# Business IT Alignment through the Lens of Complexity Science

*Research-in-Progress*

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## Abstract

*Business IT alignment has been a top concern for academics and corporate managers for over 30 years. Despite a rich literature, it is still far from been an achieved objective in companies. Leveraging on the similarities between Information and Complex Systems, researchers have recently adopted a new perspective to study Information Systems and their alignment with business. The present study is based on an extensive literature review that spans three domains of research: Information Systems, Complexity Science, and Organization Science. The paper proposes to contribute to the study and implementation of alignment by presenting a classification framework for the different alignment approaches exploiting methods derived from Complexity Science. Four types of approaches to alignment are identified and for each of them the potential contribution to alignment dimensions is discussed.*

**Keywords:** Business IT alignment, Strategic alignment, Complexity Science, Co-evolution.

## Introduction

Business IT alignment (hereafter alignment) has been a top concern for researchers and practitioners for the last three decades (Kappelman et al., 2013; Gerow et al. 2014; 2010; Chan and Reich, 2007b). Since the introduction of the notion of alignment in King's work (King, 1978) and the proposal of the Strategic Alignment Model (SAM) by Henderson and Verkatraman (1993) several studies and approaches to alignment have been presented, generating a relevant volume of publications (Aversano et al. 2013; Chan and Reich 2007b). Justification of this enduring interest in the topic lies in the correlation investigated by several studies between alignment and corporate performance (Lee et al. 2008; Gerow 2011; Gerow et al. 2016; Pollalis 2003; Yayla and Hu 2012; Croteau et al. 2001; Cragg et al. 2002). However, despite the richness of studies about the subject, alignment is still considered an unachieved objective in organizational practice (Chan et al. 1997; Preston and Karahanna, 2009; Reich and Benbasat 2000; Gerow et al. 2015) and the topic constantly ranks on top of priorities of business executives (Kappelman et al., 2013; Chan and Reich, 2007b).

Among the limitations of existing studies that hamper alignment implementation there are the proliferation of definitions and conceptualizations of alignment, and the underestimation of the role of the dynamic competitive environment. Over the years, several definitions of alignment have been proposed, but most of them are ambiguous, focus on specific aspects of alignment, and lack operational tools for implementation, according to several authors (Maes et al. 2000; Coughlan et al., 2005; Chan 2007; Gerow 2011; Gerow 2014; Preston and Karahanna 2009; Walentowitz, 2012; Tallon and Kraemer 2003; Luftman and Kempaiah 2007). Furthermore, alignment conceptualizations fail to describe the real behaviour of companies, especially in case of dynamic environment. Companies competing in dynamic environment are required to exhibit flexibility and agility, which are in contrast with the rigidity associated to an excessive alignment (Smaczny 2001, Tallon and Pinsonneault 2011; Tallon and Kraemer 2003; Chan 2002).

Recently, Complexity Science has been advocated as a source of concepts and methods to describe Information Systems (IS) and better understand their evolution and alignment with business (McBride 2005; Merali 2006; Merali 2007; Merali et al. 2012, Benbya and McKelvey 2006a; Vessey and Ward 2013). However, IS-focused research in Complexity Science has not generated sufficient results to contribute to understanding and achieving alignment (Kallinikos 2006; Merali et al. 2012).

Consequently, the research question addressed in this paper is the following: how can we use Complexity Science to better understand and achieve alignment? Based on an extensive literature review, this paper seeks to contribute to understanding and implementing alignment in companies by proposing a classification framework of alignment approaches, based on methods and tools derived from Complexity Science. In this study we do not focus on one specific dimension of alignment, but adopt a holistic definition that embraces different dimensions of alignment and highlights the contribution of each type of alignment approach identified in the framework to the main dimensions of alignment.

