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The complexity of wicked problems in large scale change

Sandra Waddock
Carroll School of Management, Boston College, Chestnut Hill, Massachusetts, USA
Greta M. Meszoely
Center for Business Complexity and Global Leadership, Sawyer School of Management, Suffolk University, Boston, Massachusetts, USA
Steve Waddell
Networking Action, Boston, Massachusetts, USA, and
Domenico Dentoni
Department of Social Sciences, Wageningen University, Wageningen, The Netherlands

Abstract

Purpose – The purpose of this paper is to extend and elaborate the notion of successful organizational change to incorporate the concept of large system change (LSC), by developing a framework that brings together complexity and wicked problems theories to understand how individual organizations and change agents can better influence LSC.

Design/methodology/approach – This conceptual paper integrates wicked problems and complexity theories to understand and cope with large system initiatives from the perspective of change agents in organizations, and uses the case of the electricity system as an illustrative example for these concepts.

Findings – The paper provides implications for LSC and action steps for change agents in organizations, arguing that by understanding change initiatives through the lenses of complexity and wicked problems, change agents are likely to be more effective.

Research limitations/implications – The integration of complexity science and wicked problems underpins the development of a comprehensive framework for creating effective LSC solutions, however, these ideas still need to be grounded in practice and empirical research.

Practical implications – Using these ideas, change agents in organizations can enhance their influence and use the power of system dynamics to support positive action for sustainable change. This paper provides a foundation to help think through the cross-sectoral, inter-organizational, and change dynamics involved in LSC efforts needed to bring about a more sustainable, secure, and equitable world for all.

Social implications – The world greatly needs system change; however, there is limited theory on effective LSC. This paper hopes to contribute to understanding the ways in which the difficulties of such change can be harnessed to move in positive directions with minimal disruption and greatest effectiveness.

Originality/value – Theories of change management that position the organization in the context of a broader system and define its role in creating change do not yet articulate the nature of the problems at hand in relation to the large systems where they are embedded. This paper builds upon wicked problems and complexity theories to shed light on the role of change agents and organizations in effective transformational change.

Keywords Complexity, Wicked problems, Change agents, Adaptive systems, Large-scale change, System change

Paper type Conceptual paper

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Introduction

The ability to adapt and change effectively relative to market conditions is central to management theory. Much organizational change management was inspired by dramatic systemic shifts that threatened the markets on which organizations depended, beginning with the great depression. There has been a significant evolution of change management from augmenting processes in hierarchical organizations to react to change, to decentralizing organizations with a focus on flexibility to support agility and responsiveness, as well as to ways in which organizations can cope with ecological and societal exigencies now facing the planet. We are, however, only beginning to appreciate change management in the context of broader systemic changes. In an era of unprecedented change where our human and technological systems have become increasingly interconnected and transformed at an unparalleled rate, and where human vulnerabilities to ecological and planetary dynamics are becoming more obvious, the notion of successful organizational change must be reassessed to incorporate the need for significant and simultaneous change in multiple institutions and organizations in the direction of greater sustainability and social justice.

Flexibility and agility have become a corner stone of management theory in the twenty-first century in order to respond effectively to opportunity while mitigating risk relative to changing market conditions. This approach inherently frames organizations in a set of larger industrial, competitive, and increasingly social and ecological contexts. Realizing a sustainable, flourishing future for humanity and organizations of tomorrow requires worldwide change in social, political, and economic systems (e.g. Daly *et al.*, 1989; Intergovernmental Panel on Climate Change (IPCC), 2007; Turner, 2008; McKibben, 2011; Randers, 2012; Worldwatch, 2013). Organizations today are not contained by their institutional or even industrial boundaries, but rather are an integral part of an increasingly interconnected dynamic system of actors and institutions that together support positive or negative change in the short and long term. Organizations must engage in active change initiatives that support a flourishing future at both an organizational and society level for their own self-interested success while positively influencing a healthy social, political, and natural environment within which it not only exists but can flourish. Most importantly, building a more promising future for societies and organizations requires challenging contemporary understanding of organizations as agents of change in the context of broad, complex, evolving systems.

To support this development, this paper: first, elaborates the framework of organizational change to extend the traditional boundaries of organizational change to include large system change (LSC) requiring multi-sector interventions; integrates, synthesizes, and describes different dimensions of complex adaptive systems (CAS) and wicked problems from various strands of literature as they apply to LSC; and provides a conceptual understanding of the integration of CAS, wicked problems, and systems change. Ultimately, we provide change agents wherever they might be with actionable recommendations to assess their own understanding of the systems that require change and how these are linked to wicked problems and CAS so they can influence more positive, sustainable, LSC. Change agents, from the point of view of CAS, are actors who can be found anywhere within the large system undergoing change, who are attempting to move an organization or institution in a different direction than it is currently moving, whether through policy, personnel, resource, technological, financial, or other means.

