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Complexity and Transition Management

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Summary

This article presents a framework, transition management, for managing complex societal systems. The principal contribution of this article is to articulate the relationship between transition management and complex systems theory. A better understanding of the dynamics of complex, adaptive systems provides insight into the opportunities, limitations, and conditions under which it is possible to influence such systems. Transition management is based on key notions of complex systems theory, such as variation and selection, emergence, coevolution, and self-organization. It involves a cyclical process of phases at various scale levels: stimulating niche development at the micro level, finding new attractors at the macro level by developing a sustainability vision, creating diversity by setting out experiments, and selecting successful experiments that can be scaled up.

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Introduction

Our society faces a number of persistent problems whose symptoms are becoming more and more apparent. Persistent problems are complex because they are deeply embedded in our societal structures; uncertain due to the hardly reducible structural uncertainty they include; difficult to manage, with a variety of actors with diverse interests involved; and hard to grasp in the sense that they are difficult to interpret and ill structured (Dirven et al. 2002). Persistent problems are the superlative form of what Rittel and Webber (1973) refer to as "wicked problems." An example of a persistent problem is the energy problem, with anthropogenic climate change as a manifestation. Persistent problems cannot be solved through *only* current policies (Ministry of Housing, Spatial Planning and Environment 2002; Social and Economic Council of the Netherlands 2001). Persistent problems are related to the system failures that crept into our societal systems and that, contrary to market failures, cannot be corrected by the market or current policies. System failures are locked-in flaws in our societal structures, such as technological bias, weak or dominant networks, institutional barriers, and path dependencies.

Q1

Combating system failures requires a restructuring of societal systems—that is, a transition. A transition is a radical, structural change of a societal (sub)system that is the result of a coevolution of economic, cultural, technological, ecological, and institutional developments at different scale levels (Rotmans et al. 2001; Rotmans 2006). In "transition language," we call the deep structure the incumbent regime: a conglomerate of structure (institutional and physical setting), culture (prevailing perspective), and practices (rules, routines, and habits). And we denote an emergent structure as a niche: a structure formed by a small group of agents that deviate from the regime and that might build up a new regime that is able to break down and replace the incumbent regime. This differs somewhat from the common definition of a niche as individual technologies, practices, and actors outside or peripheral to the regime, as loci for radical innovation (Geels 2005).

Q2

The idea is that a better insight into the functioning of societal systems provides insight into the possibilities for directing these systems. We use complex systems theory to study the dynamics of societal systems to derive a collection of basic guidelines that can be used to direct those systems. Obviously, societal systems, because of their complexity, cannot be directed in command and control terms. We do, however, hypothesize that it is possible to use the understanding of transition dynamics to influence the direction and pace of a transition of a societal system into a more sustainable direction. The explicit normative orientation of sustainability is important, because historical transitions often have not led to a more sustainable society (Rotmans 2005). Fostering sustainability transitions is what we call transition management (Rotmans et al. 2001).

In this article, we first treat basic principles of complex systems theory and of managing complex adaptive systems. That results in the formulation of core theoretical principles for transition management, on the basis of which we present a framework that contains guidelines for applying transition management in practice.

Complex Systems Theory

Complexity theory, otherwise known as complex systems theory, has its roots in the general systems theory that Von Bertalanffy (1968) published in the 1930s. Systems theory is an interdisciplinary field of science that studies the nature of complex systems in society, nature, science, and technology. It provides a framework by which a group of interrelated components that influence each other can be analyzed. That group can be a sector, branch, city, organism, or even a society. Systems theory evolved over the last century from deterministic to probabilistic, from a control engineering to a soft systems approach, and from partial to integrated. In the 1970s and 1980s, integral systems theory became an important field, focusing on the integration of social, economic, and ecological processes (Holling 1978; Hordijk 1985; Rotmans 1990). During this time, soft systems theory emerged; it takes a qualitative approach rather than a quantitative approach and is mostly applied to companies and organizations

