TIPS FORUM 2019

INNOVATION AND INDUSTRIALISATION

THE ROLE OF A SYSTEMS APPROACH IN INNOVATION AND INDUSTRIALIZATION

May 2019

B. R. Oellermann

Paper presented at the TIPS Annual Forum 2019

The Annual Forum 2019 is being hosted by Trade & Industrial Policy Strategies (TIPS) in partnership with the South African Research Chair in Industrial Development, based at the University of Johannesburg, the Technology Innovation Agency, Department of Science and Technology and the Department of Trade and Industry.

Abstract

Systems thinking is viewed as a transdisciplinary, interdisciplinary and multiperspectival domain, drawing from multiple disciplines and applicable to science, society and the environment for example. It brings together principles and concepts from ontology, philosophy of science, physics, computer science, biology, engineering, geography, sociology, political science, psychotherapy and economics and more.

In a world of ever-increasing complexity traditional methods of solving problems are no longer as effective as they used to be, if at all. This is evident across disciplines and sectors, such as in bridge construction, where social and environmental factors can determine the success or failure of a project. Other examples include manufacturing, agriculture and mining. Where many approaches utilise a reductionist approach to problems, the systems approach introduces interdependence and relationships among the components of a system.

The National System of Innovation (NSI) in South Africa is viewed as a system if we were to assume that the use of the word "system" in it implies an understanding of systems. According to a systems view, this system consists of a number of players, agents or entities which have various relationships and interactions with each other directed towards a set of results, which in this case has innovation at its core.

Industry operates similarly within an ecosystem of value chains, supply chains, trade regimes and markets which all exhibit clear system characteristics. Industrialization is generally understood to mean the widespread development of industries in a region. By its very nature this means a system consisting of a number of components that are related to each other and interact in various ways in order to achieve a set of outcomes, in this case development of industry and economic growth for example.

This paper proposes following a systems approach to describe and manage the systemic interaction between the NSI and a system for industrialization and within the systems themselves.

About the author

Bernd is director in the Regional Industrial Development unit of the Special Economic Zones and Economic Transformation (SEZ&ET) division of the dti, addressing primarily revitalization of government owned industrial parks in South Africa. Current work involves strategy and planning, policy, compliance, investment promotion, governance, financing, sustainability, operations, infrastructure, shared services, research, M&E, green transitions and stakeholder management. He has also been involved in numerous policy developments in SME development, education, ICT and industrial development during his career with extensive international experience. Bernd has worked in the private sector for most of his career which included running his own company, as management consultant and as internationally certified project/ programme management professional in sustainable development, renewable energy, water, health, agriculture, engineering, R&D, education and training, ICT, mining and the financial sector. His work spans strategy, planning, governance, administration and implementation in government, industry and commerce, unions, communities, youth, academia, research and non-profit environments. He is passionate about people and sustainable development, driven by the belief in the restoration of Creation and every person to their original purpose and identity. His approach is systemic and integrated towards working with others to find solutions to the multidimensional challenges faced by the world.

1 Systems

1.1 Definition

Definitions for "*system*" have been taken from traditional sources as set out below and are provided to demonstrate how pervasive the use of the term "*system*" is in the English language. The Oxford Dictionary defines "*system*" as follows:

1. "A set of things working together as parts of a mechanism or an interconnecting network; a complex whole.", e.g. 'the state railway system', 'fluid is pushed through a system of pipes or channels'.

Specific examples: Physiology: 'A set of organs in the body with a common structure or function.', e.g. 'the digestive system', 'The human or animal body as a whole.', 'you need to get the cholesterol out of your system'; Computing: 'A group of related hardware units or programs or both, especially when dedicated to a single application.'; Geology (in chronostratigraphy): 'A major range of strata that corresponds to a period in time, subdivided into series.', 'the Devonian system'; Astronomy: 'A group of celestial objects connected by their mutual attractive forces, especially moving in orbits about a centre.', 'the system of bright stars known as the Gould Belt'

2. "A set of principles or procedures according to which something is done; an organized scheme or method.", e.g. 'a multiparty system of government', 'the public-school system', 'don't try bucking the system'

2.1 "A set of rules used in measurement or classification.", e.g. 'the metric system'

2.2 "Organized planning or behaviour; orderliness.", e.g. 'there was no system at all in the company'

2.3 "A method of choosing one's procedure in gambling."

The Meriam-Webster Dictionary provides the following:

1 : "a regularly interacting or interdependent group of items forming a unified whole // a number system", e.g.

a(1) : "a group of interacting bodies under the influence of related forces // a gravitational system"

(2) : "an assemblage of substances that is in or tends to equilibrium // a thermodynamic system"

b(1) : "a group of body organs that together perform one or more vital functions // the digestive system"

(2) : "the body considered as a functional unit"

c : "a group of related natural objects or forces // a river system"

d : "a group of devices or artificial objects or an organization forming a network especially for distributing something or serving a common purpose // a telephone system // a heating system // a highway system // a computer system"

e : "a major division of rocks usually larger than a series and including all formed during a period or era"

f : "a form of social, economic, or political organization or practice // the capitalist system"

2 : "an organized set of doctrines, ideas, or principles usually intended to explain the arrangement or working of a systematic whole // the Newtonian system of mechanics"

3a : “an organized or established procedure // the touch system of typing”

b : “a manner of classifying, symbolizing, or schematizing // a taxonomic system // the decimal system”

4 : “harmonious arrangement or pattern : ORDER // bring system out of confusion — Ellen Glasgow”

5 : “an organized society or social situation regarded as stultifying or oppressive : ESTABLISHMENT sense 2 —usually used with the”

Lastly, Collins Dictionary gives a similar description:

1. “A system is a way of working, organizing, or doing something which follows a fixed plan or set of rules. You can use system to refer to an organization or institution that is organized in this way.”, e.g. ‘he present system of funding for higher education is unsatisfactory.’, ‘...a flexible and relatively efficient filing system.’, ‘...a multi-party system of government. [+ of]’, ‘The Court of Appeal has a pivotal role in the English legal system.’ Synonyms: arrangement, structure, organization, scheme More Synonyms of system

2. “A system is a set of devices powered by electricity, for example a computer or an alarm.”, e.g. ‘Viruses tend to be good at surviving when a computer system crashes.’

3. “A system is a set of equipment or parts such as water pipes or electrical wiring, which is used to supply water, heat, or electricity.”, e.g. ‘...a central heating system.’

4. “A system is a network of things that are linked together so that people or things can travel from one place to another or communicate.”, e.g. ‘...Australia's road and rail system.’, ‘...a news channel on a local cable system.’ Synonyms: network, organization, web, grid More Synonyms of system

5. “Your system is your body's organs and other parts that together perform particular functions.”, e.g. ‘He had slept for over fourteen hours, and his system seemed to have recuperated admirably.’, ‘These gases would seriously damage the patient's respiratory system.’, ‘...the reproductive system.’

6. “A system is a particular set of rules, especially in mathematics or science, which is used to count or measure things.”, e.g. ‘...the decimal system of metric weights and measures. [+ of]’, ‘...Trachtenberg's system of simplified mathematics.’ Synonyms: method, practice, technique, procedure More Synonyms of system

7. “People sometimes refer to the government or administration of a country as the system.”, e.g. ‘These feelings are likely to make people attempt to overthrow the system.’, ‘He wants to be the tough rebel who bucks the system.’

8. “See also central nervous system, digestive system, ecosystem, immune system, metric system, nervous system, public address system, solar system, sound system”

9. “get something out of one's system”

1. “a group or combination of interrelated, interdependent, or interacting elements forming a collective entity; a methodical or coordinated assemblage of parts, facts, concepts”, etc, e.g. ‘a system of currency’, ‘the Copernican system’

2. “any scheme of classification or arrangement”, e.g. ‘a chronological system’

3. “a network of communications, transportation, or distribution”

4. “a method or complex of methods”, e.g. ‘he has a perfect system at roulette’

5. “orderliness; an ordered manner”

6. “the system”

7. “an organism considered as a functioning entity”

8. “any of various bodily parts or structures that are anatomically or physiologically related”, e.g. ‘the digestive system’

9. “one's physiological or psychological constitution”, e.g. ‘get it out of your system’

10. “any assembly of electronic, electrical, or mechanical components with interdependent functions, usually forming a self-contained unit”, e.g. ‘a brake system’

11. “a group of celestial bodies that are associated as a result of natural laws, esp gravitational attraction”, e.g. ‘the solar system’

12. “chemistry”, e.g. ‘a sample of matter in which there are one or more substances in one or more phases’

13. “a point of view or doctrine used to interpret a branch of knowledge”

14. “mineralogy”, e.g. ‘one of a group of divisions into which crystals may be placed on the basis of the lengths and inclinations of their axes, also called: crystal system’

15. “geology”, e.g. ‘a stratigraphical unit for the rock strata formed during a period of geological time. It can be subdivided into series’

It is clear from just a cursory look at the definitions provided that the word “*system”* is pervasive in the English language. Now, while it may be of interest to do a study of the usage of similar terms in other languages that is unfortunately outside the scope of this paper. Instead, the point that needs to be made here is that “*systems*” are being applied in a range of contexts.

This can cause misunderstanding by itself because of what different users understand under the term “system”. On top of this dimension of understanding, one can add other layers or dimensions of understanding, such as the understanding informed by culture, tradition, language, education, occupation and discipline respectively, for example.

Further definitions include those provided by Ackoff and Checkland. Ackoff (1981) describes a system as follows:

“A system is a set of two or more elements that satisfies the following three conditions:

The behaviour of each element has an effect on the behaviour of the whole. […]

The behaviour of the elements and their effects on the whole are interdependent. […]

However subgroups of the elements are formed, each has an effect on the behaviour of the whole and none has an independent effect on it. […]

A system, therefore, is a whole that cannot be divided into independent parts. […]The essential properties of a system taken as a whole derive from the interaction of its parts, not their actions taken separately.” (Ackoff, 1981)

Checkland (1982) defines it similarly, namely:

“The central concept ‘system’ embodies the idea of a set of elements connected together which form a whole, this showing properties which are properties of the whole, rather than properties of its component parts.”