A LSC perspective

In this paper we are interested in movement of societal institutions and organizations toward sustainability as the core of what we mean by LSC. As we use the term, LSC has two dimensions. One is that it is "large" in the commonly understood sense: it involves large geographies (e.g. national, regional, and global), multiple institutions, and large numbers of people and resources. The other dimension involves the transformation or fundamental reframing of human systems. LSC involves multiple interrelated and connected organizations, institutions, norms, and behaviors at individual, organizational, societal, and global levels. We use the term "system" to mean interacting and connected or interdependent entities that comprise a complex network producing an outcome (Bertalanffy, 1968). Koestler (1968) noted that such entities are organized as holons (wholes consisting of other wholes as their parts). Currently the "system" taken as a whole is producing unsustainable outcomes and many observers suggest the need for transformation. Because the system, as we will explore below, is a CAS fraught with wicked problems, however, effecting change in a desired direction is difficult at best. Our framework asks how complexity and wicked problems theories can enhance understanding of how to bring about change in the midst of such complexity.

LSC is distinguished from incremental and reform change as described in Table I. Incremental change asks "How can we do more of what we have been doing?" and reform asks "What shall we create?" LSC asks the more fundamental question, "What is our core purpose and how do we make sense of the situation?" Incremental change and reform can take place within the current logics (economic-political-social) that are producing unsustainable outcomes. LSC as we have defined it involves transformation, that is, a shifting of the very foundations of some institutions and their interrelationships. A common pathway to transformation arises from experiments and actions of

Type of change	Incremental	Reform	Transformation
Core questions	How can we do more of the same? Are we doing things right?	What rules shall we create? Who should do what? What are the rewards?	How do I make sense of this? What is the purpose? How do we know what is best?
Purpose	To improve performance	To understand and change the system and its parts	To innovate and create previously unimagined possibilities
Power and relationships	Confirms existing rules. Preserves the established power structure and relationships among actors in the system	Opens rules to revision. Suspends established power relationships; promotes authentic interactions; creates a space for genuine reform of the system	Opens issue to creation of new ways of thinking and action. Promotes transformation of relationships with whole-system awareness and identity; promotes examining deep structures that sustain the system
Action frames	Mediation	Negotiations	Visioning

Source: Adapted from Waddell (2011)

Table I.
Types of change

incremental change that integrates the new understanding of reality (e.g. the importance of sustainability) and core purpose (in this case, sustainability). Support for these to become dominant new institutional framings requires fundamental reform of existing institutions and their core purposes, probably over time. LSC engages the dynamics and behavioral mechanisms of the complex network as a whole to define relevant issues, drive initiatives, and support continuous innovation for transformational change by leveraging the system and its internal dynamics in balance with its environment.

One distinctive quality of transformation is that it involves redefinition of power and power structures within the transforming system. Incremental change operates within the current logic, reinforcing existing rules and relationships. For example, incrementalism is associated with companies "rolling-out" new products, services, or delivery channels. Reform allows for the revision of rules, such as with regulatory reform, but does so within current power structures, as occurred after the banking crisis when there was no real change in power structures, though some rules changed. In contrast, LSC aims for new ways of thinking, acting, and relating with different assumptions such as the imperative for sustainability. LSC's transformational challenge involves changing the logic of organizations, their values, and decision-making processes. Therefore, organization change agents are part of LSC simply as a result of the operating and enabling environments of their organizations. The question is whether they want to be reactive or pro-active in navigating the scale of change.

Wicked problems, complex systems, and institutions

Toward the ends described above, we bring two key theoretical lenses to the understanding of LSC: complexity science (e.g. Kauffman, 1995; Lissack and Roos, 1999; Nicolis and Prigogine, 1989; Lissack and Letiche, 2002; Capra, 2006; Schneider and Somers, 2006; Suteanu, 2005; Walby, 2007) with its related emphasis on chaos theory (Gleick, 1988; Prigogine and Stengers, 1984); and the concept of wicked problems (Batie, 2008; Conklin 2005; Dentoni and Bitzer, 2013; Levin *et al.*, 2012; Rittel and Webber, 1973). To these lenses we add the implications for institutions, understood as organizations operating within a given CAS, or problem domain of interest. There is extensive literature on complexity and wicked problems, but limited efforts to link the sets of ideas in thinking about their implications for systems.

CAS of interest here are social systems that are diverse, nonlinear, consisting of multiple interactive, interdependent, and interconnected sub-elements. They are adaptive and self-organizing, tending toward ever-greater complexity operating at the "edge of chaos," and therefore in a constant state of innovation and dynamic equilibrium (Kauffman, 1995; Lissack and Roos, 1999; Nicolis and Prigogine, 1989; Lissack and Letiche, 2002; Capra, 2006; Schneider and Somers, 2006; Suteanu, 2005; Walby, 2007). Pushed too far, they can cross-over that edge of chaos into a major state change or even what Diamond called collapse (e.g. Prigogine and Stengers, 1984; Kauffman, 1995; Diamond, 2005). Social CAS are constituted by individuals, institutions, and other organized entities that interactively influence each other and are simultaneously shaped and influenced by the wicked problems or issues within the system.

Wicked problems are poorly formulated, boundary-spanning, ill-structured issues with numerous stakeholders who bring different perspectives to the definitions and potential resolution of the issue or problem. In wicked problems each issue can be seen as a symptom of others, each issue is unique, no definitive solutions are possible, and there is no "stopping rule" that determines the problem's end or is likely to satisfy all the stakeholders (e.g. Rittel and Webber, 1973; Batie, 2008; Weber and Khademian, 2008;

Dentoni *et al.*, 2012). From a change perspective, wicked problems are defined by dynamic, interconnected issues that influence and are influenced by complex systems in which institutions, such as nations, oil companies, and utilities, are important actors. Wicked problems are what Ackoff (1974) called messes and Trist (1983) labeled meta-problems.

