Sustainability, complexity and learning: Insights from complex systems approaches

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Sustainability, complexity and learning: insights from complex systems approaches

A. Espinosa
Hull Business School. Hull, UK, and
T. Porter
Maine Business School, University of Maine, Orono, Maine, USA

Abstract

Purpose – The purpose of this research is to explore core contributions from two different approaches to complexity management in organisations aiming to improve their sustainability,: the Viable Systems Model (VSM), and the Complex Adaptive Systems (CAS). It is proposed to perform this by summarising the main insights each approach offers to understanding organisational transformations aiming to improve sustainability; and by presenting examples of applied research on each case and reflecting on the learning emerging from them.

Design/methodology/approach – An action science approach was followed: the conceptual framework used in each case was first presented, which then illustrates its application through a case study; at the first one the VSM framework supports an organisational transformation towards sustainability in a community; the second one is a quantitative case study of intended greening of two firms in the supermarket industry, taken from a CAS perspective. The learning from each case study on how they support/explain organisational learning in transformations towards more sustainable organisations was illustrated.

Findings – It wase found that the VSM and the CAS approaches offer internally consistent and complementary insights to address issues of self-organisation and adaptive management for sustainability improvement: while CAS explains empowerment of bottom-up learning processes in organisations, VSM enables a learning context where self-organised networks can co-evolve for improved sustainability.

Research limitations/implications – The main aspects of both theories and examples of their explanatory power to support learning in practical applications in organisations were introduced. The initial findings indicate that it will be worth studying in greater depth the contributions to organisational learning from both conceptual models and more widely comparing their applications and insights.

Practical implications – The paper offers some guidance to both researchers and practitioners interested in using complex systems theories in action research-oriented projects, regarding the usability and applicability of both approaches.

Originality/value – It is considered that, by better understanding organisational ability to adapt and self-regulate on crucial issues for sustainability, it may help to develop one path through the ongoing socio-ecological crisis. While much has been written about sustainability initiatives and governance from conventional perspectives, much less is known about how a complex systems framework may help to address one's pressing sustainability needs. These issues from two innovative complexity approaches as well as the value of using them in action research were illustrated.

Keywords Organzational change, Learning organizations, Sustainable development

Paper type Research paper

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Introduction

The rising crisis of the sustainability of modern society on earth has been widely discussed by researchers over the last few decades: it is now clear that humankind as a

whole has reached, or at best is rapidly approaching, its limits to growth, as Donella Meadows warned 30 years ago (Meadows *et al.*, 1972). Even if many organisations around the world have set up their own sustainability agendas, the results are still poor compared with the need for change at individual, industrial and societal levels. It becomes progressively more obvious that we are incapable of governing our organisations and societies in a sustainable way. The old models are failing and no one seems to know what to do.

In this climate, it is not surprising that a new range of innovative experiments to introduce changes towards sustainability is taking place from businesses to communities and governments. In parallel, there has been a growing interest in finding new ways of understanding sustainability from a holistic point of view, following ideas from pioneers in this field (Meadows *et al.*, 1972; 2004; Lovelock, 1979; Capra, 1996, 2003, 2007; Laszlo, 2006; Bar-Yam, 2000; Holling, 2001; Midgley and Reynolds, 2004; Bawden, 2006; Ison *et al.*, 2007; Ison, 2009; White and Lee, 2009). In particular we consider that Complex Systems approaches offer valuable contributions to sustainability, by explaining the theoretical fundamentals of concepts such as self-organization, emergence, co-evolution, and organisational viability, and examining their influence in sustainability focused organisational learning (Halme, 1996; Molnar and Mulville, 2003; Senge, 1990). Complex Systems frameworks are far from monolithic, however, and newer understandings of complexity are not fully informed by their forebears in cybernetic perspectives New opportunities for theoretical and practical advancement abound from this situation.

While a growing number of papers seek to advance holistic and complexity theory and tools to deal with issues of viability and sustainability (e.g. Espinosa and Walker, n.d.; Porter, 2006a, b), the approach still represents a relatively new science characterized by disparate approaches to improve learning in the service of sustainability (Paucar and Espinosa, 2010). In this paper we explore two fruitful perspectives that have been separately and successfully applied to sustainability and organisational transformation: the Viable System Model (VSM) from the cybernetic field and Complex Adaptive Systems (CAS) from the ecological sciences. We discuss them first as distinct perspectives and then as they complement one another. To help clarifying the ideas, we present detailed examples of application of each particular framework to sustainability. The first example is from a European eco-community that has re-organised itself using a particular approach to complexity (VSM). The second is a quantitative case study of intended greening in two firms in the retail grocery industry, taken from a CAS perspective. There follows a final reflection about the need for further research to improve our understanding of self-organisation in organisations and communities aiming to improve their sustainability.