The paper is organised as follows. The following section presents an analysis of the literature on alignment and on Complexity Science applied to IS in order to justify the need for further research. Section 3 introduces the interpretation model of alignment based on Complexity Science and proposes a new classification framework for alignment approaches. Section 4 discusses the identified approaches and comments on their contribution to different alignment dimensions. Section 5 draws conclusions and presents directions for future research.

## Literature review

### *Methodology of study*

This paper is based on an extensive literature review that tackles three main fields of research, Information Systems, Complexity Science, and Organization Science, where the topic of alignment has been addressed generating an important number of publications. The literature analysis has been carried out combining different approaches in an iterative fashion (Webster and Watson 2002). Initially, papers addressing alignment and Complexity Science applied to IS have been identified within the journals suggested by the Senior Scholar Consortium of the Association for Information Systems (AIS) as top journals in the field: European Journal of IS, IS Journal, IS Research, Journal of the AIS, Journal of Information Technology, Journal of MIS, Journal of Strategic IS, and MIS Quarterly.

Search has been implemented through keywords, identified in the title and in the abstract of publications, comprising initially only ‘alignment’ and ‘complexity’. During the study of the literature, a set of concepts and corresponding keywords have been identified, leading to a taxonomy of 28 main keywords of interests at three levels of granularity (Table 1). Furthermore, some concepts have been addressed in literature using synonyms, in some cases to highlight slight differences in meaning, or acronyms. For instance, alignment is also referred to as fit, link, coherence, and harmony between business and IT. Turbulent environment is sometimes referred to using the acronym VUCA (Volatility, Uncertainty, Complexity, Ambiguity). These terms, synonyms and acronyms have been included in the search in addition to the 28 keywords. As a consequence, an initial set of 92 papers from top IS journals has been selected.

| **Aggregate dimension** | **1st Order concepts** | **2nd Order concepts (keywords)** |
|---|---|---|
| Business IT Alignment | Dimensions of alignment | Strategic alignment<br>Intellectual alignment<br>Operational alignment |

| | | |
|---|---|---|
| | | Functional alignment<br>Social alignment |
| | Conceptualizations of alignment | Alignment as a state<br>Alignment as a process |
| Complex systems | Domains of study in Complexity Science | Complexity Science<br>System dynamics<br>Chaos theory<br>Complex Adaptive Systems (CAS) |
| | Properties and characteristics of complex systems | Non-linearity<br>Emergence<br>Co-evolution (co-evolutionary theory)<br>Self-organization<br>Homeostasis<br>Feedback loops (positive/negative)<br>Multi-scale systems<br>Far-from-equilibrium/edge of chaos |
| | Types of complexity | Structural complexity<br>Dynamic complexity |
| | Theories linked to Complexity Science | Punctuated equilibrium<br>Contingency theory<br>Dynamic capabilities |
| Dynamic environment | Expected properties of IS for companies competing in turbulent environment | Agility<br>Flexibility<br>Resilience<br>Dynamicity |

**Table 1. Taxonomy of concepts and keywords used in the study**

The references used in the initial set of selected papers allowed to identify top journals outside of IS, in the fields of Organization and Complexity Science (the journals most cited in the references have been considered). Top journals, such as Organization Science, Information and Organization, Complexity, have been analysed for the identification of additional publications. The analysis of the most cited references in the identified publications and the study of some relevant works appearing in bibliographic studies on alignment (Chan and Reich 2007; Aversano et al. 2013) allowed to identify additional significant publications. Finally, for a limited number of authors whose area of research is or has been specifically focussed on the study of Complexity Science applied to Information Systems (namely Hind Benbya, Neil McBride, Yasmin Merali), all their publications addressing the topic and identified through their Google Scholar personal pages have been considered. The total set of publications of interest is showed in Table 2.