Wicked problems and CAS have many overlapping and similar characteristics. Both need to be considered holistically, are dynamically complex, with emergent, interactive, and co-evolutionary properties, where the outcomes of changes can be seen in patterns, and/or change in the nature of the problem(s), but they are ultimately not predictable. When we discuss wicked problems, we are by definition interested in the issues and problems within CAS that impact institutional changes on a local to global level, but are influenced simultaneously by the network of institutional dynamics that exists among organizational and related entities. Such CAS tend to exist in what Emery and Trist (1965), in their classic paper on organizational environments called turbulent fields, where there is a high degree of interactivity, interconnectedness, and interdependence among the various entities that comprise the field.

Institutions, for the purpose of this paper, include organizations in different sectors, including businesses, governments, and NGOs to accomplish various ends that are somehow related, e.g., within a given geographic or other type of context. The term also encompasses families, or customs, relationships, memes, or norms that help to shape and define a community or complex system (see, e.g. Scott, 1987, 2008, for syntheses of the institutional theory literature). Though we wish to focus predominantly on the organizations of different types that are embedded in a relevant field or scope of interest and interact with each other around wicked problems, we recognize that rules, memes, and logics that constitute institutions and any given institutional infrastructure (Scott, 2008) are also relevant in change situations. Institutions thus are dynamic organizations with their associated memes and rules that emerge and evolve relative to specific needs, interests, actions by various change agents, and for the ultimate goal of survival.

LSC in a CAS, with its embedded institutions (organizations and various memes) and wicked problems, can be conceived as a double helix. Like the DNA molecule, LSC in a CAS comprises a whole consisting of two distinct yet inextricably intertwined, co-evolving, systems: a production system of institutions (broadly defined) and a change system. The production system represents the institutions that structure the system, produce its outputs or outcomes, and contain and structure its institutions and organizations. For the electricity system, which will be used as an example below, the production system includes utilities, transmission and distribution companies, suppliers of fuels, government regulators and investors. Each of these institutions acts relative to its own motivations and local knowledge of the broader system and in response to its understanding of the production system, its goals and needs. The change system comprises all those efforts to restructure and redirect the production system as various change agents contend with various wicked problems.

Complexity theory in the context of wicked problems

LSC is extraordinarily difficult to deal with, understand, or plan because it includes both wicked problems and CAS – which themselves have similar characteristics related to their inherent complexity and chaotic properties.

We use as an illustrative example the case of the global change system for electricity, as distinct from other geographic levels. Included were entities focussed on integrating sustainability concerns (working to achieve sustainability energy for all's goals) into the

electricity production system, and meeting the following criteria: they are multi-organizational initiatives (networks), since even the largest of traditional organizations would have only modest impact on the global, including intergovernmental organizations like the World Bank, and the UN and its agencies which are government networks; and they have a global operation, defined as being active on at least two continents. This work was undertaken by the GOLDEN for Sustainability Energy Ecosystem Lab to address questions about how to enhance coherence and convergence in large complex change systems.

Table II lays out the intersections of wicked problems and CAS as they affect LSC processes. As the sources at the bottom of the table indicate, we have drawn extensively from a wide range of authors' overlapping ideas to draw out these implications and we refer the reader to their original sources for specifics on complexity science, chaos theory, and wicked problems. Below we explain the overlaps between complexity and wicked problems theories, and in the section that follows we illustrate these dynamics with change initiatives within the electricity system.

Problem definition and boundaries

Wicked problems are characterized by uniqueness, complexity, and the interactive dynamism of issues, making each one unique and definitive problem definition impossible, in part because each stakeholder brings different perspectives to the problem at hand. Defining a CAS can appear reasonably clear and with some capacity to determine the definition possible, however, boundaries are not static, and also tend to be very permeable. So, as with wicked problems, it is difficult to determine exactly where one begins and ends. In these contexts, organizational definitions appear quite defined, albeit changeable, and not always completely determinate.

Holistic

Both wicked problems and CAS need to be viewed holistically rather than in piecemeal or fragmented ways because their various components are interconnected, interdependent, and interrelated. In CAS the whole is considered to be more than simply the sum of its parts and much the same could be said of wicked problems, since change efforts often try to tackle only one aspect of a wicked problem, interconnections among various elements make the problem unresolvable unless tackled holistically. Institutions as organizations, generally, are seen to have specific institutional domains, roles, and activities that are, at least in theory, separable from those of other institutions, but the boundaries of these as they evolve continue to change relative to internal and external needs and dynamics.

Dynamics

Wicked problems and CAS are both characterized by non-linear, co-evolving, and emergent dynamics that are inherently unpredictable. These dynamics adapt to different forces and pressures, and are subject to sudden state changes, including what Diamond (2005) calls collapse, which is a well-described implication of current electricity system emissions in the future if they are not curtailed. Both wicked problems and CAS have numerous institutions (organizations and actors, along with the "glue" or set of memes that structures them) acting both within the production and change systems that influence developments and patterns that emerge as a result of co-evolution whereby the systems innovate through creative destruction (Schumpeter, 1962). Though possible, co-evolution can be more difficult in a wicked problems context because of the lack of