Complexity theory and thinking

This section of the paper presents a brief synthesis of the conceptual underpinnings of the Viable Systems and the Complex Adaptive Systems Models, emphasizing the contribution of cybernetics to the lineage of modern complexity theory. We then briefly review the basic dynamic principles of the complexity approach that are common to both perspectives. More detail of these two approaches and their application to organizational learning and sustainability then follow in subsequent sections.

In Gordon Pask's words, cybernetics "is about how systems regulate themselves, evolve and learn: its high spot is the question of how they organise themselves" (Pask, 1961, p. 11). Cybernetics has also been defined as "the theory of complexity" (von Hayek, 1972). The early cyberneticians explained the nature of reflexive and homeostatic mechanisms in the brain and the way that "neural-network" organisation is goal directed, self-regulated and can achieve purposeful behaviours (Ashby, 1962; McCulloch, 1965; Powers, 1973); Newer approaches, developed later but based on these early insights, have importantly influenced new understandings of organisations as complex systems; it includes the organisational cybernetics – that Beer (1979) defined as "the science of effective organization" and the Second Order Cybernetic Approach pioneered by Von Foerster (1981), Maturana and Varela (1980).

A more detailed recount on the fundamentals of Complex Systems approaches as applied to organizations and business have been presented elsewhere (e.g. Anderson, 1999; Richardson, 2008; Rihani, 2002; Wulun, 2007), and for reasons of brevity we present just a brief overview below. Complex systems are systems in which many agents, elements, and subsystems interact in densely connected networks. They are non-reductive systems, indivisible into smaller units as are traditional linear systems: "... The whole cannot be understood by being divided into or reduced to its elements ... interaction and connection are non-linear, and non-causal determinism is the rule" (Wulun, 2007, pp. 398-9). In addition to holism and incompressibility (Richardson, 2008), a complex system differs from a merely complicated system in that it is "an interacting network system, and not a reductive simple system" (Wulun, 2007: p.399). In complex systems collective action and decision-making is of greater interest than individual charisma and agency:

> Instead of asking what kinds of special charismatic traits the founders of [new enterprises] require, a complexity interpretation shifts the conceptual focus to such questions as to what kind of networks are useful for what kinds of activities and accomplishments (Goldstein *et al.*, 2008, p. 13).

Indeed, causality is networked rather than singular (Richardson, 2008), a profound shift that calls into question conventional models and methods of linear causality. By correlation, an additional shift in complex systems is growing importance of relational and social aspects of management. For example, because of its embeddedness in networks, innovation is understood to be a product of social and technical coevolution (Beinhocker, 2007), rather than solely residing in entrepreneurs (Schumpeter, 1942) or individual champions (e.g. Dutton and Ashford, 1993; Floyd and Wooldridge, 1997).

Six behavioural aspects of complex systems define the dynamic operations responsible for their ability to adapt in nonlinear, unpredictable ways. First, self-organization signifies the spontaneous, bottom up process whereby a system's elements interact and recombine with little top down design or control (Nishiguchi, 2001). Nonlinear feedback and coevolution are the central mechanisms of self-organization, the first referring to agents' ability to give and receive responses to their own and other agents' behaviour, and the second to the mutualistic evolution of agents and systems that is generated from such feedback (Baum and Singh, 1994; Porter, 2006a). In addition, emergence is the term for this arising of novel patterns, structures, and properties (Goldstein *et al.*, 2008) through which "relatively simple higher-level order 'emerges' from relatively complex lower-level processes" (Sawyer, 2005: p. 3). Path dependence indicates that emergent changes are directly tied to the

particular system and history in which they have developed, and therefore do not represent universal causes or truth. Finally, emergent adaptations tend to take place at micro-sites or "fitness frontiers" (Kauffman, 1993) that are arising and subsiding vortexes of maximum creativity. These have been termed the edge of chaos (Langton, 1992) and the sweet spot (Clippinger, 1999). Palombo (1999) writes that the edge of chaos marks the phase transition between order and chaos, and is therefore the most active site(s) of emergent innovation.

Not every complex system is adaptive, and not every emergent adaptation increases the system's chances of survival. However, when a new, emergent order is one of enhanced functioning that improves the entire system's "fitness", the system is said to be adaptive, or a complex adaptive system (CAS) (Kauffman, 1993; Longair, 1997; Rihani, 2002). Finally, it is important to point out that the adaptive capability of CAS does not necessarily equate with competitive success. As McKelvey (1997) explains, emergent anomalous behaviours cannot be assumed to reliably or predictively produce adaptations that lead to survival and success; they produce only variations in existing order which may or may not equate with success and survival for the agent, the network, or the system.