| **Source and type** | **Type of publication** | **Number** |
|---|---|---|
| Papers from top journals in IS discipline | European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of AIS, Journal of Information Technology, Journal of MIS, Journal of Strategic Information Systems, MIS Quarterly | 92 |
| Papers from ranked journals in Organization and Complexity Science | Organization Science, Information and Organization, Complexity | 21 |
| Other relevant sources (papers, books, conference proceedings, internal reports) | Papers from Information and Management, Emergence: Complexity and Organization;<br>Conference proceedings from ICIS, EICS, ACIS, PACIS, ICIME, books and internal reports | 25 |
| Publications from selected researchers | | 4 |
| Total number of publications | | 124 |

**Table 2. Set of publications included in the study**

### *State of the art in alignment and Complexity Science applied to alignment*

Alignment has been defined in literature in several forms, identifying its different dimensions. In the Strategic Alignment Model (SAM), which is accredited with being the most influential conceptualization of alignment (Gerow et al. 2016; Walentowitz, 2012; Cataldo et al. 2012), Henderson and Venkatraman (1993) define alignment as the "degree of fit and integration between business strategy, IT strategy, business infrastructure, and IT infrastructure". The connection between the 4 domains indicated in the definition leads to 6 dimensions of alignment: strategic or intellectual alignment, involving business strategy and IT strategy, operational alignment, involving business and IT infrastructures, business alignment, involving business strategy and business structure, functional integration, involving IT strategy and infrastructure, and two cross-domain links. An important extension to the SAM is represented by the introduction of the social dimension of alignment (Reich and Benbasat 1996). In the social perspective, alignment occurs when there is mutual understanding and communication between business and IT personnel. An alternative classification is proposed by Reynolds and Yetton (2015), who differentiate between functional alignment, i.e. how IT resources leverage business capabilities, structural alignment, which deals with the allocation of IT responsibilities across the organization, and dynamic alignment, which focuses on how strategic decisions to develop alignment at one point in time influence the range of decisions available in the future.

The absence of a clear and operational definition of alignment is considered one of the obstacles in its implementation. Preston and Karahanna (2009) classify and comment on 12 different definitions of alignment present in literature. Walentowitz (2012) identifies 61 publications containing different interpretations of alignment. Consequently, alignment is considered "a nebulous concept that is difficult to understand" (Chan et al. 1997, p. 126). Reich and Benbasat (2000, p. 82) claim that 'no comprehensive model for this construct [alignment] is commonly used'. Only a limited part of alignment definitions provides metrics and indicators for assessment, leading to misunderstanding and difficulty of application (Maes et al., 2000; Coughlan et al. 2005, Coltman et al. 2015; Gerow et al. 2015; Chan 2002; Preston and Karahanna 2009).

According to several authors (Lee et al. 2008; Gerow et al. 2016; Schlosser et al. 2015), three main dimensions of alignment are studied in literature: *strategic* or *intellectual alignment,* focusing on the coordination between strategy plans and IT plans (Premkumar and King 1992; Kearns and Lederer 2000; Denford and Chan 2007; Lee et al. 2008; Gerow et al. 2014; Gerow et al. 2015; Coltman et al. 2015), *operational alignment,* the coherence between business and IT infrastructures and IT processes (Gerow et al. 2016), and *social alignment,* which concentrates on the people in the organization (Reich and Benbasat 1996, Lee et al. 2008). Walentowitz (2012) illustrates how most of the other definitions of alignment can be mapped on these three main dimensions.

Instead of adopting one specific definition of alignment, in this paper we choose a more comprehensive approach that embraces the mostly studied alignment dimensions. This approach allows to overcome the limitations of a bivariate conceptualization of alignment that, looking into one single type of alignment, would not be capable of capturing the complex and interrelated nature of the relationship between business and IT (Bergeron et al. 2004; Belfo and Sousa, 2012; Chan 2002). We therefore choose the following high level definition of alignment that embraces the three dimensions of intellectual, operational, and social alignment: "alignment is the degree to which business and IT depend on each other, and share their domain of knowledge to achieve a common goal" (Ullah and Lai 2013).