(Senge 1990). In the 1990s, complex systems theory was introduced; it focuses on the coevolutionary development of systems (Holland 1995; Kauffman 1993, 1995). Although the theory is far from mature, it has attracted a great deal of attention and has many applications in diverse research fields: in biology (Kauffman 1995), economics (Arthur et al. 1997), ecology (Kay et al. 1999; Gunderson and Holling 2002), public administration (Kickert 1991; Teisman 1992) and policy analysis (Geldof 2002; Rotmans 2003). A single complex systems theory does not exist: There are multiple manifestations of it. There are (1) formalized and computational modeling approaches, (2) a set of "understandings" of the behavior of complex systems, (3) metaphorical use about complexity of social phenomena, and (4) philosophical considerations about the ontology and epistemology of complex systems. We take the second and, to a lesser extent, the first manifestation as a starting point for our transition research. Within this context, complex systems theory attempts to better understand the behavior of complex systems that run through cycles of relatively long periods of equilibrium, order, and stability interspersed with relatively short periods of instability and chaos. The primary focus is on complex systems, which have the following characteristics, as drawn from the work by Prigogine and Stengers (1984), Holling (1987), Holland (1995), and Kauffman (1995).

Complex systems are *open* systems that interact with their environment and constantly evolve and unfold over time. Complex systems contain many diverse components and interactions between components. These interactions are nonlinear: A small stimulus may cause a large effect or no effect at all. Conversely, a big stimulus may cause a small effect. Complex systems contain *feedback loops*. Both negative (damping) and positive (amplifying) feedbacks are key ingredients of complex systems. Complex systems have a history; prior states have an influence on present states, which have an influence on future states. This creates *path dependence*, whereby current and future states depend on the path of previous states. Complex systems are nested and encompass various organizational levels. They have *emergent properties*—that is, higher level structures arise from interaction between lower level components. Complex systems have multiple *attractors*. An attractor is a preferred steady system's state set, to which a complex system evolves after a long enough time.

Complex adaptive systems are special cases of complex systems. They are adaptive in the sense that they have the capacity to change and learn from experience. Expressed differently, they are able to respond to and adjust themselves to changes in their environment. What makes a complex adaptive system special is the set of constantly adapting nonlinear relationships. Complex adaptive systems contain special objects—agents that interact with each other and adapt themselves to other agents and changing conditions. This is why complex adaptive systems have unique features, such as *coevolution*, *emergence*, and *self-organization*.

In the biological or economic context, *coevolution* refers to mutual selection of two or more evolving populations (van den Bergh and Stagl 2004). In the complex systems context, however, coevolution is used to indicate the interaction between different systems that influences the dynamics of the individual systems, leading to irreversible patterns of change within each of the systems (Kemp et al. 2007a). The irreversibility aspect distinguishes coevolution from coproduction, which indicates mere interaction. Coevolution means that a complex system coevolves with its environment—that is, there are interdependencies and positive feedbacks between the complex system and its environment (Mitleton-Kelly 2003). In such a coevolutionary process, both competition and cooperation have a role to play.

Emergence can be defined as the arising of novel and coherent structures, patterns, and properties during the process of self-organization in complex systems (Goldstein 1999). Behind the notion of emergence is the basic idea that there may be autonomous properties at a higher (macro) level that cannot be understood by reduction to lower (micro) levels (Sawyer 2005). Here we speak of emergent properties if a group of components has varying properties showing deviant behavior at a higher scale level than the individual components at a lower scale level. De Haan (2006) distinguishes among three different types of emergence: discovery, mechanistic emergence, and reflective emergence. In systems exhibiting the latter type of emergence, the observers are among the objects of the system and have some reflective capacity, which enables them to observe the emergence they produce.