Owing to the early stage adoption of complexity in organizational research, we find a plurality of theoretical perspectives on complex adaptive systems and organizations. It is not our aim to touch upon all of these perspectives, but rather to examine two of them in depth with particular interest in their prescriptions for management, learning, and sustainability. The first approach, termed the open-system complex adaptive systems view (CAS), takes an open, ecological approach to the relations among multiple types of human and natural systems. It recognizes the existing conventional hierarchies in many organizations, and seeks to enhance their functioning, adaptability, and resilience through the application of the six core complexity principles in specific sustainability contexts. The second approach is called the closed-system Viable System Model (VSM) view, and is built upon cybernetic models of system behaviour. The VSM approach to management is to practice more radical changes in organizational governance, based first upon bottom up feedback and empowerment, then followed by top down adaptations. These two perspectives come from different theoretical lineages and emphasize different aspects of complexity management. Yet they are also complementary, suggesting a further opportunity to combine selectively or in total to render new, holistic and tractable approaches to managing complex adaptive organizations for sustainability. In the next two sections of the paper we discuss each approach, first conceptually and then with an empirical case study, with particular attention to their implications for sustainability and organizational learning.

Complexity and sustainability: a CAS perspective

What does the open, complex adaptive system (CAS) perspective offer for enhancing the ability of business and other complex adaptive systems to use learning to become more sustainable? To answer this question we first examine the CAS perspective in more detail, then advance a model of sustainability and organizational learning based upon this perspective, and finally we illustrate this view of complex adaptive systems through a real-world example.

The CAS approach

Conventional Newtonian theory defines systems as conglomerates of distinct parts that may be broken down and analyzed in chunks, then re-aggregated into a functioning whole. However, this reductive approach breaks down when the systems in question are turbulent, intensely interactive in multiple directions simultaneously, and self-organizing. Linear frameworks and methodologies cannot capture the multiple variabilities that are common in complexity – and indeed most business – dilemmas today (Regner, 2001). In contrast, the open systems CAS approach emphasizes the permeability and exchange of information and feedback across all boundaries (Scott, 1987), particularly those between the organization, its component subsystems, and its external environment. As with an ecosystem, survival and success are equated with timely perception of key external changes and the adaptation of internal elements and processes that successfully respond to those changes. CAS is mainly applied to organizations that are or have been governed by traditional hierarchies and chains of command. It seeks to improve their adaptability and sustainability under the radically new circumstances in which they must operate, where the pace of change and growth are outstripping the effectiveness of conventional top down interventions. CAS is a systems framework characterized by continual change and development, ongoing feedback across all levels, coevolving bottom-up and top-down development, and by a growing focus on processes replacing some of the single-minded myopia over performance. It is not a static model, and in its profound dynamism are found the key issues and the keys to solutions for enhancing sustainability

Sustainability and CAS

Figure 1 presents a working model of human and natural complex adaptive systems, depicting sustainability in three moments. First, drawing heavily from Stead and Stead (2004, p. 73), the outer two rings of the model depict the notion that human systems are nested within larger, encompassing biospheric systems, the "basic assumption that the firm has a symbiotic, coevolving relationship with the greater society and

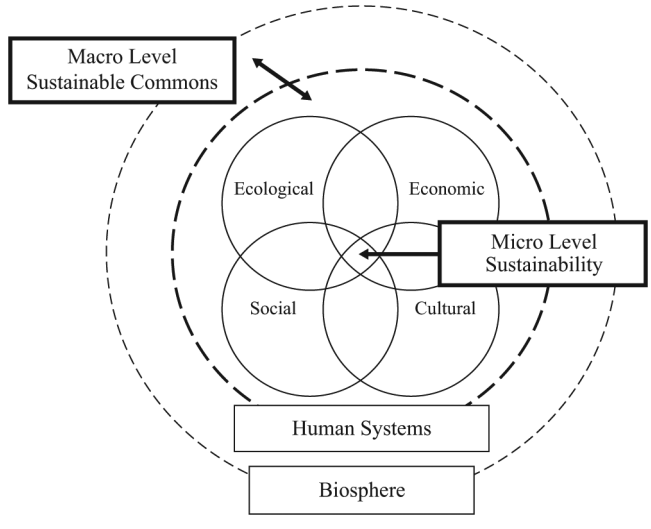

Figure 1.
A schematic model for sustainability and sustainable commons in complex adaptive systems

ecosystem . . . ". Sustainability here refers to maintaining the resiliency of the "commons" (Hardin, 1968), or common pool resources that are used by all but owned by none, such as clean air, clean water, and the like. This is an intensely difficult challenge, given the increasing scarcity of resources and the clamouring demand for their appropriation from all points on the globe. We locate macro issues at this level, for example negotiations between governments, business, communities, and civil society over boundaries, appropriations, and jurisdictions. Secondly, we address intra-system dilemmas in the inner ring of the model. At this and all levels sustainability has to do with issues that impact the ability to help meet today's needs without sacrificing the ability of future generations to meet their own needs (WCED, 1987). In business contexts this concept is often translated as the triple bottom line of economic, environmental, and social performance and viability (Elkington, 1998). Following Werback (2009), however, we add one more, the cultural, to these three dimensions. Where the social aspect has to do with internal aspects such as employee work conditions and corporate contributions to social causes, the cultural bottom line has to do with the preservation and ongoing viability of distinct cultures, or ways of life, which may come under threat by extractive industries or outmigration, for example. In sum, this zone of the figure represents micro level decisions around conflicts in the four dimensions, including individual ethics and corporate social responsibility. Finally, we recognize that the macro and micro levels of sustainability in complex human and natural systems are inseparable, only teased apart here for heuristic clarity. They cannot be evaluated separately, as for example when a firm considers tradeoffs between lowering costs and decreasing its carbon emissions at the micro level, simultaneously affecting its industry-level carbon footprint on a national scale.