The definition and description proposed by Mele et al (2010) provides an even broader perspective on what a system is, namely “an assemblage of objects united by some form of regular interaction or interdependence”. In their work, they also refer to the following definition by Tien and Berg (2003):

“A system can be natural (e.g., lake) or built (e.g., government), physical (e.g., space shuttle) or conceptual (e.g., plan), closed (e.g., chemicals in a stationary, closed bottle) or open (e.g., tree), static (e.g., bridge) or dynamic (e.g., human). In regard to its elements, a system can be detailed in terms of its components, composed of people, processes and products; its attributes, composed of the input, process and output characteristics of each component; and its relationships, composed of interactions between components and characteristics”.

For the purposes of the discussion presented here, a system is therefore defined as follows and is assumed to be described in equivalent terms in whatever frame of reference informs its usage pertaining to innovation and industrialization:

“A group or combination of interrelated, interdependent, or interacting elements or components forming a collective and complex whole, that share a common purpose and which work together in a certain way.”

1.2 Systems Theory

Systems theory is generally accepted to have originated from the work by Ludwig von Bertalanffy’s work on General Systems Theory (GST) of the 1930’s, known as the “Allgemeine System theorie”. It is seen as a transdisciplinary, interdisciplinary and multiperspectival domain and integrates principles and concepts from ontology, philosophy of science, physics, computer science, biology, engineering, geography, sociology, political science, psychotherapy (within family systems therapy) and economics among others. Systems theory is therefore an interdisciplinary theory that can be applied to many systems in nature, society and in science. It provides a framework with which phenomena can be investigated holistically (Capra, 1997).

It needs to be pointed out that while some have criticised GST as pseudoscience, the intention of Von Bertalanffy was to provide a different perspective or paradigm as a basic conceptual framework in the development of exact scientific theory, as indicated by Laszlo as well for example. This originates from the translation and loss of meaning from the German words "Theorie" (or "Lehre"), and "Wissenschaft" (translated Scholarship). These words have a much broader meaning in German than the closest English words 'theory' and 'science'.

Bertalanffy’s ideas refer to an organized body of knowledge and "any systematically presented set of concepts, whether empirically, axiomatically, or philosophically" represented, as opposed to what many associate with the term "Lehre" (Meaning the theory and science in the etymology of general systems). Again much is lost in translation as the "closest equivalent" translates as "teaching", which "sounds dogmatic and off the mark" (Laszlo, 1974). His intention was to use the term “system” to include those principles that are understood to be common to systems in general, as can be seen from his words about the subject in GST:

"...there exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relationships or "forces" between them. It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general." – Von Bertalanffy

Systems thinking comes from no longer focussing on the parts, but instead on the whole (Checkland, 1997; Weinberg, 2001; Jackson, 2003) and consideration of observed reality as an integrated and interacting "unicuum of phenomena" where the individual properties of the single parts become indistinct (Mele et al, 2010). It is no longer a matter of the whole just being the sum of its parts and therefore breaking a system down into its various parts in whatever form that may be. Neither is it any more about the whole being more than the sum of its parts, because of the impact that the relationships between the parts themselves and the events they produce through their interaction have on the system. It has become now about the **sum of the parts, the parts and the relationships between the parts**. The relationships require added attention because of their importance, introducing what Luhmann (1990) describes as "system elements are rationally connected". Furthermore, these elements stand in relationship towards a shared purpose (Golinelli, 2009) and also towards the environment surrounding the system and other adjacent systems.

Analysis from a systems perspective should therefore in the least be cognizant of the function or purpose of the system while also investigating the elementary components thereof and their relationships and interactions, which is the holistic perspective Von Bertalanffy (1968) refers to. It is understood that this enables greater understanding and insight into a system or phenomenon being studied.

A hallmark of systems theory is that it developed simultaneously across various disciplines and that scholars working from a systems theory perspective build on the knowledge and concepts developed within other disciplines. Examples of this can be found in natural and ecological sciences (organic aspects, homeostasis and equifinality (Hannan and Freeman, 1977), chemical and biological disciplines (autopoietic aspects; Maturana and Varela, 1975), sociology and psychology (cognitive aspects; Clark, 1993), and information technology (cybernetic aspects; Beer, 1975).

Because of this simultaneous development across very diverse disciplines, some of the theories encapsulated by systems theory sometimes have conflicting elements. This means that they offer effectively what can be termed alternative perspectives regarding a specific phenomenon that is being studied.

Mele et al (2010) reiterate that the fundamental unit of analysis in a systems approach, is 'a system' where the 'system' consist of many parts or structures (Parsons, 1965). This contrasts to the non-systems approach, or analytical approach, of identifying each individual component and its role and placing less or no attention on the relationships, interactions and the system as a whole.

Following a systems approach, a system exhibits relationships with supra-systems and sub-systems (as briefly described in section 1.2.4 on the viable systems approach below). Supra-systems are hierarchically ordered as a function of their influence on the system while sub-systems are found to be more or less directed and managed by the system in order to contribute to its finality (Barile, 2006, 2008) or purpose.

A consequence of these relationships with supra- and sub-systems however, is that it becomes difficult to define system boundaries because it would appear that such boundaries do not have much meaning. This is because the engagement with supra- and sub-systems shows a tendency to lead to absorption of at least parts of these into the system with the intention to develop as a whole system

(Barile 2006, 2008; Mele et al (2010). This is also reflected in the application of systems theory to organizations (further discussed in the following section) as reflected for example by Wood (1991) that society and business are interwoven rather than being entities that are distinct from each other.

Application of the concept of a system to the world we live in therefore means a system can exist at a sub-atomic level, as a microorganism, amoeba and other single cellular organism, or at large scale as a society, company, earth or even the whole cosmos.

A system can furthermore be "open" or "closed". An "open" system is able to exchange energy, matter or information with the environment for example (refer to section 1.2.2). Such exchange can result in internal processes that transform and impact on the system. These processes include for example homeostasis, self-regulation, equilibrium/balance, autopoiesis and equifinality/common finality (Mele et al 2010).

Homeostasis refers to the information exchange between the system and its external environment where the system is able to maintain a state of equilibrium over time (Hannan and Freeman, 1977). The process of Self-Regulation is an adaptive mechanism or process that the system applies to keep itself in balance. This balance is achieved within the limits of the system's structure and through information exchange with the outside world (Beer, 1975). Equilibrium on the other hand represents the attitude and ability of the system to provide an appropriate contribution to the needs of some or all supra-systems within the framework of reference systems (Beer, 1975).

While it would be useful to further expand on these processes, it is not the intention of this paper to provide an exhaustive elaboration on what a system is and how it operates. For the sake of demonstrating the broader framework, some specific theories and aspects of Systems Theory are briefly described in the following subsections.

1.2.1 General Systems Theory (GST)

Von Bertalanffy (1956) defines a system as a complex of interacting elements and pursues systems thinking across numerous disciplines in order to find general principles that can apply to all systems. GST introduces a "system" as a new scientific paradigm contrasting the analytical, mechanical paradigm, characterizing classical science (von Bertalanffy, 1950).

At the core of general systems theory is its focus on interactions between elements. It should be clear that the behaviour of a single autonomous element is different from its behaviour when the element interacts with other elements.

The second key characteristic of his theory is the distinction between open, closed and isolated systems. Open systems demonstrate exchange of resources such as energy, matter, people, and information with the external environment. Closed systems display only exchange of energy and none in terms of information and matter. Lastly, in the case of isolated systems there is no exchange of elements whatsoever, as the term indicates.

Some of the approaches that have been developed based on GST include open system theory, the viable system model and the viable system approach, as well as Autopoiesis by Francisco Varela and Humberto Maturana, Cybernetics and Complex Adaptive Systems (CAS) and others.

1.2.2 Open systems theory

Open Systems Theory (OST) describes the relationships between organizations and the environment in which they are found. This theory therefore looks at an organizations' ability to adapt to changes under environmental conditions (with or without the need for information processing) (Boulding, 1956; Katz and Kahn, 1978). This adaptation can occur at two levels, namely counteractive or amplifying.

Katz and Kahn (1978) apply the open system concept to the organization by viewing the organization as a system made up from energetic input-output where the energy coming from the output reactivates the system. Emery and Trist (1960) describe organizations as socio-technical systems, underlining the two main components of the firm when viewed in terms of a system. These two components are the social component (people), and technical component (technology and machines).

1.2.3 Viable System Model

The Viable System Model (VSM) characterises a system as an entity that is adaptable for the purpose of surviving in its environment that is continually changing (Beer, 1972). With this approach, the viable system is an abstracted cybernetic description that is applicable to autonomous organizations. Because cybernetics is an interdisciplinary study of the structure of regulatory systems, this approach refers to the study of how actions by a system cause changes in its environment. These changes are taken to be understood by the system itself in terms of feedback which then allows the adaptation of the system to new conditions. Effectively, this means that the system can change its behaviour.

In cybernetics, the system and the environment display different levels of complexity because the environment may have degrees of complexity that are not perceived by the system. When VSM is applied to organizations the observer introduces conceptual tools in order to redesign the organization by way of: i) change management; ii) understanding the organization as an integrated whole; iii) evaluating the essential functions of implementation, coordination, control, intelligence and policy (Beer, 1972; Espejo and Harnden, 1989; Espejo, 1999; Christopher, 2007).

1.2.4 Viable system approach

The Viable System Approach (VSA) introduces a different interpretation of consolidated strategic organizational and managerial models in terms of so-called sub-systems and supra-systems. Sub-systems relate to the analysis of relationships among the internal components of an enterprise whereas supra-systems look at the connections between enterprises and other influencing systemic entities in their context (Golinelli, 2000; Golinelli, 2005; Barile, 2006; Barile, 2008).

The organization or entity being studied is here 'a system' made up of many parts or structures (Parsons, 1965). Taking a systemic approach then leads to the view that every system is in relation with supra-systems and sub-systems in one way or another. The supra-systems are hierarchically ordered based on their influence on the system while the sub-systems are directed and managed by the system in order to contribute to what is termed its finality (Barile, 2006, 2008), or purpose.

The introduction of concepts as described in the viable system approach challenge the matter of system boundaries because they no longer make much sense. This originates from the application of the principle that as contact creates participation the specific system tends to absorb supra-systems and sub-systems or part thereof in order to develop as a whole system (Barile 2006, 2008).