A second obstacle in implementing alignment is the inability of alignment conceptualizations to capture the complexity of companies' real life (Chan and Reich 2007b). In literature, alignment is frequently described as a linear process where company's strategy defines business objectives and the IS is consequently designed and implemented. This approach shows two limitations: (1) The relationship between business and IS in reality is bidirectional and the IS can influence or strongly affect business (Bharadwaj et al. 2013; Chan and Reich 2007b; Coltman et al. 2015); (2) In a dynamic and unpredictable competitive environment, where the competing conditions change frequently, this mechanistic view of alignment leads necessarily to excessive rigidity and misalignment conditions (Broadbent and Weill 1993; Overby et al. 2006; Haeckel 2013).

A dynamic competitive environment requires an IS to quickly adapt and change, which refers to a system's flexibility and agility (Galliers 2006; Overby et al. 2006; Van Oosterhout et al. 2006). Van

Oosterhout et al. (2006) define *flexibility* as the degree to which an organization has a variety of actual and potential capabilities and the speed at which they can be activated, and *agility* as the capacity to swiftly change businesses and processes beyond normal level of flexibility. Key properties of agility are rapidity, resourcefulness, and adaptability (Mathiassen and Pries-Heje 2006). Alignment approaches aimed at maintaining a tight coupling between business and IT in a given framework fail to provide the required flexibility and agility in dynamic environments (Chan and Reich 2007b).

The similarities between Complex Systems and IS gave birth to a stream of research that investigates the application of principles and methods of Complexity Science to IS and in particular to alignment (Merali 2006; Merali and McKelvey 2006; McBride 2005; Benbya and McKelvey 2006a; Vessey and Ward, 2013). A complex system is a non-linear system composed of different heterogeneous and connected elements; their interaction determines the properties of the whole system, which cannot be predicted by the analysis of the characteristics of the elements (Merali 2006). The non-linearity of the system manifests in the sensitivity of the system's properties to details. Small changes in inputs can have dramatic and unexpected effects on outputs. Beside the intuitive analogies between IS and complex systems, Vessey and Ward (2013) provide an additional justification for the adoption of this theory to study IS, which connects to the importance of flexibility and agility noted above. A complex system is characterised by internal and external *co-evolution*. Internal co-evolution means that the different constituting elements interact and mutually adjust determining the properties of the whole system. The whole system interacts with the external surrounding environment and adjusts to it. Similar evolution has been recognised in an IS where the different components (applications, infrastructure, databases, personnel, etc.) interact, influencing the characteristics of the system (Courtney et al. 2008). This caused several IS researches to become interested in exploiting the richness of tools and methods of study existing in Complexity Science to understand and explain the evolution of IS (Benbya and McKelvey 2006a; Merali 2007; Teo and King 1997; Allen and Varga 2006; Karpovsky and Galliers 2015; Peppard and Breu 2003).

Complexity Science is not a unique and clearly defined theory, but a collection of concepts and constructs that originated in disciplines such as physics, biology, ecology and that share some common characteristics (Merali 2006; Morel and Ramanujam 1999). The fragmentation of the topic is reflected in the studies that applied Complexity Science to investigate Information Systems. The use of complex systems concepts in IS literature has been rather "piecemeal, with different authors selectively using particular concepts to focus on specific aspects of IS" (Merali et al. 2012, p. 135).

Initial studies on Complexity Science and IS have been largely descriptive, used to define or characterise behaviours or characteristics of IS and their states. McBride (2005) focuses on the relationship between IS and organizations through the use of concepts derived from Complexity Science. He describes IS based on the Complexity Science notions of state function, i.e. the use of mathematical functions to describe properties of the system, sensitivity to initial conditions, i.e. the property of a system to vary dramatically its characteristics if small perturbations occur, bifurcations, i.e. points at which qualitative change between two states occurs, leading to an irreversible organizational transformation. Courtney et al (2008) and Merali (2006) suggest the use of concepts and language of Complexity Science for 'sense making' in the IS domain. Merali (2007) then focuses on the interaction among the elements of the IS to explain how properties at higher level emerge and posits that agent based modelling and simulation via software tools represent the appropriate investigation methods for understanding IS behaviour.