Property	Wicked problems	Complex adaptive systems (CAS)
Problem definition and boundaries	Each issue/problem conceived as symptom of others. They are interactive, complexly related, and dynamic. Each is unique and no definitive definition is possible. No definitive boundaries	System definition can appear reasonably clear, and system definition can be determined in physical CAS, while social systems share no definitive boundaries. Permeable boundaries at multiple levels and across institutions
Holistic	Need to be dealt with holistically because piecemeal solutions do not work, because of interconnectedness, interrelatedness, and interdependence of elements	Need to be understood holistically, since the whole is different from the (sum of) parts, and all parts are interdependent, interconnected, and interrelated
Dynamics	Non-linear, cause-effect relationships difficult to determine. Emergence and co-evolution are characteristic. Highly interactive and complex. Can seem unorganized, though fractal qualities can be present, co-evolution is difficult because of dynamism and lack of definitional boundaries though possible	Non-linear, cause-effect relationships difficult to determine. Emergence, adaptation, and co-evolution are characteristic. Greater complexity operating at the "edge of chaos." Spontaneously self-organizing systems (sometimes), process of creative destruction, emerging from interaction, and interdependence of stakeholders, with layers sometimes having fractal qualities
Resolution/ outcomes	No definitive (enumerable or well-described) resolution possible as all stakeholders bring different perspectives. There is no "stopping rule"	Aggregation of actions can result in unpredictable (chaos-induced) state changes or local impacts. No definitive resolution or end point unless state change occurs
Predictability and patterning	Patterns somewhat predictable, not specifics (fractal-like quality possible), and on the whole limits on predictability. May have elements of chaotic systems with "strange attractors" defining points of interest, intervention in interrelated, interdependent, interactive difficult	Path dependent, but not predictable, with fractal-like patterns potentially visible. "Strange attractors" help define patterns. Intrinsic limits on predictability because of interrelated, interdependent, and interactive elements supporting behaviors that may be symptoms of others
Path dependent	Small and large changes bring about different, largely unpredictable system dynamics, leaving "traces," with "no right to be wrong," and no ultimate correct answer. Every solution has irreversible consequences and is a one-shot operation	Change results in unique and irreversible solutions, depending on starting point. Small changes can have large effects (butterfly effect). Collapse can be triggered if system is pushed over the "edge of chaos"

Sources: Rittel and Webber (1973), Prigogine and Stengers (1984), Gleick (1989), Nicolis and Prigogine (1989), Stacey (1991), Kauffman (1995), Stacey (1995), Anderson (1999), Lissack and Roos (1999), McKelvey (1999), Manson (2001), Lissack and Letiche (2002), Capra (2005), Suteanu (2005), Conklin (2005), Schneider and Somers (2006), Walby (2007), Batie (2008), Weber Khademian (2008), Urry (2005), and Dentoni and Bitzer (2013)

Table II.
Properties of wicked problems, complex systems, and institutions

definitional boundaries and dynamism. This definitional constraint is a core investigation of transition literature with respect to electricity (Bauknecht and Cames, 2009; Praetorius *et al.*, 2008). Still, when one actor does something to effect change that shift influences other actors to change (or resist change) and ultimately those changes

come back around to influence the original actor in a co-evolutionary pattern of interaction and engagement. Within the CAS, organizations as institutions can be highly dynamic, interactive, and willing to engage in co-evolutionary change – or rigid, bureaucratized, relatively stable, and resistant to change (at least on the surface). For any given CAS or wicked problem, there can be many organizations taking different actions that influence the dynamics in interactive and complex ways that generate unpredictable outcomes.

Resolution and outcomes

One of the defining characteristics of wicked problems and CAS is that no definitive solution is possible because different stakeholder bring different perspectives to the problem. Further, because of both the complexity of wicked problems and their dynamism, there is no "stopping rule" that determines when the problem has been resolved to satisfy the varied stakeholders. In CAS, aggregation of different actions can sometimes result in unpredictable state changes or local impacts, because the system is characterized by chaos in the mathematical use of that term.

Predictability and patterning

Wicked problems and CAS both have characteristics of chaotic systems – with predictability of outcomes of actions not possible, but with patterns of action that emerge to create system dynamics. Oil prices go up and down, policy waxes and wanes, causing the move to sustainable fuels to cycle … but there is an inexorable move to more sustainable fuels. Both can also experience what are called strange attractors in physics, i.e., elements that create defining points of interest, or leverage points for change. Such a strange attractor in a CAS or wicked problems context could be a particular leader, organization, or institution (including a vision, meme, or set of ideas) that attracts others to it. For example, resources, ideas, memes, or other ways of engaging across organizational or sector boundaries can draw attention and create an impetus for change.

Multiple stakeholders interacting

Different stakeholders in system change may not (fully) agree on what is proposed or acted upon, how change should be approached, or even what the appropriate goals for change might be. At the same time, as Ackoff (1974) noted, bringing together the relevant stakeholders to a given problem, in many cases including stakeholders from multiple sectors, is crucial to any potential for what we can call a good enough solution (Conklin, 2005; Waddock, 2013) where right answers or scientific certainty are unlikely (Batie, 2008; Peterson, 1989).

Path dependence

Path dependence is apparent in both CAS and wicked problems. In wicked problems, small and large changes, though unpredictable in their specific outcomes, shift the systems' dynamics, leaving "traces," with "no right to be wrong," and no ultimately correct answer. Every solution has irreversible consequences – and therefore, there is no way to return to the original state. Much the same is true of CAS, where small initial actions can have potentially large impacts, a process known as the butterfly effect. Collapse can be triggered by sudden state changes when what is called the edge of chaos is reached.