Self-organization is a process in which the internal organization of a complex system increases in complexity without being guided or managed by an outside source. This self-organization refers to the ability to develop a new system structure as a result of the system's internal constitution and not as a result of external management (Prigogine and Stengers 1984). The notion of organization is related to an increase in the structure or order of the system behavior. The new structures are called dissipative because they fall apart unless energy is fed from outside to maintain them (Prigogine and Stengers 1984). Emergence and self-organization are related to each other, but they are different. Self-organizing systems usually display emergence, but not always. Self-organization exists without emergence, and emergence exists without self-organization. But in complex, adaptive systems, emergence and self-organization occur together.

Complex adaptive systems continuously adapt to their changing environment. Any kind of adaptation and all self-organization (see below) involves *variation* and *selection* that is internal to the system but may well be external to components of that system. Complex adaptive systems constantly create variety, in terms of creating new components and relations, which provides a source of novelty in these systems. Selection then maintains the system in a dynamic equilibrium by preventing variation or by pushing it into a certain direction (Green 1994). The selection process means that the system preferentially retains or discards variations that enhance or decrease its fitness (the internalized system's measure for success and failure). Most of the time, complex adaptive systems are in a period of dynamic equilibrium, with ongoing variation and selection but with selection as predominating mechanism. External stimuli can force the system to shift (across the chaotic edge) to a relatively short phase of instability and chaos (punctuated equilibriums), where variation predominates. We can express system variation in terms of *diversity* and *heterogeneity*. Diversity and heterogeneity are key features of complex adaptive systems: diversity of components, of relations, of systems behavior, and so forth.

Complex Systems and Industrial Ecology

Without explicit reference to complex systems theory, industrial ecology (IE) can be considered as a systems approach to societal, predominantly production—consumption, systems (Ayres and Ayres 1996; Ehrenfeld 1997). A modest IE literature explicitly discusses complexity (e.g., Allenby 1999; Kay 2002; Spiegelman 2003). IE, loosely based on the analogy with ecosystems, views industrial systems in terms of material and energy flows and offers a comprehensive perspective, along with concepts and methods, for in-depth analysis. It has drawn attention to the need to minimize energy and material flows and offers models to design ideal—typical "closed-loop systems" (Ehrenfeld and Gertler 1997). In its systemic view, IE tends to be somewhat technocratic in that it fixates on measurable and physical streams and much less or not at all on culture, governance, agency, and power. It certainly offers a fruitful basis for debate about (un)sustainable production (e.g., De Vries and Te Riele 2006), but it does not shed light on the institutional and societal embeddedness of these industrial systems. Although IE thus offers an analytical frame and a future vision, it is much less concerned with the process of change in between and how to organize that (Green and Randles 2006).

The complex adaptive system and transition perspectives would consider production and consumption rather as subsystems of a societal system. Production of agricultural goods is, for example, largely determined by financial and institutional regulatory schemes, whereas production of mobility technologies might be much more embedded in a liberalized, consumer-driven market. In terms of sustainable development, it is clear that sustainable production and industrial ecology are concepts that push an increased eco-efficiency in production (Korhonen 2004). Herein also lies a danger of optimizing the "wrong" systems by not fundamentally questioning the need for certain industrial production or the levels of consumption associated with these systems (Braungart and

McDonough 2002). A complex, adaptive view also needs to include at least the possibility for structural change, along with the influence of outside forces that could evoke such a transition.

Managing Complex, Adaptive Systems

What does complexity, as described above, mean in terms of management? Management—in the context of complexity theory—means influencing the process of change of a complex, adaptive system from one state to another. Greater insight into the dynamics of a complex, adaptive system leads to improved insight into the feasibility of directing it. In other words, application of complexity theory can result in a collection of basic principles or guidelines that can be used to direct complex, adaptive systems. Reflexivity (i.e., reflection on the starting principles defined) is inbuilt with respect to the assumptions presumed as well as the possible effects of such a form of direction. This results in an understanding of the limitations of and scope for the management of complex, adaptive systems and, at the same time, provides insight into the opportunities and conditions under which it is possible to direct such systems. On the basis of theoretical knowledge and practical experience with complexity theory, we present a number of guidelines for management below. These guidelines are partly descriptive, in the sense of basic principles, and partly prescriptive, in terms of rules for management.