The co-evolutionary property of complex systems has been explored by several authors to describe the evolution of IS and in particular of alignment, with different foci. Peppard and Breu (2003) present the process of mutual adaptation of IS and business as a sequence of co-evolving interactions characterised by difficulty to predict results. Merali et al. (2012) describe the co-evolution of physical and social technologies in an organization and suggest that the network perspective (i.e. modelling resources as a network of connected elements) and the real options approach (i.e. the study of the opportunities to undertake initiatives and gain value at a certain point in time made available by previous investments) would be appropriate methods to further investigate the evolution of IS in companies. The punctuated equilibrium theory in alignment (Sabherwal et al. 2001; Wang et al. 2011) states that the evolution of IS towards alignment goes through long periods of relative stability, interrupted by short periods of disruptive, revolutionary changes. Co-evolution also draws attention in organization science, where the process of self-organization and the creation of new organizational forms have been studied (Anderson 1999; Lewin and Volberda 1999; Morel and Ramanujam 1999; Lewin et al. 1999).

The multi-scale perspective of alignment looks at the interactions between the different levels into which an organization, modelled as a complex system, can be divided. Benbya and McKelvey (2006a) describe alignment in companies as a series of adjustments at three levels, individual (employees and applications), operational (organizational structure and IS structure), and strategic (business and IS strategy), and propose enabling conditions to speed up dynamics among the levels. Karpovsky and Galliers (2015) identify a set of day-to-day activities that, implemented by individuals in organizations (micro level), can lead to alignment at higher level (macro level).

Despite the intuitive appeal of using Complexity Science as a lens for the study of IS and their alignment to business, current literature using this perspective does not really move beyond an analogy-based approach to the study and does not provide operational methods and tools to support alignment achievement (Kallinikos 2006; Merali et al. 2012).

## Conceptual model

In order to move from a descriptive use of Complexity Science concepts to a more analytical and operational application of alignment we develop a conceptual model through which we can interpret the evolution of alignment as a complex phenomenon. In a Complexity Science perspective of alignment, a company can be modelled as a socio-technical system composed of three sub-systems (Lee et al. 2008; Merali 2007; Courtney et al. 2008): IT (software, hardware, networks), organization (people, structures), and business (value proposition, products, services, strategy, markets) (Demil and Lecocq 2010; Osterwalder 2015; Silvius 2007). The socio-technical interpretation of a company has been adopted by and underpins several studies on complexity in IS (Lee et al. 2008; Peppard and Breu 2003; Merali et al. 2012; Benbya and McKelvey 2006a; Allen and Varga 2006).

During the evolution of the company, IT, organization, and business interact with each other, mutually adjust, re-organize themselves in order to achieve desired performances and to cope with the external competitive environment. The IS is therefore a multi-scale socio-technical system where the interaction of components at the lower level of analysis determines alignment at the higher one. The conceptual model is exhibited in Figure 1. The picture illustrates the mutual interaction of the different components and how alignment results. The organization captures needs from the business, e.g. to react to changes in external environment, to capture opportunities, etc. (arrow (a)). The organization transforms needs into requirements for the IS and implements them (arrow (b)). The organization reacts to the structure and functionalities of the IS to optimize its use (arrow (c)). The business can leverage or even be shaped by the IS (arrow (d)). It is to be noted that the model does not reflect one specific dimension of alignment, as social, intellectual, and operational alignment are the results of the interactions of the different sub-systems.