1.3 Systems and Management

Systems theory encompasses a wide field of research with different conceptualizations and areas of focus (e.g. Boulding, 1956; Maturana and Varela, 1975; Senge, 1990), as briefly shown in the previous section. Applying these to the field of management and organizations has led to various analyses of the relationship between organizations and their environment (e.g. Burns and Stalker, 1961; Lawrence and Lorsch, 1967; Aldrich, 1979) and the interactions and relationships between parts in order to understand it better with the aim to improve organizational efficiency, productivity and so on.

Turner (1991) for example, found that significant gains in performance became possible when leaders moved from managing the organization as if it were a machine or mechanical system to facilitating the organization as a social system. This introduced the concept of the social organization, which can be described as a type of very complex social system or living synergistic social system.

A living synergistic social system has the ability to create the conditions for its own existence. Living synergistic social systems are thinking systems (Maturana & Varela, 1992). Their ability to facilitate energy flow is a result of all the parts of the system working together as a whole and this energy flow means it also falls within the scope of Open Systems Theory (OST). Wholeness, thinking, and creativity are attributes that exist only when all the parts of such a living synergistic social system are viable and supportive of each other. Living synergistic social systems are products of the synergy that results from the interactions among the parts that create their wholeness. The essence and almost all of the value of a synergistic social system resides in its synergy-producing interactions (relationships) and not in its parts. As is the case for all systems, living synergistic systems also cannot be separated into parts and still maintain their essential natures.

The systems movement revealed flaws in the assumption that organizational performance is the sum of the performance of each part taken separately. In contrast, systems thinking demonstrated that the interactions among the parts of a system produce most of the system's performance, leading to the application of the 80/20 rule (Koch, 1998). Eighty percent of the system's performance potential is based on the interactions among the system's parts while twenty percent of the total performance of a typical system is ascribed to the parts themselves.

The administrative leader who treats a system as a machine is focusing only on the parts separate from the system as a whole and as a consequence is only tapping into 20% of the system's potential. According to systems theory, such a leader could increase the system's potential by shifting the focus to include the interactions of its parts. By designing and facilitating an increase in the number of meaningful interactions among the parts of the system, greater synergy is produced which increases the flow of energy.

In a living synergistic social system, the design typically refers to the structure and the parts refer to the people, which are typical characteristics of OST. The structure creates boundaries in which a certain number of interactions are possible. The workers in the organization determine if the interactions are meaningful. Therefore, meaning is shifted from the leaders to the workers.

This is reflected for example in the study of organizational performance. Wong, Ormiston and Tetlock (2011) state that the most important approach used to assess a firm's corporate social performance is a stakeholder approach, which relates directly back to the level of interactions within an organization and between the organization and others outside of it. The stakeholder approach describes the way firms act in a socially responsible manner when they take the interests of multiple stakeholders such as customers and also their own employees into account (Ruf, Muralidhar, Brown, Janney, & Paul, 2001; McGuire, Dow, & Argheyd, 2003).

Wong, Ormiston and Tetlock (2011) furthermore show from previous work that there are a number of ways (e.g. values, leadership style, past experience and training) in which an organization's strategic leaders, i.e. its CEO and senior executives, influence various organizational stakeholders, which further confirms the fact that the interactions and relations among people are of importance when examining how an organization functions as a system. They also identify a number of areas where further research is required to better understand how especially the top management team affects the social performance of the organization, which is clearly part of understanding an organization as a system, as referred to earlier.

As the systems movement further developed, scholars observed the need to look at the system's containing system in order to better understand and leverage performance. Organizations aligned with the containing system's intent produced additional gains in organizational performance. The concept of alignment became an important tool for leveraging organizational performance (Green, 2003). Green (2003) proposed additional performance tools for the next millennium that are based on:

- Facilitating the natural forces that govern individual and organizational performance;
- Relying on learning and the effective application of organizational learning;
- Featuring natural laws, mental models, living synergistic social systems, and structure (dynamics);
- Applying a pattern of systemic leadership; and
- Operating in a stable or unstable environment.

Mele et al (2010) provide a number of examples of how systems theory can be applied to management and in organizations. These are briefly summarised here in order to provide additional context for application of systems theory to organizations or firms in laying the groundwork for understanding the role of a systems approach in innovation and industrialization.

1.3.1 Learning and Knowledge

Within the context of systems theory and relating to how organizations or firms function, the organization can be described as a learning system and having a certain set of skills and competences that enables it to produce its own knowledge. (Nonaka and Tacheucki, 1995) The firm thus becomes a cognitive system that creates information and activates its skills in order to produce knowledge through continuous leaning processes (Vicari, 1992).

Knowledge is at the core of what is called an autopoietic process of resource generation, creating what is termed as resource-behaviour-resource cycles where cognitive schemes allow the entire system to function. Senge (1990) analysed how the systems method of thinking enables firms to become learning organizations by utilising systems thinking, personal mastery, mental models, building shared vision, and team learning as the basis for the development of three core learning capabilities. These core learning capabilities involve fostering aspiration, developing reflective conversation, and understanding complexity to address value generation.

1.3.2 Environment

A system inevitably exists within an environment that surrounds it. This means that if the organization is the system at the micro level, then the environment is the system at the macro level, as also pointed out by Mele et al (2010). Taken to extremes, this has interesting mathematical consequences, especially because of the concepts of infinity and current understanding of the cosmos. For most systems however, specifically those apply to organizations, the environment is significantly smaller.

In the analysis of the structure of the system and of supra-systems, an organization's leader applies various attenuating and amplifying actions of the kind needed for long-term survival, which results in the modification of the borders between the system and the individual supra-systems (viability). Brownlie (1994) presents two conceptualizations of the environment within which the system occurs, namely the objective environment and the enacted environment.

Regarding the objective environment, Brownlie (1994) states that *"the construct 'environment' corresponds to some freestanding material entity that is independent of the observer, concrete, external and tangible"*. Introducing the concept of the enacted environment however, leads to the rejection of this notion of an external objective reality. From the perspective of an enacted environment, the environment is thought of as a *"mental representation embodied in a cognitive structure which is enacted in retrospect and fashioned out of the discrete experiences of managers"*.

Organizations and environment in this approach are thus viewed as labels for patterns of activities which result from human actions and their accompanying efforts to make sense out of those actions (Smircich and Stubbart, 1985). From this point of view it is therefore possible that different organizations within the 'same' environment can interpret the same set of data about particular market conditions and circumstances very differently for example.

The organization is viewed as embedded in a set of inter-organizational relationships of different strength with a set of stakeholders (Pfeffer and Salancik, 1978). This view is adopted by the networks approach in marketing for example, which reasons that companies are 'connected' and that they operate within a 'texture of interdependencies' (Hakansson and Snehota, 1995; Ford, 2002).

1.3.3 Relationships

According to the viable system model (Christopher, 2007), competitive firm behaviour is strictly linked to the ability to identify and manage functions and relationships, thereby establishing communication channels, organizing information flow, and rationalizing and harmonizing a firm's development aligned with all external relationships.

The governance of viable organizations then has to address and direct the system towards a final goal by transforming static structural relationships into dynamic interactions with other viable systems. The ability to organize relationships delineates the efficiency of governmental action, which is a central characteristic of viable systems, contributing to the equilibrium of the system from one side and to the satisfaction of supra-systems' expectations from the other. For the organizations, it is fundamental to consider the compatibility between systemic actors (consonance) and to improve the effective harmonic interaction between them (resonance). Consonance is linked to the concept of relations and refers to a static vision. Consonance represents the potential harmonic relation, whereas Resonance instead is related to dynamic aspect, i.e. the interaction between entities.

Relationships find particular application in the area of stakeholder management and the importance is reflected through for example the application of the concept of the "mutually supportive framework" (Donaldson & Preston, 1995) that serves the interests of all stakeholders and not one at the expense of another.

The role of managers in the determination of stakeholder needs and meeting them is also recognized (Wong, Ormiston and Tetlock, 2011), as well as their role in corporate social performance (Thomas & Simerly, 1994, 1995), which further demonstrates the clear role of relationships within the organization as a system. The effect of managers and senior executives on corporate social performance can be described in various ways and frameworks, one of which is strategic leadership theory which describes how executives' orientations, made up of psychological factors (e.g., values, cognitive style and personality) and experiences (such as tenure and functional background), influence their strategic decision making and therefore as a result, firm outcomes (Finkelstein & Hambrick, 1996; Finkelstein, Hambrick, & Cannella, 2009).

1.3.4 Adaptation

Barile and Polese (2010) present that any organization has to be able to preserve its viability and stability by creating an environment internal to the organization that is able to respond effectively to external stimuli at all levels. This is in line with the viable systems approach where an organization is deemed viable as a system if it is able to survive in a particular context in the presence of continual dynamic processes and several kinds of internal changes. This ability of the organization is termed adaptation.

1.3.5 Complexity

Complexity is based on concepts such as variety, variability and indeterminacy which are used to describe networked systems for example (Golinelli, 2010). In networked systems, these parameters mean the following. Variety is the variance that is possible by what a phenomenon may present to an observer. Variability is closely related to variety in that it describes variety observed over time. Indeterminacy is defined as the ability to fully understand a particular phenomenon (Barile, 2009; Golinelli, 2010).

Complexity is recognised to be of value in the interpretation of service systems for example, because they are complex adaptive systems (Holland, 1999). Such systems are described as complex because they are diverse and consist of multiple interconnected network elements. They are also complex because they are able to change and learn from experience, which of course relates to the adaptation aspect referred to earlier.

Complexity requires significant attention within the exploration of systems, but complexity theory is a field of study in its own right and it is not the purpose of this paper to go into all the detail thereof. However, it is worthwhile to provide some further information in order to highlight its value in enhancing our understanding of systems.

Complexity theory has gained ground because of developments such as technology, globalization, competition, change, speed, complexity and paradox (Tetenbaum, 1998). Tetenbaum (1998) wrote: "The new world is full of unintended consequences and counterintuitive outcomes. In such a world, the map to the future cannot be drawn in advance. We cannot know enough to set forth a meaningful vision or to plan productively". This statement clearly indicates the need for a different approach in addressing challenges facing the globe today, which incidentally also is not a new call to action. History documents numerous such calls to think differently in order to deal with change (Blainey, 2000; Roberts, 1995). Kelly (1994, 1998) also made the case for new ideas, paradigms and practices in dealing with the changes resulting from global restructuring of the economy and radical new technologies. Introducing complexity theory and systems theory are some of the methods in which such change can be dealt with effectively, which is also why it is proposed herein as part of the approach to addressing innovation and industrialization.