- *Management at the system level is important.* Unintended side effects and adverse boomerang effects can only be recognized at the system level. A system-level perspective helps one to get a better insight into spillovers of the complex problem. This implies management at various scale levels: Emergent properties might be hidden at a higher (or lower) scale level but are already beginning to emerge at other scale levels.
- *The status (in terms of its performance) of the system determines the way it is managed.* The dynamics of the system create feasible and nonfeasible means for management: This implies that content and process are inseparable. Insight into how the system works is an essential precondition for effective management.
    - *Objectives should be flexible and adjustable at the system level.* The complexity of the system is at odds with the formulation of fixed objectives. With flexible evolving objectives, one is in a better position to react to changes from inside and outside the system. While being directed, the structure and order of the system are also changing, so the objectives set should change, too.
    - *Managing a complex, adaptive system means using disequilibria rather than equilibriums.* In the long term, equilibrium will lead to stagnation and will, in fact, hinder innovation. Nonequilibrium (the period in between multiple equilibriums) means instability and chaos, which form an important impetus for fundamental change. The relatively short periods of nonequilibrium therefore offer opportunities to direct the system in a desirable direction (toward a new attractor).
- *Creating space for agents to build up alternative regimes is crucial for innovation.* Stimulating emergence and divergence is crucial for innovation. A diversity of emerging niche agents at a certain distance from the regime can effectively create a new regime in a protected environment. For this to happen, a certain degree of protection is needed to permit agents time, energy, and resources.

Managing Societal Systems

The management principles underlying transition management are built around the paradox that societal change is too complex to handle in terms of managing, but still we have formulated a set of relatively simple rules how to influence societal change. The rationale for handling this management paradox is that gaining insight into societal complexity by taking a complex systems approach can help one to fathom the possibilities for influencing societal complexity. This logically connects content and process, which are explicitly linked in transition management: The complexity analysis of a societal system under observation also determines the opportunities for managing such a system (Loorbach 2007, 86). Analytical lenses such as the multistage, multilevel (Rotmans et al. 2001), and multipattern concepts (de Haan and Rotmans 2008) provide us with opportunities for identifying patterns and mechanisms of transitional change. Once we have identified transitional patterns and mechanisms, we can determine process steps and instruments to influence these patterns and mechanisms. Our approach differs from earlier attempts to use a complex systems approach for management of policy issues (e.g., Kickert 1991; Kooiman 1993; Stacey 1996) in that it is more oriented toward reflexive planning—not deterministic but reflexive rules. We have formulated rules for managing societal change, but we realize that once we apply these rules in a process context, they need to be adjusted because the conditions and dynamics (content) will change as a result of the application of these rules. Therefore, learning, searching, and experimenting are crucial in transition management. In that sense, it has similarities with strategic niche management—that is, experimenting with new technologies in an experimental space (Kemp, Schot and Hoogma 1998).

Principles of Transition Management

Here we briefly describe the theoretical principles of transition management that arise from complexity theory. The first principle is that of *creating space for niches* in so-called transition arenas. The notion of arena originates from that part of complexity theory that indicates that a small initial change in the system may have a great impact on the system in the long run. In systems terms, this is called an emergent structure: an environment that offers some protection for a small group of agents. The self-organizing capacity of the system generates new, dissipative structures in the form of niches. A niche is a new structure, a small core of agents, that emerges within the system and that aligns itself with a new configuration. The new alignment is often the emergent property of the system. An emergent structure forms around niches, stimulating the further development of these niches and the emergence of niche regimes.