An illustrative example: the electricity system

In the electricity system introduced briefly above, change agents in organizations are struggling to find coherence in their joint efforts as they work to address local concerns given the complexity of the systems and the "wicked" nature of the problems at hand. By reflecting conceptually on the nature of CAS and wicked problems, we can begin to see how understanding the system as both wicked and complex can help provide actionable suggestions for change agents.

Problem definition and boundaries

In the electricity system, the wicked problems involve determining what sources of energy are appropriate in a context of climate change and which elements of the existing system need to change so that the climate change and sustainability crises are not made worse. The CAS consists of the panoply of different elements that constitute electricity production today – and that are subject to current demands and issues of resiliency along with change in the future as new efforts to switch to renewable or non-fossil-fueled-based sources of energy are engaged. It would appear that it is relatively easy to define the electricity system. However, the system is comprised of companies, agencies, fuel and equipment suppliers, customers, and numerous others so that where the system begins and ends is not so readily determined; some actors have multiple roles in the context of unique social, political, technological, and natural dynamics at various levels of the system. Different sources of energy to produce electricity create permeable and shifting barriers and have differential impacts on the natural environment, depending on any number of factors.

Holistic: interrelated problems, systems, and institutions

Electricity as a system needs to be viewed holistically because its different elements are connected to each other as well as to economic development, the environment, and health, among other issues. The electricity system, consisting of electricity generation-transmission-distribution-consumption, also illustrates the distinction between LSC and other types of change. Incremental change involves activities to extend or curtail this current system with current business models, policies, and technology such as providing greater amounts of electricity to current users or adding previously unserviced users through new or expanded distribution channels.

Reform occurred when the electricity system, which was usually unitary, was broken up through public policy change into the constituent parts in most of the USA with different businesses for generation, transmission, and distribution. This segmented parts of the traditional business model, regulatory approach, and technology infrastructure. In contrast, the electricity system is now tackling transformation or LSC with integration of sustainability into its logic. Transformation requires exploration and development of still unknown business models that involve fundamentally different technologies that are changing the power and relationships between the "parts" of the system in basic ways. A holistic approach is needed, for example, with the arising of "prosumers" where consumers can be net energy producers through solar, wind, and other technologies (Insights, 2014), because all elements of the system will be affected in unknown ways by such shifts.

Dynamics

The dynamics of CAS are clear within the electricity system, which has many interacting parts that become less predictable than when traditional technology was used, especially in the context of climate change. Transformation is about developing

resilience and its adaptive ability, in the face of traditionally inflexible, long-term investments in electrical power plants, which are now being supplemented by the distributed and less predictable prosumer model noted above. The threat of collapse is treated by actors within the system as a real possibility, on the one hand from climate change and on the other from the potential for system collapse if sustainability is pushed too far, too fast. For example, at 40 percent renewable energy on its grid, Denmark is far in advance of any other country for renewables. While pushing for continued progress, Denmark is going where no country has gone before. One big worry is that the result of the transformation will be brownouts (i.e. temporary reductions or restrictions on electricity availability) (Gillis, 2014). So a key question is: how can the electricity system be changed from a complex, poorly adaptive system to a highly adaptive complex system in the face of all the unknowns?

Resolution and outcomes

The problems embedded in complex electricity systems are wicked in nature. Climate change issues associated with the electricity system, for example, are associated with increasingly severe implications that can produce collapse, rather than well-defined ones. Indeed, climate change has been called a "super wicked" problem (Levin *et al.*, 2012), because of the many interacting and interconnected elements that are involved. There is continual debate about current effort for change, vs future benefit. The economic and climate impacts of the electricity system, particularly changing the electricity system from its current coal-basis to renewable energy sources, demands both holistic consideration and understanding of the dynamic interactions that result from changing any given element of the system, but it will very likely never be quite clear when the system itself has been fully transformed and it is likely that no outcomes will satisfy all the key stakeholders, some of which want to maintain centralized structures, for example, while others will prefer decentralized, distributed power sources, and distribution.

Predictability and patterning

In electricity, the need for new patterns expresses itself as the need to develop a new business models and sources of energy for utilities, which involves new actors and new roles, while, coal producers and other traditional energy suppliers resist change, making it difficult to predict what is likely to happen. Embedded in the electricity system, and dealing with the described wicked problems, a number of institutions undertake change initiatives both in isolation and in joint initiatives. These include companies, governmental energy agencies, and civic organizations concerned about the natural environment and energy production. In the electricity arena, there are thousands of initiatives working on various aspects and from various perspectives, as noted above, some of which are new and dynamic, offering nontraditional sources of energy production or newer technologies, while other stalwarts are embedded in the existing system and highly resistant to any significant changes.

Multiple stakeholders interacting

In electricity, one big lesson is that there is need for a big shift from the one big utility-generator fits all model, to one that is highly varied depending on context and resources (wind, sun, biomass, etc.), that, use numerous sources of local production such as wind energy or even consumer-based production of energy from solar panels feeding excess energy into the system, not all of which can readily be predicted. Different

stakeholders in the electricity sector bring considerably varied views to thinking about what needs to be done, ranging from business as usual to all non-fossil-fueled production, with any number of positions in between. Environmental impact of electricity systems is never going to end, and how electricity is produced will continue to be contested terrain for the foreseeable future. Indeed, in both contexts, it is likely that when some stakeholders are satisfied with a path or outcome, others may well be unsatisfied. Because of this system complexity in electricity production, we cannot predict with certainty what outcomes, for example, numerous sources of local production, will bring to the entire system.