Importantly, the model is not static or stable as it might appear. Quite to the contrary, it aims to depict sustainability as an ongoing process taking place between ever-changing, self-organizing systems (Hawkin, 2007). Such complex systems and their interrelations are characterized by continual change and development, ongoing feedback across micro and macro levels, and by coevolving bottom-up and top-down development.

Sustainability and learning in CAS

Based on the model presented above, we next advance an approach to improving sustainability from within its purview. For the best chances of success, we join with others who consider this process to be an action science approach to system-wide organizational learning (Argyris, 1982; Halme, 1996). For instance, Regner (2001, p. 54) notes that complex conditions require that management shift from directing or dominating strategy to "actively cultivating and enriching conditions for knowledge assimilation". This process involves learning "mechanisms", "skills", and "practices" that closely correspond with the six dynamic operations of complex adaptive systems described above. Similarly, Molnar and Mulville (2003) document a strong link between organizational learning and sustainability, reviewing the literature and coining a new acronym, SFOL, or sustainability focused organizational learning. The literature on SFOL and similar approaches link the CAS approach, organizational learning, and sustainability, but are only "fledgling" at this time (Molnar and Mulville, 2003), meaning that this is an exciting avenue awaiting new discoveries and insights.

Two underlying guidelines guide the interventions we propose. First, when organizations find themselves in environments and marketplaces that are

characterized as complex (rather than merely complicated), managers should mimic complexity principles in their own structure and operations. As an ecological model, the open systems CAS approach here reflects the idea that organisms and their environments evolve together. Sensitivity to external events and the flexibility to adapt in a timely manner are key success factors for organizations seeking to improve sustainability under such conditions. Specifically, managers may apply complexity principles by operationalizing the six principles of Complex Systems as shown in Table I below. For example, the principle of self-organization requires capabilities for bottom-up and inside-outside, as well as top down communication, and management's role is to officially enable such channels. In this way unofficial connections can be made and direct, nonlinear feedback can take place outside officially designated channels. With awareness generated in this way, agents may then recognize core opportunities and threats, and may be empowered by management to focus at least some energy on those most relevant and interesting. The edge of chaos thus consists of sites where conflict and opportunity is great, and where informal networks of agents may actively work on responses.

The second premise is that successful adaptation in the CAS view is characterized by organizational learning through the empowerment of bottom up and emergent processes (Kauffman, 1993; Longair, 1997; Rihani, 2002). Top managers do indeed set a sustainability vision for the organization, but this alone will not produce improvements without the systematic enabling of organic processes of local experimentation, initiative development and testing, eventually leading to top down ratification and dissemination of the most promising innovations system wide (Floyd and Wooldridge, 2000). In CAS terms, this process describes the process of coevolution of internal edges of chaos and external sustainability dilemmas.

We next present an example of the CAS approach that is similar in design to other research that examines a case or context through a complexity lens (e.g. Browning *et al.*, 1995; French, 2009; Lichtenstein, 2000; Plowman *et al.*, 2007), aiming to contribute to emerging theory through case study research (Eisenhardt, 1989). This case is part of a larger empirical study one of us conducted on bottom up innovation for sustainability in the supermarket industry (Porter, 2006ab).

An example: bottom-up innovation in the supermarket industry

One of the authors conducted a quantitative case study, which sought to explore self-organization, co-evolution, and emergent adaptations in environmental innovation in the retail grocery industry. A total of 63 middle-level store

Complexity principle	Managerial intervention
Self-organization	Generate conditions where cross-channel communication is unhindered
Nonlinear feedback	Sanction conversations across boundaries
Edge of chaos	Enable productive energy to shift to key problems
Coevolution	Support the formation of collaborating networks that focus on promising innovations
Emergence	Facilitate the bottom-p process of idea generation, progressing to initiative development, trial projects, and (some) adopted new innovations
Path dependence	Assist translation of new innovations from one context into others

Table I.
Managerial interventions based on core complexity principles

managers and 406 line-level department managers were surveyed in two supermarket firms, both of which had adopted a top down sustainability policy. We sought to better understand how bottom up innovation processes might be contributing to the realization of these top down intentions. The supermarket business was an ideal research site because it consists of traditional hierarchical firms with distinct stores where the store manager is seen as top management by employees in the store, but as a middle manager by the executive team at headquarters. Each store acts semi-autonomously and therefore may, theoretically at least, have some leeway in how it applies official policy. Research questions concerned whether the policy was achieved equally in every supermarket of each company; whether local conditions and relations made a difference in the policy's realization in their own store; and the extent to which any extant variability could be understood through the six core principles of the CAS approach to sustainability.