Keene (2000) states that organizations still try to manage themselves based on principles of scientific management, i.e. focussing on control, order, predictability and cause and effect. This requires strong attention on analytical analysis (vs a systems approach). Her statement that the mechanistic approach of reducing all systems to their constituent parts is inadequate to allow managers to deal with the changing environment which further supports the systems approach to how organizations function as briefly touched on here. Smith and Humphries (2004) extend this by stating that the need for non-reductionist ways in addressing management problems has led to the pursuit of complexity theory as a method to be considered in finding solutions.

Complex systems can be described as "robust, involving multiple, often redundant chains of interaction and causation…" (Marion and Bacon, 2000). They identify complex systems in terms of three key characteristics, the first of which is that the whole is more than the sum of the parts. This is reinforced by the second key characteristic which states that complex organizations stimulate outputs that cannot necessarily be predicted simply by understanding all of the inputs. They present that such uncertainty in prediction of outputs is the result of the fact that complex organizations can create behaviour that can neither be predicted nor that is entirely unpredictable. This has been termed as the 'edge of chaos' (Peters, 1992) which is a scenario where there is enough chaos to make predictions impossible but at the same time demonstrates sufficient order to maintain functionality.

Further to the concept of chaos and with respect to innovation, Pascale (1999) stated that organizational innovation occurs in the delicate balance between rigid structure and unbounded chaos (Pascale 1990) and also identified some characteristics of complex systems that can inform management implementation, as highlighted by Smith and Humphries (2004). The first aspect identified states that complex systems are at risk when at equilibrium because stability and equilibrium are viewed as precursors to failure. The second characteristic is that complex systems are able to self-organize and demonstrate emergent properties, which means that what might be viewed as chaos is not necessarily chaotic. The third identified aspect is that complex systems seem to move closer to chaos when faced with a complex task. The fourth and last characteristic states that complex systems are living systems and that they can only be disturbed and not directed.

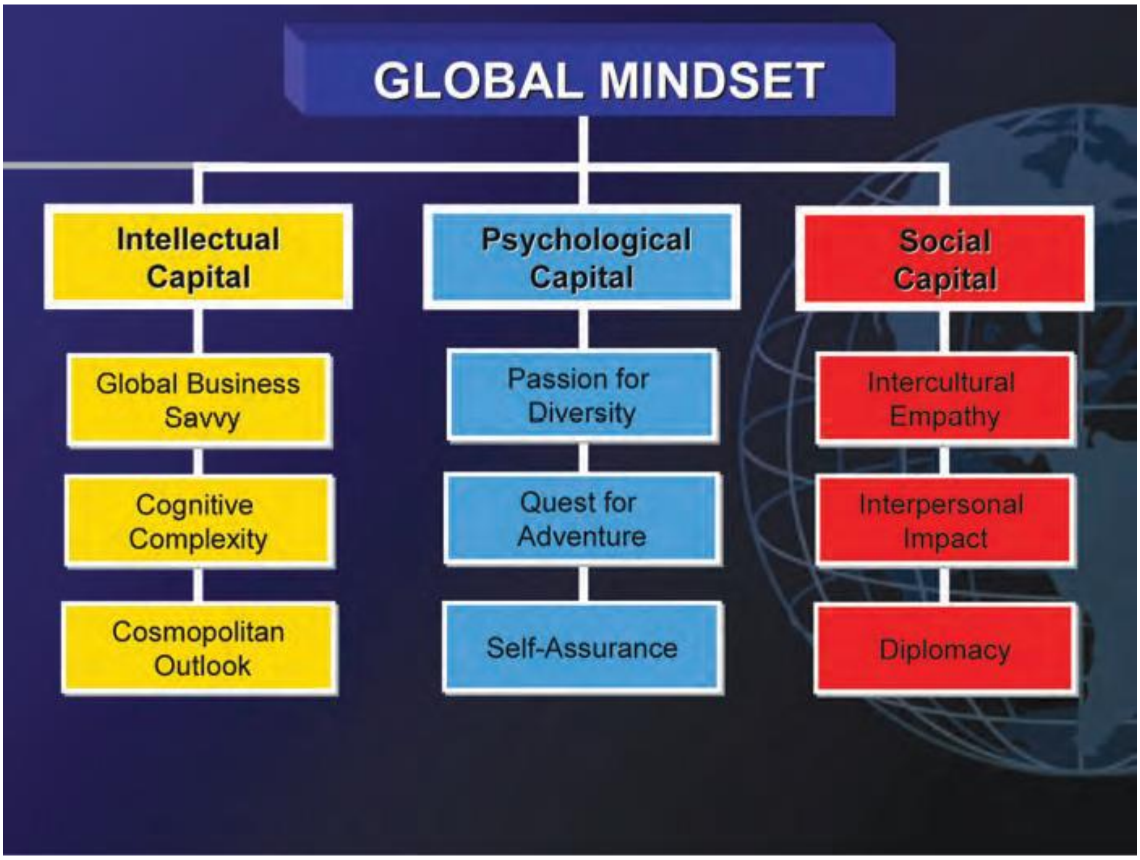
The concept of complexity also occurs in various other areas, one of which involves the application of complexity in socio-cognitive processes that guide the decision-making behaviour of senior executives (Hambrick, 2007), which if course is equally relevant in an exploration of complexity in terms of systems theory. Cognitive style is defined by Finkelstein and Hambrick as "how a person's mind works—how he or she gathers and processes information" (1996: 64). These cognitive styles can be described by a range of typologies which have been proposed. These typologies cover for example Mintzberg's "planners versus thinkers" and Jung's typology of executives based on how people perceive and judge information (Wong, Ormiston and Tetlock, 2011).

One of these cognitive styles which is of particular relevance here because it relates to complexity and relationships, two of the examples of how systems theory applies to organizations as mentioned earlier, is the concept of integrative complexity. Integrative complexity has been applied to understand how top leaders, such as U.S. Supreme Court justices (Tetlock, Bernzweig, & Gallant, 1985), military commanders (Suedfeld, Corteen, & McCormick, 1986; Suedfeld & Granatstein, 1995), and presidents (e.g., Tetlock, 1981) influence macro-level outcomes, e.g. military conflicts and elections. The cognitive style identified as integrative complexity has furthermore been linked to moral development (deVries & Walker, 1986; Sullivan, McCullough, & Stager, 1970) and to trade-off reasoning (Tetlock, Peterson, & Lerner, 1996), both of which have clear consequences in ethics and corporate social performance (Hemingway, 2005).

Integrative complexity firstly involves what is termed evaluative differentiation, i.e. "the capacity and willingness to tolerate different points of view". Secondly, integrative complexity involves so-called conceptual integration, which is termed as the ability to "generate linkages between points of view, to understand why people look at the same event in different ways, to confront trade-offs, and to appreciate interactive patterns of causation" (Tetlock, Peterson, & Berry, 1993). On the basis of evaluative differentiation and conceptual integration, integrative complexity can be applied to describe a person along a scale, from simple (low integrative complexity) to complex (high integrative complexity). This is of particular interest because of its relevance in a systems approach to innovation and industrialization as described herein. One application of this particular cognitive style is demonstrated by Wong, Ormiston and Tetlock (2011), who explored how integrative complexity (that is effectively the ability to differentiate among and integrate multiple perspectives) in senior executives affects how stakeholder needs are met.

Another example of the application of complexity, which is again relevant in this exploration of systems theory, is within the concept of Global Mindset, as proposed by Javidan and Walker (2012) and which indicates not only complexity but also introduces an additional level of systems understanding required by senior executives in organizations. The key attributes of their Global Mindset can be summarised by the following figure.

Figure 1 The key attributes that makes up a Global Mindset as identified by Javidan and Walker (2012).



Source: Javidan and Walker (2012)

1.4 Analytical vs Systems thinking

It is useful to refer to work done by Oyebisi, Momodu and Olabode (2013) who have provided some simple tools to compare systems thinking to what they term analytical thinking. This assists in better understanding the benefits of a systems approach as presented here.

Table 1 Comparison of the Three Stages of Analytical and Systems Thinking.

Stage	Analytical thinking	Systems thinking (synthesis)
1	Take apart the thing to be understood	Identifying a containing whole (system) of which the thing to be explained is a part
2	Try to understand the behaviour of parts taken separately	Explain the behaviour or properties of the containing whole
3	Try to assemble this understanding into an understanding of whole	Explain the behaviour or properties of the thing to be explained in terms of its role(s) or function(s) within its containing whole

Source: Fasser and Brettner (2002) from Oyebisi, Momodu and Olabode , 2013

Table 2 A Comparison of the Attributes of Analytical Thinking and Systems Thinking.

Analytical thinking	Systems thinking
Focuses on structure (how things work)	Focuses on function (why things operate as they do)
Yields knowledge	Yields understanding
Enables us to describe	Enables us to explain
Looks into things	Looks out of things

Source: Fasser and Brettner (2002)

Table 3 Analytical Thinking vs. Systems Thinking.

	Analytic thinking (analysis of today)	vs.	Systems thinking (synthesis for the future)
1	We/they	vs	Customers/stakeholders
2	Independent	vs	Interdependent
3	Activities/tasks/means	and	Outcomes/ends
4	Problem solving	and	Solution seeking
5	Today is fine	vs	Shared vision of future
6	Units/departments	and	Total organizations
7	Silo mentality	vs	Cross-functional teamwork
8	Closed environment	vs	Openness and feedback
9	Department goals	and	Shared core strategies
10	Strategic planning project	vs	Strategic management system
11	Hierarchy and controls	and	Serve the customer
12	Not my job	vs	Communications & collaboration
13	Isolated change	vs	Systemic change
14	Linear/begin-end	vs	Circular/repeat cycles
15	Little picture/view	vs	Big picture/holistic perspective
16	Short term	and	Long term
17	Separate issues	vs	Related issues
18	Symptoms	and	Root causes
19	Isolated events	and	Patterns/trends
20	Activities/actions	and	Clear outcome expectations (goals/values)

Source: Haines Centre for Strategic Management (2007)

2 Innovation

Because the aim here is to demonstrate the link between innovation systems and systems theory, only a brief overview of innovation systems is presented.

