Life Sciences*, 1 (1): 69–97.

Drucker, P.F. (1995), “The New Productivity Challenge”, *Quality in Higher Education*, 37: 45–53.

Fan, W., and Bifet, A. (2013), “Mining Big Data: Current Status, and Forecast to the Future”, *ACM sIGKDD Explorations Newsletter*, 14 (2): 1–5.

Forrester, J.W. (1961), *Industrial Dynamics*, New York/London: Massachusetts Institute of Technology and Jon Wiley and Sons.

Forrester, J.W. (1994), “System Dynamics, Systems Thinking, and Soft OR”, *System Dynamics Review*, 10 (2-3): 245–256.

Frakes, W.B., and Baeza-Yates, R. (eds) (1992), *Information Retrieval: Data Structures & Algorithms*, Englewood Cliffs, NJ: Prentice Hall.

Gaeta, M., Loia, F., Sarno, D., and Carrubbo, L. (2019), “Online Social Network Viability: Misinformation Management Based on Service and Systems Theories”, *International Journal of Business and Management*, 1 (1): 17–35. DOI: 10.5539/ijbm.v14n1p17.

Golinelli, G.M. (2010), *Viable Systems Approach (VSA): Governing Business Dynamics*, Padua: CEDAM.

Gould, S.J., and Vrba, E.S. (1982), “Exaptation: A Missing Term in the Science of Form”, *Paleobiology*, 8 (1): 4–15.

Gruber, T. (2008), “Collective Knowledge Systems: Where the Social Web Meets the Semantic Web”, *Web Semantics: Science, Services and Agents on the World Wide Web*, 6 (1): 4–13.

Gummesson, E. (2008), “Extending the Service-Dominant Logic: From Customer Centricity to Balanced Centricity”, *Journal of the Academy of Marketing Science*, 36 (1): 15–17.

Gummesson, E., and Mele, C. (2010), “Marketing as Value Co-Creation through Network Interaction and Resource Integration”, *Journal of Business Market Management*, 4 (4): 181–198.

Holland, J.H. (1995), *Hidden Order: How Adaptation Builds Complexity*, New York, NY: Addison-Wesley.

Holling, C.S. (1996), "Engineering Resilience versus Ecological Resilience", in National Academy of Engineering (ed.), *Engineering Within Ecological Constraints*, 31–44, Washington, DC: The National Academies Press. DOI: 10.17226/4919.

Holling, C.S., and Gunderson, L.H. (2002), "Resilience and Adaptive Cycles", in L.H. Gunderson (ed.), *Panarchy: Understanding Transformations in Human and Natural Systems*, 25–62, Washington, DC: Island Press.

Iandolo, F., Barile, S., Armenia, S., and Carrubbo, L. (2018), "A System Dynamics Perspective on a Viable Systems Approach Definition for Sustainable Value", *Sustainability Science*, 13: 1245–1263. DOI: 10.1007/s11625-018-0565-2.

Janssen, M., van der Voort, H., and Wahyudi, A. (2017), "Factors Influencing Big Data Decision-Making Quality", *Journal of Business Research*, 70: 338–345.

Johnson, J.E. (2012), "Big Data + Big Analytics = Big Opportunity", *The Financial Executive*, 28 (6): 50–54.

Lam, A. (2000), "Tacit Knowledge, Organizational Learning and Societal Institutions: An Integrated Framework", *Organization Studies*, 21 (3): 487–513.

Laudon, K.C., and Laudon, J.P. (1999), *Management Information Systems*, Upper Saddle River, NJ: Prentice Hall.

Laudon, K.C., and Laudon, J.P. (2011), *Essentials of Management Information Systems*, Upper Saddle River, NJ: Pearson.

LaValle, S., Hopkins, M.S., Lesser, E., Shockley, R., and Kruschwitz, N. (2010), "Analytics: The New Path to Value", *MIT Sloan Management Review*, 52 (1): 1–25.

Levin, S.A. (1998), "Ecosystems and the Biosphere as Complex Adaptive Systems", *Ecosystems*, 1 (5): 431–436.

Lévi-Strauss, C. (1962), *La Pensée Sauvage* (Vol. 289), Paris: Plon.

Lévy, P., and Bononno, R. (1997), *Collective Intelligence: Mankind's Emerging World in Cyberspace*, New York, NY: Perseus Books.

Liew, A. (2007), "Understanding Data, Information, Knowledge and Their Inter-Relationships", *Journal of Knowledge Management Practice*, 8 (2): 1–16.

Lincoln, Y.S., and Denzin, N.K. (1994), "The Fifth Moment", in N.K. Denzin and Y.S. Lincoln (eds), *The Handbook of Qualitative Research* (1st edn.), 575–586, Thousand Oaks, CA: SAGE.

Malone, T.W., Laubacher, R., and Dellarocas, C. (2010), "The Collective Intelligence Genome", *MIT Sloan Management Review*, 51 (3): 21–31.

McAdam, R., and McCreedy, S. (1999), "A Critical Review of Knowledge Management Models", *The Learning Organization*, 6 (3): 91–101.

McAfee, A., and Brynjolfsson E. (2012), "Big Data: The Management Revolution", *Harvard Business Review*, 90 (10): 60–68.

Meadows, D.H. (2008), *Thinking in Systems: A Primer*, London: Chelsea Green Publishing.

Miller, H.G., and Mork, P. (2013), "From Data to Decisions: A Value Chain for Big Data", *It Professional*, 1: 57–59.

Mirchi, A., Madani, K., Watkins, D., and Ahmad, S. (2012), "Synthesis of System Dynamics Tools for Holistic Conceptualization of Water Resources Problems", *Water Resources Management*, 26 (9): 2421–2442.