The *focus on frontrunners* is a key aspect of transition management. In complex system terms, frontrunners are agents with the capacity to generate emergent structures and operate within these deviant structures. They can only do that without being (directly) dependent on the structure, culture, and practices of the regime. In the context of transition management, we mean by frontrunners agents with peculiar competencies and qualities: creative minds, strategists, and visionaries. If a new regime is to be created effectively, agents are needed at a certain distance from that regime.

Another principle of transition management is *guided variation and selection*. This is rooted in the notions of diversity and coherence within complexity theory. Diversity helps avoid rigidity within the system; without it, the system could respond flexibly to changes in its environment. *Coherence* refers to the level of interrelatedness among the entities of a complex system. In the equilibrium phase, there is continuous variation and selection, but when a regime settles, it becomes the dominant selection environment and thus decreases the diversity. But a certain amount of diversity is required for us to explore a variety of innovative options instead of looking for the optimal solution. Rather than selecting innovations in a too early stage, we keep options open to learn about the pros and cons of available alternatives before making a selection. Through experimenting, we can reduce some aspects of the high level of uncertainty, which leads to better informed decisions.

The principle of *radical change in incremental steps* is a paradox that is derived from complexity theory. Radical, structural change is needed to erode the existing deep structure (incumbent regime) of a system and ultimately dismantle it. Immediate radical change, however, would lead to maximal resistance from the deep structure, which cannot adjust to a too fast, radical change. Abrupt forcing of the system would disrupt the system and would create a backlash in the system because of its resilience. Incremental change allows the system to adjust to the new circumstances and to build up new structures that align to the new configuration. Radical change in incremental steps implies that the system heads in a new direction toward new attractors, but in small steps.

Empowering niches is an important principle of transition management. By *empowering*, we mean providing with resources, such as knowledge, finances, competences, lobby mechanisms, exemptions of rules and laws, and space for experimenting (Avelino 2007). An empowered niche may cluster with other empowered niches and emerge into a niche regime. Multiple regimes coevolve with each other—a dominant regime and one or more niche regimes. Crucial is the coevolution of a regime within the existing power structure and a niche regime outside the power realm. Coevolving regimes influence each other in an irreversible manner, with an unknown outcome. The niche regime may take over the incumbent regime but may also be absorbed and encapsulated by the incumbent regime.

Anticipation of future trends and developments, with account taken of weak signals and seeds of change that act as the harbingers of the future, is a key element of a proactive, long-term strategy of transition management. This future orientation is accompanied by a strategy of *adaptation*, which means adjusting while the structure of the system is changing. This requires adequate insight into the dynamics of a complex system. Although in general complex system dynamics are highly nonlinear and unpredictable, there are periods when the system behaves in a relatively orderly manner and, to a limited extent, is predictable. But there are also periods in which chaos rules and the behavior of the system is quite unpredictable. So although the degree of predictability is rather small, transitions do imply generic patterns that indicate the future pathway. Path dependency is an example of such a pattern.

A transition is the result of a coevolution of economic, cultural, technological, ecological, and institutional developments at different scale levels. So transitions, by definition, cross *multiple domains and scales* (Rotmans et al. 2001). Complex systems also involve multiple domains and scales. They are nested and encompass various organization levels, where higher level structures arise from interaction between lower level components. The transition literature often makes clear that there is a macro level at which novel emergent structures arise from the interactions between components at the micro level. Every transition domain has its own dynamics: Cultures only change slowly, but economic changes take place in the short term, whereas institutional and technological changes are somewhere in between. The various domains shift over each other and constantly influence each other through interactions and feedbacks. The resulting dynamics are a hybrid picture of alternating fast and slow change. Analyzing the interactions and feedbacks across levels and domains is of importance for identifying patterns and mechanisms of transitional change and for determining instruments to influence these patterns and mechanisms.