Path dependence

Thousands of change initiatives aim to integrate sustainability into the electricity system including intergovernmental (e.g. the Kyoto Process, Sustainable Energy for All), technological such as the MIT Energy Initiative, business such as the World Business Council for Sustainable Development's (WBCSD) Electricity Utilities Project, NGOs such as the Electricity Governance Initiative, and multi-stakeholder such as the Carbon Disclosure Project. To a significant extent, the same institutions and actors comprise the production and change systems (e.g. WBCSD). Various agents from the production system participate in change initiatives that can be differentiated by their overt efforts to change the broader CAS or tackle a wicked problem. The chances of complete agreement in such a context are slim. However, once decisions have been made (e.g. to move to the prosumer model), they create pathways that are not readily (or feasibly) reversed.

Path dependence can also be seen in the search for holy grails, such as hydrogen energy providing low-cost clean electricity that would cause massive disruption of traditional fuel providers. Path dependency also produces outcomes that may or may not be desired. For instance, the building of a coal-powered energy production plant has long-term consequences for a shift to renewable sources because of the sunk costs, embedded expertise, and resource usage patterns that are not readily shifted once the initial decision to invest in coal power has been made. Similarly, if the decision is made to invest in renewables, then momentum is established in that direction with the result that it is harder to shift back to non-renewables.

Implications for LSC

Ackoff (1974) in his seminal discussion of systems argued that single institutions cannot successfully tackle LSC (messes) independently. Yet institutions as part of a broader system, acting (seemingly) independently are in a state of constant dynamic exchange with the broader CAS. They can potentially support co-evolutionary change when dealing with wicked problems, or they can thwart it if their efforts move in the opposite desired direction. Complexity and wicked problems theories support this idea, because system change requires changes in institutions, including organizations with their rules and memes and the interstices or spaces between organizations that constitute a broader whole. Organizations that are able to appreciate their location in a broader system are more likely to engage in networks and collaborations of organizations as in the case of the electricity network: creating resources and competencies beyond those of a single organization are required (Waddell, 2005). Below we discuss the implications of CAS and wicked problems for LSC.

Understanding system dynamics

CAS and wicked problems are complex, dynamic, interdependent, emergent and co-evolving. They have no predetermined or predictable outcomes from efforts to

change systems, and each system is unique. Therefore, no established change methods or approaches are likely to work consistently. Identifying leverage points for change (Senge, 1990) or nudges (Thaler, 2009), often through shifting vision, values, and other memes (which, for shorthand, are simply cultural expressions that shape how things are perceived), that will move the system in the hoped for direction at various levels, is critical for creating momentum for LSC. Such nudges or shifts need to be determined by engaging a critical mass of the multiple stakeholders across whatever boundaries exist within the relevant system (Yarime *et al.*, 2012), or by shifting the memes, regulations (ground rules), and values that operate within a system of interest. In the electricity arena, transition theorists have pointed to policy and technological innovations creating disturbances for emergence of new approaches to issues like electricity, that aim to create a new regime of values and operating principles (Geels, 2004; Geels and Schot, 2007; Markard and Truffer, 2008).

Harness complexity, do not simplify it

Orchestrated LSC is impossible, but guiding nudges are. Systems innovate and adapt to local and system conditions, co-evolving in unpredictable ways in spite of centralized planning. (Co)-evolution and emergence of new initiatives, visions, and memes will likely co-exist among the different entities involved, creating wholly new sets of relationships and outcomes that cannot be predicted in advance. Organizations that are able to look outward to effect change will often catalyze or engage initiatives to support internal and external change. Engagement at this level is often looked at as positive. Complexity, and wickedness contribute to a system's resilience and ability to adapt and change, meaning that no single entity or institution is sufficiently powerful to take the entire system down single-handedly. LSC initiatives must harness complexity (Axelrod and Cohen, 2001) rather than simplify or control it to effectively address wicked problems embedded in the CAS. In the electricity field the general trend is toward decentralized systems of generation, distribution, and transmission, but the exact configurations of new business models is still unclear and requires experimentation driven by local contexts such as the potential for wind and solar energy. All of this has led to an emphasis on the development of much more resilient and adaptable strategies that can more easily incorporate and respond to technologies as they emerge (Praetorius *et al.*, 2008).

Seek ways of creating coherence

From a complexity perspective, LSC faces a number of fundamental hurdles. Social and biological systems are by nature CAS. Social problems are, mostly, by nature wicked. These systems are highly non-linear and evolve on many dimensions, levels, and domains simultaneously (or sequentially). Any attempts to change the system must address the underlying mechanisms that support change along with controls that keep the system in check. For electricity, like many change challenges, this leads to a focus on policy, finance, technology, consumers, and service provision (Waddell, 2014). If we accept the basic tenets of CAS that also apply to wicked problems, (including self-organization, adaptation, and change relative to internal and external conditions to maintain a state of dynamic equilibrium, co-evolution, non-predictability), non-linearity, lack of controls by a centralized authority, agents acting independently relative to localized knowledge and conditions, path dependence, and unpredictability, then we can appreciate and leverage the complex interactions of agents or institutions needed to nudge a system to positive and sustainable change by fostering coherence in core

memes, values, norms, and policies, for example. Importantly, organizations can also begin to see their role in creating emergent futures rather than simply reacting to its dynamics. Given the large number of change initiatives that have arisen in the sustainable electricity sphere, a key question involves development of coherence and convergence as a change system, rather than ad hoc actions of individual change initiatives (Waddell, 2014).