2.1 Innovation systems

Literature shows progression from national innovation systems (NIS or NSI) (Freeman, 1995, 2002; Lundvall, 1992; Nelson, 1993) to regional innovation systems (RIS) (Cooke, 1992; Cooke et al., 1997; de la Mothe and Paquet, 1998; Parker and Tamaschke, 2005) and even sectoral systems and smart specialization. The nature of innovation systems are described here based on some of the definitions presented in literature to show the clear association of a systems approach with innovation and to provide a brief description of what is understood to be an innovation system.

National systems of innovation have been developed through the work of Freeman (1995, 2002), Lundvall (1992), Nelson (1993) and others and provide a "consistent conceptual framework for integrating key science, technology and innovation institutions into economic development" (Niosi, 2008). Lundvall (1992) includes organizations and institutions involved in research such as universities, R&D departments and technological institutes in the NSI in a narrow context, but all of the learning institutions, the economic structure and those institutions involved in "searching and exploring" form part of the NSI in a broader context. Universities, government laboratories and innovative firms can form the centre of the NSI. (Niosi, 2008).

The innovation system should include factors that impact innovation such as economic, social, organisational and other factors that affect the creation, dissemination and use of knowledge (Edquist, 2008). Such factors should also have an impact on the learning capacity of organisations and therefore the capacity to innovate (Lundvall, 1992). Factors impacting innovation are often used interchangeably with system specific functions (Edquist 2001 from Suriyani et al, 2012; Liu and White, 2001; Johnson and Jacobsson, 2000; Hekkert et al, 2007).

Resele (2015) presents that weak performance of functions creates innovation barriers with the main functions of the NSI proposed to be development of new knowledge and use of knowledge. The NSI further should support indirect functions by supplying resources, facilitate the exchange of information and knowledge and define the framework or rules of the game for example.

The NIS/ NSI is presented by Resele (2015) as more focussed on the relationships within the system, i.e. "the set of measures implemented within the cooperation between the public and private sector to create, accumulate, change and use new knowledge with the aim to promote the implementation of innovation and subsequently – the sustainable development of the economy." Similarly, he describes the RIS as "a complex system with strong interactions between several actors systematically engaged in interactive learning" based on the definitions from Asheim & Isaksen (2002), Cooke (1998) and Morgan (1997).

More specifically, a RIS can be described as a systemic and administratively supported interaction (Carrincazeax and Gaschet, 2015) between the "knowledge exploitation subsystem" (Asheim and Coenen, 2005) within a company and regional support infrastructure (e.g. technology incubators, government or private research laboratories, technology transfer agencies, training systems). This systemic interaction, together with collective learning in the RIS to support company innovation needs typically takes place informally (norms, routines, trust, etc.) (Cooke et al, 2004) even though the intention is to provide specific institutional arrangements (Cooke and Schienstock, 2000). These institutional arrangements consist of “a geographically defined, administratively supported arrangement of innovative networks and institutions that interact regularly and strongly to enhance the innovative outputs of firms in the region” which results very often in a high level of local interaction and interdependence present in the RIS. This means that the learning capability of the region must be properly separated from the knowledge infrastructure. (Carrincazeax and Gaschet, 2015)

One of the assumptions very often provided concerning innovation, is that some form of geographical proximity or concentration of entities and relevant linkages between entities are conducive to innovation and associated development (Arundel & Geuna, 2001). Regional agglomeration also seems to best support an innovation based learning economy which promotes localized learning as well (Asheim & Isaksen, 2002).

Resele (2015) presents that the resulting interactions among companies, industry associations, research institutions and training centres provides a collective strategic response to the challenge of increasing competition. This statement clearly identifies at the same time the multiple actors in a much bigger system, which can also therefore be viewed as a system containing subsystems and supra systems, as defined earlier. Furthermore, novelty and economic benefit are identified as the two most important aspects that define innovation, which leads to a definition of innovation as follows:

“innovation in this research is defined as the development and implementation of new to the market or company or significantly improved product or process that brings economic benefit to the company.”
– Resele (2015)

Fritsch and Slavtchev (2009) define innovation activity as the interaction and flow of knowledge between institutions and actors and as a “collective learning process taking place in a system of interconnected actors”, which demonstrates the intuitive and inherent understanding of innovation as a system. They furthermore relate the system’s efficiency to the availability of actors, intensity of interaction and the respective knowledge flows within the system, which addresses one of the main features of a system, namely relationships and interactions among the components of the system.

Kaufmann and Tödtling (1999) also refer to a system, e.g. “Broader and more lasting effects of renewal can only be achieved if innovation is becoming systemic in the region, i.e. if a regional innovation system emerges”. Their definition of innovation refers to “an evolutionary, non-linear and interactive process between the firm and its environment”, which they base on work by Kline and Rosenberg (1986), Dosi (1988) and Malecki (1997).

Their reference to non-linearity in this definition means that numerous actors and sources of information, both within and outside a firm or organization, stimulate and influence innovation while the experience of customers, production and marketing is fed back into earlier phases of the innovation process through additional interactions. To them, the interactivity in this definition is about the internal collaboration between several departments within a company but also with other companies (especially customers and suppliers), knowledge providers (e.g. universities, technology centres) and organizations in finance, training and public administration, all of which contribute to that company’s capacity to innovate.

This makes it clear that the innovation system, regardless of whether it is a RIS or NIS/ NSI or some other form, is as much about the relationships between the various actors as it is about the flow of information and knowledge.

Carrincazeaux and Gaschet (2013) extend the role of relationships and interactions beyond the system, pointing out the importance of these external to the regional “system”. They present that these relationships can be considerably underestimated, referring to literature on clusters (Simmie, 2004; Bathelt, 2005) for example. The important role of external interactions is highlighted, as demonstrated through other studies (Crevoisier & Jeannerat, 2009).

Carrincazeaux and Gaschet (2013) and Niosi (2008) also recognise the strong focus on the regional dimension of innovation systems, which implies underestimating sectoral factors impacting innovation (Carrincazeaux and Gaschet, 2013). This means that the industrial composition of regional economies from the perspective of its knowledge base and technological specificities has a large impact on regionally performance of industries. They present that the regional "performance" of an industry depends on coherence between the knowledge base of the industry and the knowledge creation and diffusion set-up, as well as on governance structure, also referring to studies that link the knowledge base of industries and the nature of regional innovation systems.

The Social Systems of Innovation and Production (SSIP) (Carrincazeaux and Gaschet, 2013) is another view on innovation systems that is described as a "coherent combination of institutional components", but the focus is on institutional arrangements (i.e. only on the components and not on the system as a whole) and therefore it is evidence rather of a non-systems approach. However, this is valuable in that it further describes the innovation system, e.g. the six institutional sub-systems as identified by Amable et al. (1997). These sub-systems include science, technology, industry, financial system, human resources and the education/training system. In the SSIP approach, the Science, Technology and Innovation (STI) "core" is again referred to which has already been highlighted earlier in this section. Their focus on institutional arrangements was intended to demonstrate the diversity of regional systems and their performance. They found that the complementarities from this approach between scientific, technological, industrial and educational profiles elevated the role of the national dimension in the systems and their performance and that these complementarities appeared to have a greater impact at a national level rather than a regional level.

The current System of Innovation Model is the sixth generation of innovation models (Oyebisi, Momodu and Olabode, 2013). Lundvall introduced the concept of system of innovation in 1985 by referring to the work by Friedrich List's on the "National System of Political Economy" (1841). Freeman (1988) labelled it "the national innovation system" based on the social and economic effects identified by the model (Du Preez & Louw, 2008).

3 Industrialization

Similar to the approach taken for systems and innovation, this section on industrialization provides a brief overview of what is understood by the term. This begins with some definitions, such as that provided by Investopedia, which states that:

"industrialization is the process by which an economy is transformed from primarily agricultural to one based on the manufacturing of goods. Individual manual labour is often replaced by mechanized mass production, and craftsmen are replaced by assembly lines. Characteristics of industrialization include economic growth, more efficient division of labour, and the use of technological innovation to solve problems as opposed to dependency on conditions outside human control."

The Merriam-Webster Dictionary defines industrialization as “the act or process of industrializing: the widespread development of industries in a region, country, culture, etc” while the Cambridge Dictionary states that it is “the process of developing industries in a country”.

Simandan (2009) presents Industrialization as “a generic name for a set of economic and social processes related to the discovery of more efficient ways for the creation of value.”

From these definitions it becomes clear that while terms such as system and innovation are typically applied in the context of an object or noun, the term industrialization is applied as a process or verb. For the purpose of describing the process of industrialization in terms of a systems approach, it is therefore needed to describe the environment within which industrialization takes place, i.e. the industrialization system.

The industrialization system is typically described by referring to industry subsectors, while the industrial activity is performed by companies (firms) who interact with a supply chain or value chain that involves suppliers, service providers, buyers, users and a transport and logistics subsystem.

Government is typically seen as an outside influence on the system and impacting on it by way of policy, regulations, incentives, tax and other related instruments. The role of industrial policy in this context is of particular importance, as it is understood to either support or limit industrialization.

Within the South African context, industrial policy is referred to in terms of the Industrial Policy Action Plan (IPAP) of the Department of Trade and Industry (the dti) and the National Industrial Policy Framework (NIPF). The dti offers a range of incentives, policies and regulations and applies instruments, such as Special Economic Zones (SEZ’s) programme and the Industrial Parks Revitalization Programme (IPRP), to drive industrialization.

The NIPF Vision addresses diversification of the economy firstly, as well as the following, which makes it clear that the focus is on a process and not a system:

- The long-term intensification of South Africa’s industrialisation process, and movement towards a twenty-first century knowledge economy;
- The promotion of a more labour-absorbing industrialisation path with a particular emphasis on tradeable labour-intensive goods and services and economic linkages that catalyse employment creation;
- The promotion of a broader-based industrialisation path characterised by greater levels of participation by historically disadvantaged economic citizens and marginalised regions in the mainstream of the industrial economy;
- Contributing to industrial development in Africa, with a strong emphasis on building regional productive capabilities.