Through experimental implementation of the complex adaptive systems approach to transitions in societal systems, we have translated the theoretical principles underlying transition management into so-called systemic instruments. Table 1 summarizes the main insights from complexity theory and their translation into theoretical principles of transition management as well as these system instruments. The next section describes a framework for doing transition management in practice, using theoretical principles of complex systems theory.

Transition Management: The Framework

The challenge with transition management is to translate the above, relatively abstract management rules into a practical management framework without losing too much of the complexity involved and without becoming too prescriptive. We have attempted this by delineating transition management as a cyclical process of development phases at various scale levels. In complex system terms, transition management can be described as consisting of the following steps (Loorbach 2007; Loorbach and Rotmans 2006):

1. Stimulate niche development (emergence, variation) at the micro level and try to interconnect niches with the same direction. In the transition management framework, one does this by establishing and organizing a transition arena, a quasi-protected

Table 1 Linking of complexity characteristics, theoretical principles of transition management, and systemic instruments for transition management

Complexity characteristics	*Theoretical principles of transition management*	*Systemic instruments for transition management*
Emergence	Creating space for niches	Transition arena
Dissipative structures	Focus on frontrunners	Transition arena and competence analysis
Diversity and coherence	Guided variation and selection	Transition experiments and transition pathways
New attractors, punctuated equilibriums	Radical change in incremental steps	Envisioning for sustainable futures
Coevolution	Empowering niches	Competence development
Variation and selection	Learning by doing and doing by learning	Deepening, broadening, scaling up experiments
Interactions, feedbacks	Multilevel approach, multidomain approach	Complex systems analysis
Patterns, mechanisms	Anticipation and adaptation	Multipattern and multilevel analysis

area for frontrunners (niche players and change-inclined regime players).

2. Try to find new attractors for the system by developing a sustainability vision and derived pathways at the macro level that can act as guidance for niche development.
3. Try to stimulate the formation of niche regimes by creating coalitions and new networks around the transition agenda and the different pathways.
4. Create diversity by setting out transition experiments that are related to specific pathways onto the vision.
5. Select the most promising ones that can be scaled up to a higher level as you learn from these experiments and develop an upscaling strategy.
6. Try to further modulation between the micro and macro levels (coevolution) by adjusting the vision, agenda, and coalitions, if necessary, by monitoring and evaluating (analyzing patterns and mechanisms) the transition management process, after which the cycle starts again.

For the sake of simplicity, we present the cycle of transition management as a sequence of steps, as presented in figure1. In practice, however, there is no fixed sequence of steps in transition management, and the steps can differ in importance in each cycle. In the real world, the transition management activities are carried out partially and completely in sequence, in parallel, and in a random sequence.

In effect, transition management comes down to creating space for frontrunners (niche players and change-inclined regime players in transition arenas), forming new coalitions around these arenas, driving the activities in a shared and desired direction, and developing coalitions and networks into a movement that puts societal pressure on regular policy. In the transition management framework, activities related to the content (integrated systems analysis, envisioning, agenda building, and experiments) are linked to activities related to the process (network and coalition building, execution of experiments, and process structuring). The preferred actors to be involved (based on the necessary competencies) and instruments (e.g., scenarios, transition agendas, monitoring instruments) are derived from this framework. The four activity clusters depicted in figure1 are described in more detail below.

Integrated Systems Analysis and Actor Selection

An integrated systems analysis forms the basis of every transition management process, providing a common ground for a variety of actors and