Create continuous learning systems

Even if assumptions, objectives, and controls are aligned, however, complexity theory suggests that the system often evolves before objectives are reached. Therefore wicked problems must be addressed over time by the system itself through learning and new initiatives over time. Sustainable solutions to wicked problems therefore must assume that change occurs over time, sometimes considerable time, and the characteristics of complexity will require constant innovation and continuous reflection on how to recalibrate the structural mechanisms to achieve desired outcomes. This aspect of complexity can require willingness to make big changes in change strategies: enormous effort, for example, was poured into the Kyoto Process with the idea of a global accord as a core strategy, but that had to be abandoned in favor of more localized strategies.

Create prototypes

As a system is subjected to major change or perturbation, it needs internal mechanisms of self-healing and resilience. These systems evolve through a gradual integration of innovative solutions that create an intricate balance of structural robustness at the local level that supports a resilient network in the broader CAS. This need explains why there are so many electricity change initiatives: identifying "what works" while building dispersed capacity to implement it allows for such integration of new solutions within the electricity domain, with an eye toward creating a sustainable, resilient system for the long term. Because of the complexity of the system, an outside (or inside) change agent will not be able to keep up with all the things that break (or work) within the system and fix (support) them. In contrast, successful LSC requires a process of leveraging small changes that have positive outcomes into larger actions that influence the system as a whole using networks and interlinkages productively. This involves even more nudging toward desired ends (Thaler and Sunstein, 2008), and seeing what directionality evolves, rather than attempts at control. Thus, we see "incremental change" and "prototypes" based on new logics within the electricity system as core elements of realizing transformation.

Create shared visions

As the system evolves or goes through turbulent times, some artifacts, including social structures, memes, principles, cultures, and behaviors, emerge that ground the system in new patterns, values, and interactions. The system then adapts around these artifacts, making them defining elements, i.e., part of the vision of the whole system. For example, in the electricity arena in California, Europe, and other locations carbon markets have been established as a way to stimulate new behaviors. Whole ecosystems become defined by these artifacts, e.g., mountains in natural ecosystems, and new institutions that have both long term and widespread impacts in social systems. Future change initiatives thus need to take past ones into consideration.

Implications for LSC agents in organizations

Change agents must take all of these dynamics into account and use them to their advantage in order to achieve any desired set of changes. It is important to note that these are necessary but not sufficient conditions for change in a desired direction. No change agent can survive long enough to see completion of the change because there is no stopping rule and long-term horizons can sometimes be involved. For example, the electricity system continues to evolve in response to the sustainability imperative and new technologies in ways we cannot now foresee, LSC consists of cultivating the dynamics and putting the system onto a path that leads to desired outcomes, with the recognition that other stakeholders and change agents in the system will have different perspectives on what outcomes and approaches are desired, and take different actions themselves. The effects of any one initiative can be uncertain, changing the system subtly, or more grandly.

Conceptually, we argue there are a number of things that change agents in organizations need to consider in potential LSC initiatives. Change agents need to:

(1) *Recognize the central role of memes*: addressing complex wicked problems requires transformation of memes, that is, the cultural elements that constitute vision, values, norms, and cultural artifacts that shape a given situation, industry, or broader culture. At the organization, institution, and systems level these are central in creating sustainable change. For example, moving from a world where carbon emissions are not considered a public issue – or, indeed, one that the public even has a right to concern itself with – to one where carbon emissions are simply unacceptable is the core meme that is changing in response to climate change concerns. This type of LSC has happened to tobacco and smoking. Change agents need to understand how to work with and shape new memes that are in the desired direction and that can be readily understood by the numerous actors (with different perspectives) whose actions can shift the relevant context. Organizations and institutions that are out front on these issues are more likely to preempt even unanticipated change to build on rather than react to.

(2) *Distinguish between incremental, reform, and transformational change*: Table I points out that each of these types of change requires different frameworks, methods and actions. Incremental change requires a group of skills and methods that are appropriate for a mediation logic: there is no question about what to do, only minor questions about how to do it. Reform action requires supporting a negotiations logic: defining roles and benefits to achieve an agreed-upon set of goals. Addressing wicked complex challenges and changing memes requires transformation skills based in a visioning logic that includes methodologies to change how and what people see and make sense of data and their world, identify previously unimagined goals and possibilities, and experiment with radically innovative ways of doing and organizing. It involves changing the memes or cultural norms that apply in a given situation because these memes shape the logic guiding change as well as hoped for outcomes. Applying the wrong action logic undermines ability to address wicked problems.

(3) *Prioritize learning in the context of constant change*: complex wicked problems are confusing and often experienced as overwhelming because addressing them

involves changes beyond our experience. We can talk about a sustainable energy system, but no one really knows what it will look and function like. Two types of learning cycles are needed. One is the traditional experienced-based type of learning that produce generalizations about historic or past experience. The other arises from experiments, e.g., prototyping what a sustainable energy system – or components of it – could be. Prototyping essentially means articulating the visioning and transformation logics that provide the core impetus for dealing with the wicked problem of concern and making the subtle shifts that can move the system in the desired direction, recognizing that there is no panacea change that will bring about all the desired shifts and that smaller, more subtle moves will be needed in a variety of places and from a variety of actors.