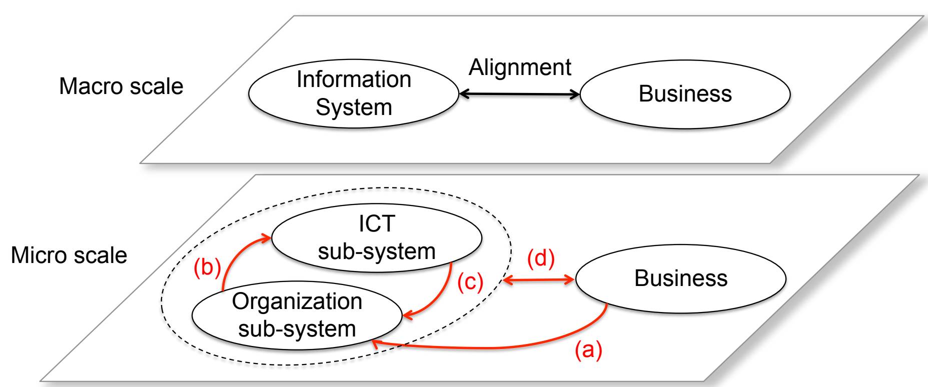


**Figure 1. A model to interpret the alignment between Information System and business**

Most IS literature is converging on a classification of alignment conceptualizations according to two perspectives: alignment as a *state* and alignment as a *process* (Chan and Reich 2007b; Benbya and McKelvey 2006a; Karpovsky and Galliers 2015; Aversano et al. 2013; Cataldo et al. 2012; Silvius 2007). Alignment as a *state* refers to alignment as a condition that can be achieved, assessed, measured and targeted. In the state perspective, variance or factor models have been developed to explain how alignment can be achieved by manipulating a number of antecedents (Baker et al. 2011). Alignment as a *process* encompasses a vision of the company in a constantly evolving state while searching to align its various components. Alignment is seen as a continuous sequence of adjustment steps where both top-down planning as well as improvisation play a relevant role (Silvius 2007; Chan and Reich 2007b). This classification of alignment is consistent with two broad approaches in the study of complex systems: structural complexity (understanding the factors underlying complex properties) and dynamic complexity (understanding the emergent behaviours exhibited by complex systems) (Arévalo and Espinosa 2015; Xia and Lee 2005; Moldoveanu and Bauer, 2004). Structural and dynamic complexities constitute two complementary perspectives for understanding complex systems and pose different challenges. In structural complexity, researchers are challenged by the identification of state or utility functions, which can describe information of the system through the elaboration of specific parameters (Bischi et al. 2015). In dynamic complexity the centre of attention is the identification of the relationships (usually non-linear) between the parameters.

Concerning the methods of study, complex systems can be investigated through un-codified approaches (e.g. qualitative descriptions of the parameters influencing the properties or the behaviour of systems) and codified approaches, based on equations or models that can be analysed through theoretical analysis or software computation (Merali 2006). Codified and un-codified methods have been applied in all types of studies of complex systems, structural and dynamic complexity, as well as to the investigation of the correlation between the dimensions of alignment (Lee et al. 2008; Gerow et al. 2016).

# Discussion

Based on the above, we propose two conceptual distinctions that may help organize the different approaches to alignment derived from Complexity Science: (i) conceptualizations of alignment, i.e. the distinction between alignment as a state or as a process, and (ii) the degree of formalization of complexity methods and tools, i.e. to which extent the structure, characteristics, properties, and behaviour of the Information System viewed as a complex system can be coded through formal descriptions. The combination of the two dimensions yields a 2x2 matrix, through which the different approaches of Complexity Science applied to alignment can be located (Figure 2): (a) metaphors, (b) functional complexity models, (c) co-evolutionary models, and (d) complexity dynamics models.

| **Degree of formalization** \ **Alignment conceptualization** | Alignment as a state | Alignment as a process |
|---|---|---|
| Un-codified | (a) Metaphors | (c) Co-evolutionary models |
| Codified | (b) Functional complexity models | (d) Complexity dynamics models |