In doing so, a number of strategic programmes are proposed, of which the following are particularly relevant to the discussion here:

- SP4: Skills and Education for Industrialization
- SP8: Innovation and Technology
- SP13: Coordination, Capacity and Organisation

It is important to note that the NIPF also identifies coordination and alignment as requirements for successful industrialization. Yet that talks directly to the interactions identified in systems theory earlier. This coordination and alignment should cover other supporting policies and institutions such as those addressing the macroeconomic and regulatory environment, skills and education for industrialisation, traditional and modern infrastructure and innovation and technology.

This is evidence that the industrialization process requires significant interaction, while the various components of the industrialization system and its subsystem further demonstrate that a systems approach may be of value to the industrialization system and more so to its relation to innovation.

4 A systems approach to innovation and industrialization

Based on the brief summary of systems provided earlier and evidence of the presence of various system characteristics it would seem that systems approach can be applied to innovation and industrialization. A systems approach has benefits for innovation and industrialization, as well as in the area where innovation and industrialization meet, not just to better understand the organizations that innovate or drive industrialisation, but also to better understand the system per se.

The system of innovation, whether at national or regional level clearly has a purpose that is related to knowledge, learning or economic benefit, which of course is one of the key aspects in the definition of a system presented earlier. Secondly, there are very clear components or sub-systems identified, which relate to universities, R&D institutions and government for example. This is of course again a key aspect of a system as per the definition(s) provided herein. Lastly, there is extensive reference in the literature about innovation systems to interactions, functions or processes, which constitutes the third key aspect of what a system is.

Applying a systems approach to innovation is therefore aligned with the definition, which is further supported by the wide usage of the term “system” in concepts such as the National System of Innovation (NSI) or Regional Innovation System (RIS) as described already.

Looking at the industrialization environment, one can again clearly identify specific actors or components, such as government and industry. Industry sectors and the existence of logistics and supply chain management all provide further evidence of sub-systems within the industrialization environment. This takes care of the first aspect of components of a system, while the purpose generally relates to production or economic benefit (e.g. profit), which forms the second aspect of a system as per the definition(s). The third aspect relating to interaction or processes, can be found in the production or manufacturing processes, the engagements involved in supply and demand and development of the industry and so forth. It would therefore again seem to inform the application of a systems approach to the industrialization environment.

If both innovation and industrialization can be described in terms of a systems approach, it would imply that they can be viewed as systems that impact each other, or even forming sub-systems of a greater whole within the environment of economic activity or something similar and one can therefore apply the concept of supra and sub-systems as explained in the Viable Systems Approach. (Refer to section 1.2.4.)

As pointed out earlier, a systems approach is not just about the components, but is in fact, much more about the system as a whole. Therefore, applying systems theory firstly means that much greater attention needs to be given to the relationships and roles of each organization (or component) or groups of organizations (e.g. industry associations, business chambers, labour unions) within each system. Secondly, it needs to be applied to the various parts (departments, programmes, units or other organizational components) within its hierarchy whether the components refer to government or a company or university. Of course, one can very easily (and should) view each of these components as systems in their own right, but describing each according to systems theory is not the purpose here.

It needs to be made clear that the systems approach can be applied to organizations that innovate and operate as industrial entities, as much as it can be applied to those that support and drive innovation and industrialization by way of training, policy, etc. such as government, academic institutions or R&D entities.

The systems approach needs to be applied to the greater system that includes all these organizations and extends to include anyone or any organization that somehow contributes towards innovation and industrial development/ growth or supporting industrial activities, .e.g. industry associations, business chambers, supply chain and logistics companies, entrepreneurs, inventors, researchers, academia and so on.

The various engagements or interactions (processes) in this system (which forms the second key aspect of a system as described already) and understood to be central to working together as per the definition in section 1.1, firstly involve regulatory and legislative functions of government, as well as its compliance and monitoring function which can either aid or limit innovation and industrialization. The interactions also involve the various aspects of production or manufacturing in industry, which includes management, financial, marketing and other aspects. It also includes education, training, R&D, continuous improvement, quality management, Intellectual property management.

At another level, the interactions relate to those among various actors or organizations in the system, whether these are industry, government, academic institutions, R&D entities or others. A third level can be added to this, which is often not sufficiently recognised, namely the level of interaction between individuals within and across organizations. Another to view this would be to classify the interactions according to the function they serve, i.e. production, procurement, marketing, operations and so on.

The aspect pertaining to interactions or relations in systems theory are of particular interest because it would seem that these are either neglected or addressed at a very low level, which would point to one of the reasons therefore why the "system" is not working. These interactions and relations are often referred to in terms of coordination, collaboration and partnerships.

The UNECA report on Dynamic Industrial Policy in Africa (2014) states that "Economies that have industrialized have at their core—regardless of policies— institutions and processes to promote strategic collaboration between the private sector and the government" and also that "Successful industrial policy require close government–private sector collaboration that ensures its relevance and effectiveness". This demonstrates the understanding that collaboration, i.e. the interactions as per a systems approach, are absolutely critical to industrialization. The role of collaboration in policy has also been recognised by others (Rodrik, 2004; Evans, 1995; Maxfield and Schneider, 1997) further reinforcing the understanding that interaction and relations, as per the definition of systems theory, is required for policy, which is one way in which governments can support industrialization.

Unfortunately, it appears that this collaboration and also coordination is not in place sufficiently in Africa, including South Africa (UNECA Report, 2014). This is especially noted in terms of collaboration between government and the private sector, which is evident from the lack of trust between these two sectors in South Africa as seen from media and other statements at this point in time. The UNECA Report (2014) therefore recommends that high-level coordination needs to be increased because it is recognised that "More successful countries understand, however, the need for systematic coordination and regularly co-opt the private sector and encourage super-ministerial collaboration".

The third key aspect of a systems approach refers to a shared purpose. It becomes apparent by observing the actions of the various components or players within the systems of innovation and industrialization, that there is a lack of shared purpose and vision. While this may not be so evident from organizational vision and mission statements, policy statements or business objectives, it is found that the perception of government officials (and therefore government as a component of the system or corresponding sub-system) is that private sector (industry, business, commerce) has only one focus, which is to generate a profit for its shareholders and that government needs to protect the people in the country against the resulting exploitation.

Private sector on the other hand views government as controlling, slow, ignorant and lacking the knowledge and insight to support it so that work and economic activity can be provided. Private sector views itself as the primary driver for economic activity and therefore prosperity in the country.

In similar fashion, academia and R&D institutions are viewed by many outside of that sector as being disconnected from reality and to have a limited understanding of implementation and "real-world" challenges.

None of these perceptions are true however as all of them are firstly perceptions, which per definition mean that they are shaped by the frame of reference of the observer. Secondly, all of these perceptions, and the many others that exist, may contain some aspects of truth and some aspects that are not true, and therefore a lie. Exactly how much is truth and how much is lie needs further attention, but for the purposes of the discussion here, it is sufficient to point out that the purpose of various components within the systems of innovation and industrialization vary greatly based on their actions and statements. This is of course further corroborated by the intentions or focus of academia, government and industry, which are generally different, i.e. the first addresses primarily education and research, the second policies and governing the country and the last economic activity.

In terms of a systems approach it becomes therefore clear that the purpose also needs urgent attention in order to make the larger system of innovation and industrialization work more effectively and efficiently. Both the divergence of purpose and absence of or insufficient relations and interactions in a system can be addressed through similar means, involving planning, intentionality and action.

Ultimately it is people that are doing the work, not some organization or programme or business unit somewhere that are faceless and enable people to hide behind. The application of systems theory to how people work is equally important. Firstly, leaders need to be raised up that have a systems perspective and commensurate ability to work with systems, instead of being groomed to perpetuate current non-system approaches to the workplace as is the natural tendency in any organization to do. This would be supported by embracing diversity, not in word, but in deed. Embracing diversity should not be some flavour of the month or political nicety but instead should be pursued actively because the benefit is understood to be required.

This means therefore that such leaders will be raised up if the appropriate organizational change and transformation policies are in place that are open to diversity of all kinds. At the same time organizations need to exhibit the necessary organizational culture and characteristics to raise up such leaders, while also enabling its people to deliver the particular purpose for which it exists.

It is important to note that even domestically based leaders are faced with increasing diversity, as borne out for example by a survey of five hundred senior executives at hundred global corporations conducted by the Economist Intelligence Unit (2010). The survey found that nearly sixty percent reported that their workers will have more diverse backgrounds and experiences and more than half expected managers to become more international in composition.

Current technological developments such as those associated with the Fourth Industrial Revolution are sometimes termed as disruptive exactly because from an organizational perspective, organizations have not adapted and changed in terms of their processes, culture, thinking and therefore the services or products they offer. This provides evidence that there is a need for a different approach, especially within the context of innovation and industrialization. This approach should be based on systems theory, especially because of the complexity of the larger systems within which life exists on this planet.

Such complexity can be further explained by the impact human society has had on biodiversity and climate change, such as presented in reports by the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), various United Nations organizations and a multitude of others. In many conversations and discussions about the complex issues faced in the 21st century, the high complexity is often mentioned, while the need for coordination and collaboration is increasingly at the forefront of such engagements, which of course points exactly to the systems approach.

Engagements and relations as per systems theory, require communication. Therefore it is further proposed that the systems approach also introduces extensive and inclusive communication and awareness campaigns within organizations and at various levels of the systems of innovation and industrialization. Communication is necessary for understanding and it motivates and encourages participation and contribution by all the components of the particular system, whether it is an organization, part thereof or the whole system in a country, region or in the world.

While social media has the potential to serve as a platform for such communication, the ability for any Tom, Dick and Harry to give an opinion that is not automatically an expert view severely hampers this. From another perspective, the fact that social media shows that so many have the need to be heard and therefore have a right to an opinion directly demonstrates that the required communication in relations and interactions needed for the system to be effective and efficient, is not present or sufficient.

The proposed communication in the systems of innovation and industrialization should therefore be transparent, verifiable, accountable and responsible among others. Such communication and associated mechanisms should also take place simultaneously at a personal level among people, at different levels in organizations and among organizations and other sub-systems.