(4) *Work with a co-evolution and emergence action framework*: all the pieces of wicked problems and CAS are connected and constantly in motion – you cannot simply hold them still. There are also huge problems in isolating parts because once connected to the system, they may act very differently than expected because of the influence of the system's dynamics and inherently unpredictable nature of such problems. Moreover, when a new meme comes to dominate, the very nature of the nature of the change challenge moves from transformation to reform and incremental change. Issues are also deeply interconnected: energy, water, food security, poverty are all connected, and shifting the dynamics in one of these will have impacts on the others, again in ways that are not necessarily predictable. Changing memes also involves changing the very way we categorize and talk about issues. All this requires working on complex wicked problems with an eye to emergence and making what is first a peripheral innovation (technological, belief, economic, etc.) more central. This type of action requires both a dynamic of pushing "forward" relentlessly, and taking advantage and creating ad hoc opportunities to support emergence of multiple possibilities, since it is not clear which bet will be successful.

Co-evolution also requires a change system consciousness, rather than simply attending to a particular change initiative. After all, it is a new system that is evolving, not simply an organization. This change system perspective can produce substantial synergies, reduce duplication, and address gaps in needed change efforts to speed the transformation, when the dynamics of complexity and wicked problems are harnessed rather than ignored.

(5) *Emphasize resilience and adaptation*: rather than thinking in terms of "permanent" as a highly valued attribute, wicked problems emphasize giving primacy to the concepts and values of resilience and adaptation. "Permanent" suggests a non-learning entity that is brittle and unresponsive to changing contexts and shifting needs. Complex responses must respond to context, which requires valuing diversity as a key source of adaptive power to support multiple actions. A resilient and adaptive electricity system will shift from the permanence of large system energy generation infrastructure, to highly decentralized multi-source systems. Of course, creating such resilience requires dealing with huge power issues among the current actors who will be displaced or substantially transformed, and supporting considerable experimentation.

Conclusion

Successful organizational change can no longer focus only on creating systems and structures that respond to a changing world, but rather engages and contributes to the evolution of sustainable realities. Organizational change management needs to recognize its position of influence in creating systems that support a flourishing future. Social, political, technological, and natural system sustainability creates the conditions for prosperity, resilience, and sustainability. By recognizing our individual and collective influence on our broader systems we are able to more effectively position organizations to not simply prepare for change, but create positive LSC. LSC, as we have noted, involves shifting the dynamics of multiple, interacting, and interdependent institutions organized around complex issues and wicked problems in desired directions over time.

The unparalleled interconnectivity of human systems has supported a pace of change unprecedented in human history. While we have seen great progress and innovation we have also seen human and natural devastation of unimagined proportions only decades ago. As we face social, political, natural, and financial crisis of unparalleled significance organizations are faced with tremendous opportunity and unfathomable risk. Organizational change management has, hence, become increasingly important. New models for understanding the organization and its role in creating a sustainable future for itself and the broader system are needed. Change agents must expand their framework of understanding leadership and innovation beyond organizational boundaries to include the broader systems within which an entity exists. There is also wide recognition that people and organizations should play an active role in influencing change in the large systems in which they live – at least to do well, i.e., to create value for themselves, others, and the system as a whole, and possible to do good, i.e., to create value for the systems they live and thrive in. LSC is essential to support a flourishing future, complexity science, and our understanding of wicked problems has created a framework for appreciating the context and dynamics of systems and their corresponding behaviors while providing parameters for action.

The integration of complexity science and our understanding of wicked problems can underpin the development of a comprehensive framework for supporting effective LSC solutions. By integrating these concepts we expand our understanding of organizational change management and provide change agents with a view to how they can enhance their roles and influence and use the power of system dynamics to support positive action for sustainable change. We recognize that this paper only begins that task of evolving our understanding of organizational change management and its application and implications in a dynamic, complex, and interdependent world. We urge other scholars and change agents to help think through the cross-sectoral, inter-organizational, and change dynamics involved in the types of LSC efforts need to bring about a more sustainable, secure, and equitable world for all.

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About the authors

Dr Sandra Waddock is the Galligan Chair of Strategy, the Carroll School Scholar of Corporate Responsibility, and a Professor of Management at the Carroll School of Management, Boston College, USA. Dr Sandra Waddock is the corresponding author and can be contacted at: waddock@bc.edu

Dr Greta M. Meszoely was Founder and executive Director of the Center for Business Complexity and Global Leadership and Associate Professor of Strategy in the Sawyer School of Business at Suffolk University in Boston, MA when she began working on this article. She is currently launching two new companies that allow universal access to advanced data science capabilities to better understand complex systems for more effective decision-making.

Dr Steve Waddell is Principal at the Networking Action and Founding Executive Director of the Global Action Network Net (GAN-Net). He is also a Lead Steward for the GOLDEN Ecosystems Labs.

Domenico Dentoni is an Assistant Professor at the Management Studies Group, Department of Social Sciences and a Principal Investigator of the Global Center for Food Systems Innovation at the Wageningen University, the Netherlands.