The project was narrowly focused as a micro-process study to compare certain previously significant middle manager attitudes and behaviours with the flow of bottom up ideas and initiatives from line level managers. Independent variables, including store managers' communication style, personal commitment to environmentalism, perception of corporate environmental commitment, and support for bottom up experimenting networks, represented the principles of self-organization and co-evolution. These were assessed in relation to the dependent variables of emergent ideas, developing initiatives, and pilot test projects (Floyd and Wooldridge, 2000), which represented emergence in the study. Briefly, the hypothesized relationships were indeed found to be significant, but in very different patterns for each company. Upon further investigation we found that the company's culture type (Cameron and Quinn, 1999) readily accounted for the different company patterns we observed in bottom up initiatives. These results suggested that there is no "one best way" for a company that wishes to adopt a bottom up innovation strategy, but instead the strategy should be allowed to work through existing culture. This approach enables the self-organizing processes of emergence and coevolution to work within established channels and customs in the organization. Two sets of recommendations also followed from this study. For top managers, sustainability focused organizational learning (SFOL) (Molnar and Mulville, 2003) requires not only that they set a strong sustainability vision, but also that they recognize the value of bottom up innovation, educate middle managers in sustainability policy and cultural values, "incentivize" new initiative development, and that they also reward both quantity and quality of initiative development. For middle managers the recommendations include recognizing the value of emergent self-organization, actively seeking time and resources for employee innovation, communicating regularly with local stakeholder groups, and nurturing and championing initiative development in their stores and company wide.

In sum, this brief study overview illustrates some of the ways in which knowledge in the CAS approach to complex adaptive systems may be advanced. Case application is appropriate at this early stage of theory development (Yin, 2002), where some or all of the six core principles of complexity dynamics are operationalized in investigations of some or all of the four dimensions of sustainability – eco, socio, cultural, and economics – in specific organizational settings. Study results may reveal multilevel patterns in agent behaviour which may in turn be examined for their relevance for

other settings. Only the barest start has been made in this genre of research, but already a number of excellent studies as referenced above is very promising for further investigation. We now turn to the second of our two primary theoretical streams of complexity theory, the viable system model.

Complexity and sustainability: a VSM perspective

The viable systems model

The second stream of complexity research argues that ecological mimicry does not alone provide a full answer to the management of complex organizations. The theoretical foundation of the VSM is a scientific understanding of neural network type of organisations and a revised reading of cybernetic theory (Stark, 2000). Building from the work of Ashby (1962), Mc Culloch (1965), Bateson (1973), Beer (1979, 1981, 1985), and others (Espejo, 1989; Espejo *et al.*, 1996; Espinosa and Walker, n.d.), it sees the organization as a "viable system," defined as: "a system or complex entity capable of maintaining an independent existence – not an existence totally separate from an environment, but one where structural changes take place without loss of identity and without severance from a niche" (Espinosa *et al.*, 2008, p. 640).

Beer argued that in order to be viable, any social system needs to learn how to deal with excessive complexity and this requires developing appropriate structures, neither centralised nor decentralised, but with the right balance and thus capable of dealing with environmental variety. Beer and Casti (1975) explained the mathematics of disaster management, from a complex systems approach and Beer developed later the full theory of viability (encapsulated in the Viable System Model) and a comprehensive set of diagnostic tools to enable his theories to be used in real-world situations to solve problems; it includes the VSM theory of viability and tools to support organisational transformation (Beer, 1979, 1981, 1985); Cybersyn, a performance management system (Beer, 1981, part IV); and Team Syntegrity, a tool to support synergistic interactions in large organisational teams (Beer, 1994).

The VSM is a recursive model that explains core principles of viability. It asserts that viable systems contain and are contained in other viable systems: they are organisationally closed, exhibit structural patterns of interaction at every recursive level of organisation, and retain their coherence and identity even as they adapt to external changes. Each viable system is able to take core decisions locally; all viable systems belonging to an organisation share basic rules of interaction and share information and communication channels and tools that allow them to serve their own purposes as well as those from the embedding organisation they belong to. The viability of complex interacting systems is a result of adaptive interactions between embedded (viable) systems (Beer, 1979). The idea of recursive viable systems is fundamental to understand their entangled complexity.