A last means that can be considered is the importance of value systems, paradigms, belief systems and other frames of reference in the interactions among various players at the various system levels within the larger systems of innovation and industrialization. This also involves a focus on truth because truth seems to be less and less visible when one considers propaganda, the concept of fake news and marketing. Very often a particular message that is sent, whether by a politician, blogger, sales person or journalist, is presented to create a particular perception by the receiver (customer, supporter, reader, employee and so on) that will favour the sender in some way or other. Therefore the perception of the receiver shapes how the system functions instead of the real characteristics of the components of the system. This makes the management and operation of the systems and its components much more difficult or even dysfunctional.

5 Conclusion

In spite of the loss of much of the meaning of GST, Systems theory has become a widespread term that is very often used to explain the interdependence of relationships created in organizations. In addition, as a result of the very diverse area of application of this theory, it can act as a bridge for interdisciplinary dialogue between autonomous areas of study as well as within the area of systems science itself. It is for both these reasons that systems theory and systems thinking are introduced as an approach to innovation and industrialization.

The systems of innovation and industrialization provide evidence of typical systems characteristics and aspects. Three primary aspects, namely those pertaining to system components, interaction or engagement and shared purpose that are found to be present in the systems of innovation and industrialization have been used to identify shortcomings in the functioning of these systems and associated means of intervention have been proposed, but further work would still need to be done, such as involving the concepts of complexity, collaboration, coordination, partnerships and value.

Much like quantum mechanics is needed to explain and understood the cosmos, which is at a very large scale, one needs to implement the systems approach throughout the system, its sub-systems and components with a specific focus on the relations and interactions between and among all of these in order to improve the systems of innovation and industrialization.

6 References

Ackoff, R. 1981. *Creating the Corporate Future*. New York: John Wiley.

Ackoff, R. 1991. *From mechanistic to social systems thinking*. Williston, MA: Pegasus Communications.

Ackoff, R. 2003. *Redesigning society*, Stanford. CA: Stanford University Press.

Ackoff, R. 2010. *Systems thinking for curious manager.* London, England: Triarchy Press.

Aldrich, H. 1979. *Organization and Environment*. Prentice-Hall: Englewood Cliffs.

Amable, B., Barré, R. & Boyer, R. 1997. *Les syste`mes d'innovation a` l'e`re de la globalization.* Paris: Economica.

Arundel, A. and Geuna, A. 2001. 'Does proximity matter for knowledge transfer from public institutes and universities to firms?', *SPRU Electronic Working Paper Series*, 73.

Asheim, B. T. and Coenen, L. 2004. 'The role of Regional Innovation Systems in a globalising economy: Comparing knowledge bases and institutional frameworks of nordic clusters'. Paper presented at the DRUID Summer Conference 2004 on Industrial Dynamics, Innovation and Development, Elsinore, Denmark, 14–16 June.

Asheim, B. T. and Isaksen, A. 2002. 'Regional Innovation Systems: The integration of local 'sticky' and global 'ubiquitous' knowledge', *The Journal of Technology Transfer*, 27(1): 77–86.

Barile, S. (eds.) 2006. *L'impresa come sistema. Contributi sull'Approccio Sistemico Vitale*. 1st ed. Torino: Giappichelli.

Barile, S. (eds.) 2008. *L'impresa come sistema – Contributi sull'Approccio Sistemico Vitale*. 2nd ed. Torino: Giappichelli.

Barile, S. 2009. *Management sistemico vitale*. Giappichelli: Torino.

Barile, S. and Polese, F. 2010. 'Linking the viable system and many-to-many network approaches to service-dominant logic and service science', *Journal of Quality and Service Science*, 2(1), in print.

Bathelt, H. 2005. 'Cluster relations in the media industry: Exploring the "distanced neighbour" paradox in Leipzig', *Regional Studies*, 39(1): 105–127.

Beer, S. 1972. *Brain of the Firm*. London: The Penguin Press.

Beer, S. 1975. Preface, in Maturana H.R., Varela F.J. 'Autopoietic systems', in *BLC Report 9*. University of Illinois.

Blainey, G. 2000. *A short history of the world*. Melbourne: Penguin Books.

Boulding, K. 1956. 'General Systems Theory - The Skeleton of Science', *Management Science,* 2(3): 197-208, reprinted in General Systems, Yearbook of the Society for General Systems Research, 1.

Brownlie, D. 1994. *The Marketing Book*. 3rd ed. Baker. 139-192.

Burns, T. and Stalker, G. M. 1961. *The management of innovation.* London: Tavistock.

Capra, F. 1997. *The web of life*. New York: Doubleday-Anchor Book.

Carrincazeaux C. and Gaschet F. 2015. 'Regional Innovation Systems and Economic Performance: Between Regions and Nations', *European Planning Studies*, 23(2): 262–291.

Checkland, P. 1981. *Systems Thinking, Systems Practice.* New York: John Wiley.

Checkland, P. 1997. *Systems Thinking, Systems Practice.* Chichester: John Wiley & Sons Ltd.

Christopher, W. F. 2007. *Holistic Management: Managing What Matters for Company Success*. Hoboken: Wiley-Interscience.

Clark, A. 1993. *Associative engines.* Boston: MIT Press.

Cooke, P. 1992. 'Regional innovation systems: competitive regulation in the new Europe', *Geoforum*, 23(3): 365–382.

Cooke, P. 1998. 'Introduction. Origins of the concept of Regional Innovation System' in: Braczyk, H. J. et al. eds. *Regional Innovation Systems.* London: UCL Press.

Cooke, P. and Lorenzen, M. 2004. 'Regional Innovation Systems & clusters: Issues of scale, abstraction and difference', Abstract for DRUID Summer Conference 2004 on Industrial Dynamics, Innovation and Development, Elsinore, Denmark, 14–16 June.

Cooke, P. and Scheinstock, G. 2000. 'Structural competitiveness and learning regions', *Enterprise and Innovation Management Studies*, 1(3): 265–280.

Cooke, P., Uranga, M. G. & Etxebarria, G. 1997. 'Regional innovation systems: institutional and organizational dimensions', *Research Policy*, 26(4–5): 475–491.

Crevoisier, O. and Jeannerat, H. 2009. 'Territorial knowledge dynamics: From the proximity paradigm to multilocation milieus', *European Planning Studies*, 17(8): 1223–1241.

De la Mothe, J. and Paquet, G. (eds.) 1998. *Local and Regional Systems of Innovation*. Boston: Kluwer.

deVries, B. and Walker, L. J. 1986. 'Moral reasoning and attitudes toward capital punishment', *Developmental Psychology*, 22: 509–513.

Donaldson, T. and Preston, L. E. 1995. 'The stakeholder theory of the corporation: Concepts, evidence and implication', *Academy of Management Review*, 20: 65–91.

Dosi, G. 1988. 'The nature of the innovative process', in Dosi, G., Freeman, C., Nelson, R., Silverberg, G. & Soete, L. eds. *Technical Change and Economic Theory*. London: Frances Pinter.

Economist Intelligence Unit. 2010. Global Diversity and Inclusion Report [online]. Available from http://graphics.eiu.com/upload/eb/DiversityandInclusion.pdf [Accessed 10 April 2019]

Edquist, C. 2001. 'The Systems of Innovation Approach and Innovation Policy: An account of the state of the art', paper presented at the DRUID Conference, 12-15 June, Aalborg

Edquist, C. and Hommen, L. 2008. *Small Country Innovation Systems. Globalization, Change and Policy in Asia and Europe*, Edward Elgar.

Emery, F. E. and Trist, E. L. 1960. 'Socio-Technical Systems' in C.W et al. *Management sciences, models and technique*, Churchman. London: Pergamon.

Espejo, R. 1999. 'Seeing systems: overcoming organisational fragmentation', in Castell, A. M., Gregory, A. J. Hindle, G. A., James, M. E., Ragsdell, G. eds. S*ynergy Matters: Working with Systems in the 21st Centur*. New York: Kluwer Academic / Plenum Publishers.

Espejo, R. and Harnden, R. J. 1989. *The Viable System Model*, London: John Wiley.

Evans, P. 1995. *Embedded Autonomy: States and Industrial Transformation*. Princeton, NJ: Princeton University Press.

Finkelstein, S. and Hambrick, D. C. 1996. *Strategic leadership: Top executives and their effects on organizations*, St. Paul: West.

Finkelstein, S., Hambrick, D. C., & Cannella, A. A. 2009. *Strategic leadership: Theory and research on executives, top management teams, and boards*. New York: Oxford University Press.

Ford, D. 2002. *Understanding Business Marketing and Purchasing*. 3rd ed. London: Thomson.

Freeman, C. 1995. 'The national system of innovation in historical perspective', *Cambridge Journal of Economics*, 19(1): 5–24.

Freeman, C. 2002. 'Continental, national and sub-national innovation systems', *Research Policy*, 31(2): 191–211.

Golinelli, G. M. 2000. *L'approccio sistemico al governo dell'impresa. L'impresa sistema vitale.* 1st ed. Padova: Cedam.

Golinelli, G. M. 2005. *L'approccio sistemico al governo dell'impresa. L'impresa sistema vitale.* 2nd ed. Padova: Cedam.

Golinelli, G. M. 2009. *L'approccio sistemico vitale: nuovi orizzonti di ricerca per il governo dell'impresa*. Sinergie. (80): IX-XXII.

Golinelli, G. M. 2010. *Viable Systems Approach (VSA), Governing Business Dynamics*. Padova: Kluwer Cedam.

Green, R. 2003. *Natural forces*. Tallahassee, FL: Educational Services Consortium.

Hakansson, H. and Snehota, I. 1989. ‘No Business is an Island’, *Scandinavian Journal Of Management*, 5(3), 187-200, in Hakanson, H., and Snehota, I. eds. *Developing Relationships in Business Network*. New York: Routledge.

Hambrick, D. C. 2007. ‘Upper echelons theory—An update’, *Academy of Management Review*, 32: 334–343.

Hannan, M. T. and Freeman, J. 1977. ‘The population ecology of organizations’, *American Journal of Sociology*, 82(5): 929-964.

Hekkert, M. P. et al. 2007. Functions of innovation systems: A new approach for analysing technological change’, *Technological Forecasting and Social Change*, 74: 413-432.