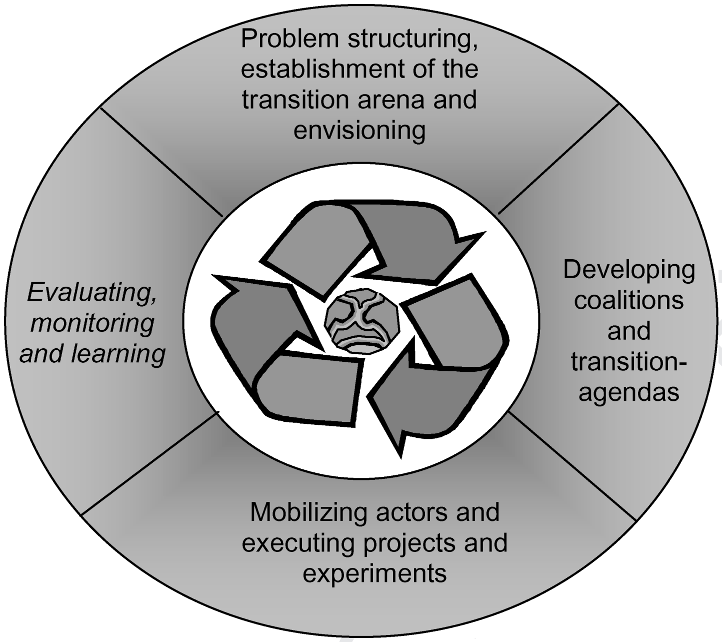

Figure 1 The transition management cycle.
Source: Loorbach (2007)

enough information for informed debates and discussions. Informed insight into the complexity of the system, its major defining subsystems, the dominant causal relations, feedback loops, the roots, and the nature of structural problems establish a baseline as well as conditions for discussing visions, strategies, and actions in the future. In addition, such a preliminary assessment yields knowledge about the main actors influencing the system in both a conservative and an innovative way and helps to guide the selection of participants for the transition arena. Such a selection is of vital importance. Participants need to have some basic competencies at their disposal: They need to be visionaries and frontrunners, and they must have the ability to look beyond their own domain or working area and be open-minded.

Problem Structuring and Envisioning: Establishment of a Transition Arena

The transition arena is best viewed as a virtual network, which is a legitimate experimental space in which the actors involved use social learning processes to acquire new knowledge and understanding that leads to a new perspective on a transition issue. Such a transition arena has to be supported by political actors or regime powers but not dictated by them—for example, through the support of a minister or a director. In general, around 15 to 20 frontrunners (i.e., pioneering individuals) are involved in the beginning of the transition arena, although, over time, only around 5 will become the core group.

Within the transition arena, multiple in-depth discussions take place, structured according to the system approach. Facilitators synthesize discussions and work toward convergence of perspectives, assumptions, and ambitions. The transition arena develops a shared understanding of the persistence of a problem at the level of a societal system, the necessity of a transition or radical change, and the definition of the challenge this poses. Key outcomes are a new, shared perspective; language to discuss the transition; and the definition of a set of guiding principles for the envisaged transition. This relates to the earlier mentioned notion of emergence (De Haan 2006): The awareness of and insight into the complexity of their environment helps individuals to better Q7 understand the complexity and realize that they can, on a small scale, exert influence.

Development of Sustainability Images, Pathways, and a Transition Agenda

Transition images are the "translation" of the generic guiding principles or "sustainability criteria" to specific concrete settings, subsectors, or themes. These images must be appealing and imaginative so as to be supported by a broad range of actors and inspire and guide short-term action. Inspiring images are useful for mobilizing social actors and represent a consensus among different actors on what sustainability means for a specific transition theme, which could evolve over time as new insights emerge. Transition images embrace multiple transition pathways to represent a variety of possible options. They include transition goals, which are qualitative rather than quantitative and are multidimensional, representing the three dimensions of sustainability: economic, ecological, and sociocultural.

Various transition pathways lead to a particular transition image (i.e., a sustainability vision comprises various transition images), and from various transition images a particular transition pathway may be derived. The transition images can be adjusted as a result of what has been learned by the players in transition experiments. The transition process is thus a goal-seeking process, in which the transition visions and images, as well as the underlying goals, change over time. During the course of the transition process, the actors will choose the visions and images that appear to them as the most innovative, promising, and feasible. The transition agenda contains content objectives, process objectives, and learning objectives. Although the transition visions, images, and objectives form the guidelines for the transition agenda, the transition agenda itself is the compass for the frontrunners, which they can refer to during their search and learning process.