At each recursive level of organisation there are several "meta-systemic" roles responsible for providing the right managerial and technical services to all viable systems, like: maintaining organisational identity and closure (System 5); exploring likely and desirable futures (System 4); regulating embedded sub-systems and optimising synergies (System 3 and 3*); and avoiding oscillations (System 2). Meta-systemic management can also be described as a cognitive coordination mechanism for the system, making resources and other services available while balancing the need for structural integrity (as in Browning *et al.*, 1995). Importantly,

most decisions emerge from bottom up agent- and network-based activity rather than from *a priori* central control (as in Axelrod, 1997).

The VSM, sustainability, and learning

We have recently presented a detailed explanation on how the VSM may be useful to re-understand the ideas of sustainability, environmental management and sustainable development and provided theory, methodology and applications of this approach to complexity – see Espinosa and Walker, n.d. – Throughout this work, we develop the view that viability – as defined by the VSM – is a necessary condition for sustainability. We view sustainability as the result of an ongoing co-evolutionary process constituted through the dynamic relationships between complex human organisations and the reality that these relationships lay down into their realization. Sustainability refers more to the biological and ecological conditions for survival, while Beer sees viability as the ability to maintain a separate existence, and the VSM as a model of the structural conditions for viability – which is a prerequisite for sustainability (Espinosa *et al.*, 2007, 2008; Espinosa and Walker, n.d.).

At the heart of the VSM approach to sustainability resides the idea that in order to deal with the problems of sustainability in socio-ecological systems, we need to take a view as observers at a logically higher (meta-systemic) level, where we are not being constituted by the interactions we are observing. The language of the VSM allows us to understand a complex organisation as clusters of self-regulating autonomous agents and institutions, structurally coupled to its socio-ecological niche. Our hypothesis is that without proper complexity management tools, and enough autonomy to make decisions, the probabilities of an organisation making effective, self-evolutionary responses are lessened. We focus on "organism in (not and) its environment" as the basic unit of analysis, and offer a set of tools that support the identification and redesign of patterns of interaction– at different recursive levels of organisation; we also focus on monitoring essential variables, those essential for the co-evolution of socio ecological systems.

From this perspective, each viable system takes care, in an autonomous and synergistic way, of issues concerning its sustainability. Ideally, each one must observe and measure – in as close to real time as possible – the dynamics of those variables that are essential for its viability. As viable systems are recursive, that is, each one is embedded and embeds viable systems, the criteria of sustainability "cascades" through different recursive levels of organisation (e.g. from individual from to global and viceversa). Regarding Figure 1, if seen through a VSM lens, we all identify several "layers" or embedment of viable systems from the micro to the macro level. For each viable system, at each layer of recursive organisation, we will observe – in a holistic way- the social, economic, ecologic and cultural aspects of its co-evolution with its niche. At each level sustainability requires organisations to be able to keep their essential variables for sustainability within stable limits, and this will only happens as a result of the organisation having a balanced interaction with its niche. Our hypothesis is that if we manage to learn more about the essential variables for sustainability – at each embedded level of organisation – and self-govern our organisations to keep them within physiological limits, then the possibilities for long-term survival increases.

Translating this into practice requires serious cognitive, structural and political changes in the way we understand and deal with organisational sustainability and organisational transformations: the object of an intervention in an organisation would be to enable a context for effective organisational learning and adaptation, that is a precondition for long-term sustainability. The hypothesis is that a proper learning context will facilitate the emergence of more sustainable behaviours. The focus of an intervention will be in the design of learning and adaptation mechanisms to support people awareness on core sustainability issues and skill to act timely enough to keep the organisation within physiological limits – in terms of its interaction with its socio-ecological system. Acting timely enough is not just an issue of finding a sustainable strategy to steer the organisation but a way of knowing about the socio ecological system, a different way of modelling it (cognitive models), and a different way of jointly learning about it. The object of analysis is the way recurrent forms of interaction between people and organisations evolve and the support they require in their co-evolutionary process. Different experiences using this sort of approach demonstrate that an action learning approach to organisational transformation having the VSM as the conceptual framework for interpretation and analysis could be useful for organisations aiming to improve their sustainability – as next example illustrates.

An example: self-governance in an eco-community

One of the authors had recently participated in an action research project to support an eco-community's self-organisation process, using the VSM approach described. It happened within the context of a European project[1], aiming to create a sustainable eco-community, and also "to create a model sustainable community from which others may learn". After several years of design, selling the idea, getting the land and the resources and obtaining planning permissions, they started building the eco-community in a rural town in need of regeneration in 2006. They aimed to build about 130 family units and community, agricultural, woodland and wildlife areas. In 2007, when the VSM project started the community members have got the planning permission and established a cooperative type of organisation. They operated on the basis of personal commitment and voluntary work from members, and also contracted a few paid staff on administrative roles. They had around twenty self-organised working groups, whose representatives met at a monthly "Group Coordinators" meeting to monitor progress and make decisions. They held a monthly "Members Meeting" – often involving all members – where major policy decisions were taken by consensus. They had a "Process Group" to facilitate ongoing learning about organisational structures and processes. The Board of Directors was legally responsible for the project, and elected democratically.