Hemingway, C. A. 2005. ‘Personal values as a catalyst for corporate social entrepreneurship’, *Journal of Business Ethics*, 60: 233–249.

Holland, J. H. 1999. *Emergence: from chaos to order.* Reading Mass: Perseus Books.

Jackson, M. 2003. *Systems Thinking: Creative Holism for Managers*. Chichester: John Wiley & Sons, Ltd.

Javidan M. and Walker J., 2012. ‘A Whole New Global Mindset for Leadership’. *People & Strategy*, 35(2).

Johnson, A. and Jacobsson, S. 2000. ‘The Emergence of a Growth Industry: A Comparative Analysis of the German, Dutch and Swedish Wind Turbine Industries’, paper presented at the Schumpeter Conference, 28 June-2 July, Manchester, United Kingdom.

Katz, D. and Kahn, R. L. 1978. *The Social Psychology of Organizations, II ed*. New York: Wiley.

Kaufmann A. and Tödtling F., 2000. ‘Systems of Innovation in Traditional Industrial Regions: The Case of Styria in a Comparative Perspective’, *Regional Studies*, 34(1): 29± 40.

Keene, A. 2000. ‘Complexity theory: the changing role of leadership’, *Industrial and Commercial Training*, 32(1): 15-21.

Kelly, K. 1994. *Out of control: The new biology of machines, social systems, and the economic world*. New York: Addison-Wesley.

Kelly, K. 1998. *New rules for the new economy*. New York: Viking.

Kline, S. J. and Rosenberg, N. 1986. ‘An overview of innovation’, in Landau, R., Rosenberg, N. eds. *The positive sum strategy*. National Academy Press, Washington. 275–305.

Koch, R. 1998. *The 80/20 rule principle*. New York, NY: Doubleday.

Laszlo, E. 1974. Foreword by Ervin Laszlo to *Perspectives on GENERAL SYSTEM THEORY* by Ludwig von Bertalanffy [online]. Available from http://www.isss.org/laszlofw.htm [Accessed 15 April 2019]

Lawrence, P. and Lorsch, J. 1967. ‘Differentiation and Integration in Complex Organizations’, *Administrative Science Quarterly*. 12: 1-30.

Liu, X. and White, S. 2001. ‘Comparing innovation systems: a framework and applications to China’s transitional context’, *Research Policy*, 30: 1091-1114.

Luhmann, N. 1990. *Soziale Sisteme. Grundriß einer allgemeinen Theorie*. Frankfurt: Suhrkamp Verlag.

Lundvall, B. A. (Ed.) 1992. *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning.* London: Pinter.

Malecki, E. J. 1997. *Technology and Economic Development*. Harlow: Addison Wesley/Longman.

Marion, R and Bacon, J. 2000. 'Organizational extinction and complex systems', *Emergence*, 1(4):71-96.

Maturana, H. and Varela, F. 1992. *Tree of knowledge*. Boston, MA: Shambhala Publications.

Maxfield, S. and Schneider, B. R. 1997. *Business and the State in Developing Countries.* Ithaca: Cornell University Press.

McGuire, J., Dow, S., & Argheyd, K. 2003. 'CEO incentives and corporate social performance', *Journal of Business Ethics*, 45: 341–359.

Mele C., Pels J. & Polese F., 2010. 'A Brief Review of Systems Theories and Their Managerial Applications', *Service Science* 2(1-2):126-135.

Morgan, K. 1997. 'The learning region: Institutions, innovation and regional renewal', *Regional Studies*, 31(5): 479–503.

National Industrial Policy Framework, the dti, ISBN 1-920106-10-3.

Nelson, R. R. (Ed.) 1993. *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.

Niosi J. 2008. 'Technology, Development and Innovation Systems: An Introduction', *Journal of Development Studies*, 44(5): 613–621.

Nonaka, I. and Takeuchi, H. 1995. *The Knowledge-Creating Company*. New York: Oxford University Press.

Oyebisi, T. O., Momodu, A. S. & Olabode S. O. 2013. 'System Thinking in Managing Technological Innovation Systems in Manufacturing Companies', *Our Economy,* 59(3–4): 50–57.

Parker, R. and Tamaschke, L. 2005. 'Explaining regional departures from national patterns of industry specialization: regional institutions, policies and state coordination', *Organization Studies*, 26(12): 1787–1807.

Parsons, T. 1965. *Il Sistema Sociale Torino*. Edizioni: Comunità.

Pascale, R. 1990. *Managing on the edge*. New York: Simon and Schuster.

Pascale, R. 1999. 'Surfing the edge of chaos', *Sloan Management Review*, Spring: 83-94.

Peters, T. 1992. *Liberation management: Necessary disorganization for the nanosecond nineties*. London: Macmillan.

Pfeffer, J. and Salancik, G. R. 1978. *The External Control of Organizations: A Resource Dependency Perspective*. New York: Harper & Row Publishers.

Roberts, J. M. 1995. *A history of the world.* 3rd ed. London: Penguin Books.

Rodrik, D. .2004. *Getting Institutions Right*. Cambridge, MA: Harvard University.

Ruf, B. M., Muralidhar, K., Brown, R. M., Janney, J. J., & Paul, K. 2001. 'An empirical investigation of the relationship between change in corporate social performance and financial performance: A stakeholder theory perspective', *Journal of Business Ethics*, 32: 143–156.

Senge, P. M. 1990. *The Fifth Discipline, The Art and Practice of the Learning Organization*. New York: Doubleyday Currency.

Siegrist G., Green R.B., Brockmeier L., Tsemunhu R., Pate J. 2013. 'A Brief History: The Impact of Systems Thinking on the Organization of Schools', *National Forum of Educational Administration and Supervision Journa*l, 31(4).

Simandan D. 2009. Brock University, St. Catharines, ON, Canada, Elsevier Ltd. All rights reserved.

Simmie J. (Ed) 1997. *Innovation, Networks and Learning Regions*. London: Regional Studies Association/ Jessica Kingsley.

Smircich, L. and Stubbart, C. 1985. 'Strategic Management in an Enacted World', *The Academy of Management Review*. 10(4), October: 724-736.

Smith and Humphries, 2004. 'Complexity Theory as a Practical Management Tool: A Critical Evaluation', *Organization Management Journal - Linking Theory & Practice*, Eastern Academy of Management, 1(2): 91-106.

Suedfeld, P., Corteen, R. S., & McCormick, C. 1986. 'The role of integrative complexity in military leadership: Robert E. Lee and his opponents', *Journal of Applied Social Psychology*, 16: 498–507.

Suedfeld, P. and Granatstein, J. L. 1995. 'Leader complexity in personal and professional crises: Concurrent and retrospective information processing', *Political Psychology*, 16: 509–522.

Sullivan, E. V., McCullough, G., & Stager, M. 1970. 'A developmental study of the relationship between conceptual, ego, and moral development', *Child Development*, 41: 399–411.

Suriyani, M. et al. 2012. 'The Missing Link of Human Capital Development in National System of Innovation Model', *Advances in Natural and Applied Sciences*, 6(6): 875-881.

Tetenbaum, T. 1998. 'Shifting paradigms: From Newton to chaos', *Organizational Dynamics*, 26(4): 21-32.

Tetlock, P. E. 1981. 'Pre- to post-election shifts in presidential rhetoric: Impression management or cognitive adjustment?', *Journal of Personality and Social Psychology*, 41: 207–212.

Tetlock, P. E., Bernzweig, J., & Gallant, J. L. 1985. 'Supreme Court decision making: Cognitive style as a predictor of ideological consistency of voting', *Journal of Personality and Social Psychology*, 48: 1227–1239.

Tetlock, P. E., Peterson, R. S., & Berry, J. M. 1993. 'Flattering and unflattering personality portraits of integratively simple and complex managers', *Journal of Personality and Social Psychology*, 64: 500–511.

Tetlock, P. E., Peterson, R., & Lerner, J. 1996. 'Revising the value pluralism model: Incorporating social content and context postulates', in Seligman, C., Olson, J., & Zanna, M. eds. *Ontario symposium on social and personality psychology: Values*. Hillsdale, NJ: Erlbaum.

Thomas, A. S. and Simerly, R. L. 1995. 'Internal determinant of corporate social performance: The role of top managers', *Academy of Management best papers proceedings*: 411–415.

Tien, J. M. and Berg, D. 2003. 'A case for service systems engineering', *Journal of Systems Science and Systems Engineering*. 12(1): 13-38.

Turner, B. 1991. *The social system*. London, England: Taylor & Francis Group.

United Nations Economic Commission for Africa. 2014. *Dynamic Industrial Policy in Africa: Innovative Institutions, Effective Processes and Flexible Mechanisms.* Addis Ababa, Ethiopia: UNECA

Vicari, S. 1992. *Risorse aziendali e funzionamento d'impresa in Finanza, Marketing e Produzione*, 3.

Von Bertalanffy, L. 1956. 'General System Theory', in Emery, F.E. eds. *General System, Yearbook of the Society for the Advancement of General System Theory*.

Von Bertalanffy, L. 1962. *Modern Theories of Development*. New York: Harper.

Von Bertalanffy, L. 1968. *General System theory: Foundations, Development, Applications*. New York: George Braziller.

Weinberg, G. M. 2001. *An Introduction to General Systems Thinking*. Dorset House Publishing Company, Incorporated; 25th Anv edition, April.

Wood, D. J. 1991. 'Corporate social performance revisited', *Academy of Management Review*, 16: 691–718.

Wong E. M., Ormiston M. E., Tetlock P. E. 2011. 'The Effects of Top Management Team integrative Complexity and Decentralized Decision Making on Corporate Social Performance', *Academy of Management Journal*, 54(6): 1207–1228.

TIPS is a research organisation that facilitates policy development and dialogue across three focus areas: trade and industrial policy; inequality and economic inclusion; and sustainable growth. The Annual Forum is platform for researchers, policymakers and other stakeholders to present research and engage in dialogue on policy-relevant issues. The Forums have overarching themes and have been running since 1997.

For details of past Forums and copies of research presented go to Forum Papers

info@tips.org.za +27 12 433 9340 www.tips.org.za
forum.tips.org.za

TIPS
TRADE & INDUSTRIAL POLICY STRATEGIES