**Figure 2. Different approaches of Complexity Science applied to alignment**

(a) Metaphors. Metaphors use analogical reasoning to raise awareness or to influence the way of thinking, and therefore organization actions (Sulkowski 2011). Metaphors have been used in descriptive studies of Complexity Science (McBride 2005; Merali 2006; Courtney et al. 2008) mainly as explanatory device for complex phenomena. The metaphoric approach can be presented at different scales of the study of complex systems: at the micro level for describing the components of the IS and the structure and types of connections, and at the macro level for describing the emerging properties that derive from structural complexity. The metaphor of ‘spaghetti integration’ (Loonam and McDonagh 2005), for instance, has been proposed to underline the potential problems in a company caused by an application portfolio composed to several interconnected applications. The ‘butterfly effect’ became popular to explain with an effective and intuitive image the problems caused by the sensitivity to initial conditions in a complex system (Shinbrot et al. 1992). Metaphors proved to be an effective and valuable approach in management literature (Morgan 2007; Carley 2002,) and their contribution to alignment is mainly related to the social dimension (Merali 2006; Courtney et al. 2008). Metaphors can synthesize the state of the IS to corporate management, clarifying knotty concepts and abstracting from technological details.

(b) Functional complexity models. In a complex system, the state and properties of higher levels depend on the characteristics of lower levels. These relationships can, in some cases, be expressed through mathematical models, formulated in the form of payoff functions that link specific properties of the whole system to structural characteristics or properties of the components. The functions can therefore be studied through mathematical analysis or computer-based simulation. This approach can contribute to alignment at strategic and operational level or through the correlation of different dimensions of alignment. A functional approach has been developed by Luftman (2000), who assesses the strategic alignment maturity of a company on basis of a set of antecedents (communication, competency, governance, skills, etc.). Similarly several researchers have investigated the parameters, precursors and inhibitors, determining the degree of alignment (Chan et al. 2006; Preston and Karahanna 2009; Sabherwal and Chan 2001). At operational level, specific performances can be linked to parameters of the IS. The speed of communication of a network can be described as a function of the structure and properties of the nodes, persons and applications (Benbya and McKelvey 2006a). The robustness in a communication network can be explained by the scale-free property of the network and by the redundancy of its elements (Albert et al. 2000). A functional relationship has been demonstrated between different dimensions of alignment by Gerow et al. (2016) and by Lee et al. (2008).

(c) Co-evolutionary models. Co-evolutionary models study the evolution of a complex system based on the interaction of the constituting elements. Their focus is on the evolution of IS, identifying causes, inhibitors, influencing factors, and rules of interaction. Studies on these models have identified and explored principles, originated in biology and physics, that may be used to govern the evolution of IS towards alignment (Mitleton Kelly 2003; Benbya and McKelvey 2006a; Vessey and Ward 2013). For instance, the principle of requisite complexity (Benbya and McKelvey 2006a; Vessey and Ward 2013), derived from Ashby's (1956) principle of requisite variety, suggests to embed into the Information System those characteristics that can yield the flexibility and adaptability necessary match the dynamicity of the environment. The bootstrap principle is proposed to describe the necessity of an initial strong action to force change and overcome inertia in organizations (Hanseth and Lyytinen 2010). The exploitation of feedback loops (positive and negative) is indicated as instrumental to the evolution of IS towards alignment (Merali 2006; Benbya and McKelvey 2006a). A co-evolutionary view contributes mainly to the strategic dimension of alignment. Understanding the parameters that trigger and the rules that govern the evolution of IS helps identifying the alignment principles that should be incorporated into strategy and IS plans. Awareness of the mechanisms that govern the relationships between the parameters guides management in the implementation of alignment actions, overcoming a linear and deterministic representation of IS evolution (Peppard and Breu, 2003)