Until the winter 2009 one of the authors and her partner supported them in improving their organisation, as several situations had threatened the viability of the project and the organisation failed to respond quickly enough – see details of the case study at Espinosa and Walker (n.d.) -. Following an action learning approach we facilitated their learning process about their organisation: through a series of workshops we helped them to self-diagnose their current organisation and performance using the VSM; then we jointly reflected, discussed and designed ways of improvement and put into practice the agreed actions (self-transformation). Finally we all reflected on how they worked, re-assessed the situation, decided on new issues

for further development and re-started the learning loop (self-reflection). In this period they self-organised from about 20 working teams into seven primary activities (PAs) enclosing them, and redesigned their meta-systemic management roles and tools. The new PA groups (Systems 1) met more regularly, completed tasks on time and continuously reported on their achievements and learning constraints. There were several improvements on their System 2 (i.e. new conflict resolution processes, improved e-forums; standard reporting systems from Systems 1); System 3 roles were re-designed: a manager appointed (responsible for servicing Systems 1), the Coordinators Group made more efficient and responsive, and new reporting systems implemented; System 4 was developed for the first time and it included roles responsible for System 4 issues at each System 1 and at the organisation, as well as a slot for S4 issues at the Coordinators meetings and new S4 workshops inviting all members. System 5 was improved, making sure the Board members concentrate on S5 issues and communications with all members improved.

In summary, the main structural problems, which were threatening the survival of the community in 2007, have now been dealt with, and the resulting organisation is both effective and compatible with their fundamental ideology of equality, sustainability and democracy. Everyone seems much clearer about its roles and decisions are getting made in the right moment, which has resulted in a better working environment, and more effective interaction with their environment. Based on the feedback we have received from them we consider that our VSM approach proved to be useful to them.

Implications and conclusion

In a word, our caveats all illustrate ways in which the complexity "paradigm" is not a replacement for classical approaches to management, nor is it a universal panacea for management dilemmas. Indeed, attempting to replace one system with another would only create new sets of problems (Richardson, 2008). First, all systems and organizations are not by any means complex. Diffused, less dense, smaller and simpler systems, where change takes place more slowly, are not complex. They have fewer and/or more dispersed agents that interact less frequently and with less speed and intensity; feedback is not recursive; and co-evolution is not in evidence. Such systems may be very complicated, but they do not exhibit the key qualities of self-organization and emergence, and therefore do not fall under complexity rubrics or thinking. Second, not all complex systems are adaptive.

Searching for new avenues to address the complex challenges and risks of global changes and long-term sustainability of our socio-ecological system, we have explored in this paper the insights that two complexity approaches offer to understanding sustainability of organisations. The VSM, which takes a closed systems view of socio-ecological systems (SES), and CAS, which takes an open system perspective – together offer internally consistent and complementary insights to address issues of self-organisation and adaptive management for sustainability improvement. While CAS offers insightful analytical tools to observe and understand the dynamics and co-evolution of organisational networks, VSM offers a language to map patterns of interaction among core agents in such networks. Each view offers suggestions for improving the system's ongoing adaptability in complex sustainability dilemmas. The VSM approach explains how fully self-organizing systems can co-evolve aiming for

self-regulation and improved sustainability footprint. The CAS framework, on the other hand, explains managerial orchestration of top down empowerment for bottom up learning processes in more conventionally structured organizations. The two strands may thus be very generally compared as an "inside out" system for self-governance, and a "top-down bottom-up approach" for improving sustainability performance. See Table II for a comparison on main characteristics of the two approaches.

The VSM and CAS models address different types of organizations – or organizations on differing developmental pathways – yet when combined they lead to a holistic and tractable approach to improving the ability of complex adaptive organizations to learn and self-govern, as illustrated in the case studies. In the example shown, the VSM project enabled a learning context where the eco-community members themselves learned about self-organisation and self-regulation and thereby reinvented their own roles and communication mechanisms. Once they learned the core VSM distinctions and criteria the members made those changes to which they all agreed, and felt their organisation worked far more effectively than before at all levels. The CAS study of supermarket companies, on the other hand, illustrated how bottom up innovation and learning may be inherently present but not activated in hierarchical types of business organizations, and how it may be enhanced and brought more into mainstream operations and strategy with targeted empowering interventions and particularly middle manager support.