Morecroft, J.D. (1983), "System Dynamics: Portraying Bounded Rationality", *Omega*, 11 (2): 131–142.

Nickols, F. (2000), "The Knowledge in Knowledge Management", in J.W. Cortada and J.A. Woods (eds), *The Knowledge Management Yearbook 2000-2001*, 12–21, Oxford: Butterworth-Heinemann.

Nonaka, I., and Takeuchi, H. (1995), *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford: Oxford University Press.

O'Connor, J., and McDermott, I. (1997), *The Art of Systems Thinking*, San Francisco, CA: Thorsons.

Polese, F., Mele, C., and Gummesson, E. (2017), "Value Co-Creation as a Complex Adaptive Process", *Journal of Service Theory and Practice*, 27 (5): 926–929.

Powell, W.W., and Snellman, K. (2004), "The Knowledge Economy", *Annual Review of Sociology*, 30: 199–220. DOI: 10.1146/annurev.soc.29.010202.

Prescott, E.M. (2014), "Big Data and Competitive Advantage at Nielsen", *Management Decision*, 52 (3): 573–601.

Reuchlin, M. (1978), "Processus Vicariants et Différences Individuelles", *Journal de Psychologie*, 75: 133–145.

Rowley, J. (2007), "The Wisdom Hierarchy: Representations of the DIKW Hierarchy", *Journal of Information Science*, 33 (2): 163–180.

Rubenstein-Montano, B., Liebowitz, J., Buchwalter, J., McCaw, D., Newman, B., Rebeck, K., and Team, T.K.M.M. (2001), "A Systems Thinking Framework for Knowledge Management", *Decision Support Systems*, 31 (1): 5–16.

Senge, P. (1990), *The Fifth Discipline*, New York, NY: Currency Doubleday.

Simon, H.A. (1955), "A Behavioral Model of Rational Choice", *The Quarterly Journal of Economics*, 69 (1): 99–118.

Stacey, R. (2003), *Complex Responsive Processes in Organizations: Learning and Knowledge Creation*, London: Routledge.

Sterman, J.D. (1994), "Learning in and about Complex Systems", *System Dynamics Review*, 10 (2-3): 291–330.

Sterman, J.D. (2000), *Business Dynamics: Systems Thinking and Modeling for a Complex World*, Boston, MA: Irwin/McGraw-Hill.

Sterman, J.D. (2001), "System Dynamics Modeling: Tools for Learning in a Complex World", *California Management Review*, 43 (4): 8–25.

Sterman, J.D. (2012), "Sustaining Sustainability: Creating a Systems Science in a Fragmented Academy and Polarized World", in M. Weinstein and R. Turner (eds), *Sustainability Science*, 21–58, New York, NY: Springer. DOI: 10.1007/978-1-4614-3188-6_2.

Svyantek, D.J., and Brown, L.L. (2000), "A Complex-Systems Approach to Organizations", *Current Directions in Psychological Science*, 9 (2): 69–74.

Ten Berge, T., and Van Hezewijk, R. (1999), "Procedural and Declarative Knowledge: An Evolutionary Perspective", *Theory & Psychology*, 9 (5): 605–624.

Troisi, O., D'Arco, M., Loia, F., and Maione, G. (2018), "Big Data Management: The Case of Mulino Bianco's Engagement Platform for Value Co-Creation", *International Journal of Engineering Business Management*, 10: 1–8. DOI: 10.1177/1847979018767776.

Uddin, M.F., and Gupta, N. (2014), "Seven V's of Big Data: Understanding Big Data to Extract Value", in *Proceedings of the 2014 Zone 1 Conference of the American Society for Engineering Education*, Bridgeport, CT, 1–5. DOI: 10.1109/ASEEZone1.2014.6820689.

von Bertalanffy, L. (1952), *Problems of Life: An Evaluation of Modern Biological Thought*, New York, NY: Wiley & Sons.

von Bertalanffy, L. (1956), "A Biologist Looks at Human Nature", *The Scientific Monthly*, 82 (1): 33–41.

von Bertalanffy, L. (1967), "General Theory of Systems: Application to Psychology", *Social Science Information*, 6 (6): 125–136. DOI: 10.1177/053901846700600610.

Wise, S., Paton, R.A., and Gegenhuber, T. (2012), "Value Co-Creation through Collective Intelligence in the Public Sector: A Review of US and European Initiatives", *Vine*, 42 (2): 251–276.

Wu, X., Zhu, X., Wu, G.Q., and Ding, W. (2014), "Data Mining with Big Data", *IEEE Transactions on Knowledge and Data Engineering*, 26 (1): 97–107.

Wu, J., Dai, L., Chiclana, F., Fujita, H., and Herrera-Viedma, E. (2018), "A Minimum Adjustment Cost Feedback Mechanism-Based Consensus Model for Group Decision Making under Social Network with Distributed Linguistic Trust", *Information Fusion*, 41: 232–242.

Yolles, M. (2000), "Organisations, Complexity, and Viable Knowledge Management", *Kybernetes*, 29 (9-10): 1202–1222.

Yolles, M. (ed.) (2006), *Organizations as Complex Systems: An Introduction to Knowledge Cybernetics*, Greenwich, CT: Information Age Publishing.

Zaslavsky, A., Perera, C., and Georgakopoulos, D. (2013), "Sensing as a Service and Big Data", in *Proceedings of the International Conference on Advances in Cloud Computing (ACC)*, Bangalore, India, arXiv:1301.0159.

Zikopoulos, P., and Eaton, C. (2011), *Understanding Big Data: Analytics for Enterprise Class Hadoop and Streaming Data*, New York, NY: McGraw-Hill Osborne Media.