Initiation and Execution of Transition Experiments and Mobilization of Actors

From the transition vision, images, and pathways, transition experiments can be derived that are either related to or combined with existing activities. Transition experiments are high-risk experiments with a social learning objective that are supposed to contribute to the sustainability goals at the systems level and should fit within the transition pathways. It is important to formulate sound criteria for the selection of experiments and to make the experiments mutually coherent. The crucial point is to measure to what extent the experiments and projects contribute to the overall system sustainability goals and to measure in what way a particular experiment reinforces another experiment. Are there specific niches for experiments that can be identified? What is the attitude of the current regime toward these niche experiments? The aim is to create a portfolio of transition experiments that reinforce each other and contribute to the sustainability objectives in significant and measurable ways. Around and between these experiments, all sorts of actors can be involved that will not engage regularly in debates about long-term issues: small businesses, consumers, citizens, local groups, and so on. Here, as well, the emphasis is on involving frontrunners.

Monitoring and Evaluating the Transition Process

Continuous monitoring is a vital part of the search and learning process of transitions. We distinguish between monitoring the transition process itself and monitoring transition management. Monitoring the transition process involves attending to physical changes in the system in question, slowly changing macro-developments, fast niche developments, seeds of change, and movements of individual and collective actors at the regime level. Monitoring of transition management involves different aspects. First, the actors within the transition arena must be monitored with regard to their behavior, networking activities, alliance forming, and responsibilities and also with regard to their activities, projects, and instruments. Next, the transition agenda must be monitored with regard to the actions, goals, projects, and instruments that have been agreed on. Transition experiments need to be monitored with regard to specific new knowledge and insight and how these are transferred but also with regard to the aspects of social and institutional learning. Finally, the transition process itself must be monitored with regard to the rate of progress, the barriers, and the points to be improved, for example. Evaluating these monitoring aspects within each phase may stimulate a process of social learning that arises from the interaction and cooperation between different actors involved.

In each of the above activity clusters, coalition and network formation are of vital importance, combined with the systemic structuring and synthesizing of discussions. The transition arena is meant to stimulate the formation of new coalitions, partnerships, and networks that together create a new way of thinking. Mostly, coalitions emerge around transition pathways or experiments or around specific subthemes, where subarenas arise. The very idea behind transition management is to create a societal movement through new coalitions, partnerships, and networks around arenas that allow for building up continuous pressure on the political and market arena to safeguard the long-term orientation and goals of the transition process.

Conclusions

In this article, we have presented a transition management framework for addressing persistent societal problems that is grounded in complex systems theory. Variation and selection, emergence, coevolution, attractors, diversity and coherence, and interactions and feedbacks are key elements of transition management. The underlying premise is that a better understanding of the dynamics of complex, adaptive systems provides insight into the opportunities, limitations, and conditions under which it is possible to influence such systems. This implies a strong linkage of content and process: The combination of analytic insights into systems complexity and understanding of the process of governance complexity is new and has resulted in a set of management principles that forms the basis for the management framework. The management principles are reflexive rather than deterministic, reflecting a belief in directing transitions to a limited degree by furthering transition processes toward sustainability. Q8 Applying these principles implies adjusting them to the new conditions and dynamics, which will change when these principles are applied. On the basis of this approach, the management framework itself has been the result of experiences within testing grounds and has evolved in the past several years. The concept of transition management and the derived framework is promising but still needs to largely prove itself empirically. It is a great challenge to empirically validate the partly descriptive and partly prescriptive parts of transition management in such a manner that the framework can be further developed and used in a broad international societal context. One of its potential contributions lies in application to nonenvironmental domains, such as health care and city restructuring. In this sense, transition management can be considered as an extension of and a step beyond industrial ecology into broad societal (socioeconomic) systems.

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