In contexts where the organization is free to conduct its own organization-wide, democratic self-governance, the VSM provides a clear model for working through embedded, recursive complex systems to improve their communication and responsibilities, and as a result, their ability to self-govern on a course towards its sustainability ideals. When the organization has a history and governance system that is committed to operating with top down control, the CAS approach may provide a means for managers to increase its mimicry of CAS principles, thereby setting processes in place for bottom up learning and innovation around a central set of desired outcomes. An important avenue for further research is to examine both approaches within one case situation, to actively co-develop the two perspectives towards a perhaps broader set of tools than either one can provide alone. Together with several doctoral students we have been exploring in more depth such complementarity of VSM and CAS analyses, and the findings confirm the usefulness and complementarities of joint VSM/CAS analyses (see for example Watts, 2009, 2010; Knowles and Espinosa, 2009; Knowles, 2010; Cardoso, 2010, Espinosa and Walker, n.d.). One of the challenging questions regarding further research at this point is about epistemological challenges of complex systems approaches to research. The examples introduced here present two different epistemological choices: the eco-community project followed an action research method and used a multi-methodological research approach (as in Mingers, 1997). On the other side, the supermarket research followed a more traditional survey/hypothesis testing strategy to test the application of the CAS theory in a number of businesses within a particular business sector. In order to progress comparative analyses between both approaches to complex systems we may require of multi-paradigmatic and multi-methodological approaches (as in Zhu, 1998; Gasparatos *et al.*, 2009) and innovative research tools and methodologies.

Finally, in the broader context of sustainability, both approaches aim at improving the learning context of individuals and teams within organisations and their awareness

Table II. Organisational cybernetics vs. complex systems. Approaches to management

	Complex adaptive systems	Organisational cybernetics
Identification of relevant variables	Focus on the patterns of interactions between the agents but without pre-establishing "relevant variables"	Identify both entities and the relevant niche, pin-pointing the essential variables in the interaction
View of organisation	Self-organisation within the system tends to occur when the system is far from equilibrium, or at the edge of chaos. The behaviour of complex systems is not predictable	Self-organised autonomous viable systems recursively nested; meta-systemic functions guaranteeing cohesion and synergy. Complex systems are organisationally closed and exhibit "patterns of viability"
View of control role of authority	The six key principles of complex adaptive systems should be allowed to function to the greatest extent possible, within the limits of existing management. Top management's role is to empower their activation rather than to control from the top	Self-organisation resulting from embracing shared rules and communication protocols. Distributed control
Role of participation/empowerment	Empowered employees are freed up from many controlling processes in a way that enables a number of self-organising abilities to emerge for the benefit of the organisation	Empowerment and participation in decision making is explicitly required to cope with the variety of complex organisation vs environment interactions
Response to environmental change	CAS demonstrates path dependence: its history influences the present behavior of a system	Immediate: people on the operational level have autonomy to operate and respond to real time changes. Closed feedback loops in all interactions

and capacity to act upon essential issues for sustainability. This is undoubtedly a big undertaking that implies moving into neural network type of organisations – each one being autonomous to make local decisions, and all together still acting in consonance with the embedding organisation and their embedded sub-organisations. This is clearly the main coincidence between the two approaches. The main difference between them is the domain at which they work: CAS explains the dynamics of interaction while VSM explains the patters of interaction at the structural level. VSM focuses on understanding learning and complexity management within teams of people responsible for core organisational tasks (what in CAS language would be the attractors – see Arcaute *et al.*, 2009). CAS supports the understanding of innovative and chaotic processes of self-organisation and change – where individuals and teams are left to experiment and learn, resulting in innovative and radical changes.

Hopefully, we have explained in this paper how these complementary complex systems approaches do offer valuable insights to support organisational learning and transformations towards sustainability. Both supports self organisation and the development of awareness on core issues for sustainability. More research needs to be done to fully explore the complementarities of using both approaches in particular businesses or communities striving for their sustainability: and we consider is a research direction worth taking, giving the urgencies and challenges we are facing nowadays in the twenty-first century global society.

Note

1. We will refer to the "Eco-community" to protect identity of the real community where this research is still taking place.

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About the authors

A. Espinosa was born in Bogota, Colombia and graduated as a computer and systems engineer in 1981 from Los Andes University. She worked originally as an Information Systems Manager, in private and public enterprises, and then as the Director of the Secretariat of Information and Systems of the Colombian President's Office (1990-1992). From 1993 to 2002, she taught systems and cybernetics in Los Andes University and provided consultancy for both the private and public sectors. Since 2002 she has been researching and teaching within Hull Business School (originally at Scarborough Management Centre). Since 2007 she has done research about Complexity and Sustainability, funded by two EPSRC projects; in particular she focuses on topics of self-organisation and transition management. She has published extensively on systems and complexity (theory and applications). Angela Espinosa is the corresponding author and can be contacted at: a.espinosa@hull.ac.uk

T. Porter is an Assistant Professor of Management at the University of Maine. She received her degree from the University of Massachusetts, where her research focused on dynamic capabilities and strategic change in corporate environmentalism. Current research interests include strategic processes, sustainability, complexity theory and systems, identity and social networks. An Olympic cross-country skier, she enjoys outdoor sports and recreation of all kinds, as well as gardening, woodworking, and photography.