(d) Complexity dynamics models. Complexity dynamics models capture the dynamics of a complex system through mathematical descriptions, usually in the form of non-linear equations, that can be studied analytically or through the use of software computation. These methods have been extensively applied in ecology, physics, economics, and social sciences (Strogatz 2001). Newman et al. (2002) and Strogatz (2001) demonstrate how complexity dynamics models remarkably replicate the behaviour of several real social networks. Krugman and Venables (1993) use a complexity dynamics model to explain the industrial localization of companies in USA and Europe. Rzevski (Rzevski 2010) uses a multi-agent software system implementing complexity dynamics models to predict financial crisis. Describing in a quantitative fashion the dynamics of the evolution of an IS may contribute to all dimensions of alignment and in several respects: the identification of critical conditions (e.g. bifurcations or transitions of phase can be associated to disruptive events for the IS), identification of basins of attractions (e.g. combination of parameters that lead to specific conditions of the system), optimization of resources during evolution (Arevalo and Espinosa 2015; Sterman 2000). It should be noted that these properties are not identifiable through other approaches. However, the application of complexity dynamics to IS is still an unexploited area of research. Furthermore, the application of complexity dynamics models require reductionism techniques to identify the limited number of relevant variables and rules that may explain the behaviour of the system, for instance through the application of co-evolutionary models.

## Conclusions and future research

In order to overcome the limitations of current approaches to alignment, the paper investigates the application of concepts and methods derived from Complexity Science. Concepts and methods are analysed through a classification framework based on two conceptualizations of alignment and study of complex systems (alignment as a state or as process, corresponding, respectively, to the study of structural and dynamic complexity) and on the degree of formalization. 4 types of approaches are described and commented.

Two main contributions can be identified in the study. First, alignment is a wide and complex phenomenon that has been studied by literature through partial approaches, focusing on specific aspects, and lacking operational tools for implementation. The proposed framework addresses alignment in a holistic manner. It identifies 4 types of approaches, highlighting the methods of study in view of implementation and the potential contributions to the main dimensions of alignment. The framework represents an epistemological classification of knowledge that is necessary to transform theoretical concepts into practical methods (Maes et al. 2000; Gutierrez et al. 2008). The framework also enables the identification of mixed strategies of alignment combining different methods to pursue manifold objectives. For instance, a company may adopt a metaphor approach to improve social alignment and generate the conditions for implementing other alignment actions, apply co-evolutionary models to pursue alignment on day-to-day basis, and monitor key properties through a functional complexity model. Second, the analysis of the literature on alignment and on Complexity Science exhibits a concentration of studies on functional and co-evolutionary models. The study highlights the opportunity, as yet mainly unexplored, of adopting complexity dynamics approaches to the study of alignment.

The present paper is part of the authors' research project aimed at investigating alignment methodologies based on concepts and methods of Complexity Science. The analysis of existing methods and of their potential contributions to alignment dimensions is necessarily the initial phase of the study and provides suggestions for future areas of investigation. In particular, the following areas of further research have been identified. Some co-evolution principles have been suggested, but not yet tested (Benbya and McKelvey 2006a; Merali et al. 2012; Oh and Pinsonneault 2007). Their development through the identification of enabling conditions, inhibitors, and moderators and the evaluation of their efficacy through the implementation of case studies is currently in phase of implementation. Similarly the evaluation of the efficacy of mixed approaches combining different could be addressed. The design of non-linear models to describe alignment is under investigation.

Two main limitations of the study have been identified. First, in the conceptualization of alignment as a complex phenomenon, the interaction between the system and the external environment has not been investigated in detail. Different external pressures may require different complex properties of the system. The different forms of flexibility and agility of an IS in response to the external needs could therefore be further studied. A second limitation of the study is related to the intrinsic property of complex systems to be difficult to be modelled. Mikulecky (2001, p. 344) states that complexity is 'the property of a real world system that is manifest in the inability of any one formalism being adequate to capture all its properties.' Any approach proposed in the framework should therefore require application to real cases to be validated. The implementation of case studies is now in progress only for co-evolutionary models and could be extended to all the methods discussed in the paper.

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