INTERMEZZO

BEHAVIOUR OF SYSTEMS

Knowledge on the behaviour of societal systems helps us better understand transitions. Support in this context is provided by models describing how systems behave and how they react to transition impulses. These insights help policy to develop a coordinated mix of systemic solutions.

Systems in equilibrium and transition impulses

Societies worldwide are going through rapid and dramatic changes. These changes are caused by global developments - megatrends - and burgeoning innovations ('niches') that challenge the existing situation ('pressure'). There are, however, also internal tensions in the dominant and stable configuration of the societal systems ('regimes').

Thus, the effects of the accumulation of greenhouse gases in our atmosphere are becoming increasingly apparent on a global scale. New technologies based on non-fossil, renewable energy sources are emerging. They lay the foundations for the change of various societal systems, including energy and mobility. However, also the internal tension in existing systems is becoming ever more apparent. The low cost of our fossil fuel-based mobility system leads, for example, to traffic jams and adverse health effects. In short, what we have here is a 'transition impulse', which drives to leave the existing situation.

Every societal system - and therefore also energy, mobility and food - is made up of human actors, institutions and infrastructures that interact with each other and with the environment. When a system is in equilibrium, numerous internal processes are active to preserve this equilibrium. Internal and external triggers will initially not lead to change: the system is robust enough to resist them. Because of vested interests, investments made and economies of scale, the existing stable state is maintained for as long as possible ('inertia'). However, when triggers persist and become stronger, a tipping point can be reached. Minor changes or disturbances can then lead to unexpectedly large and rapid system changes. The system will then leave its stable state and reconfigure itself relatively quickly (over a few decades) until a new equilibrium is reached. The impulse thus leads to a transition.

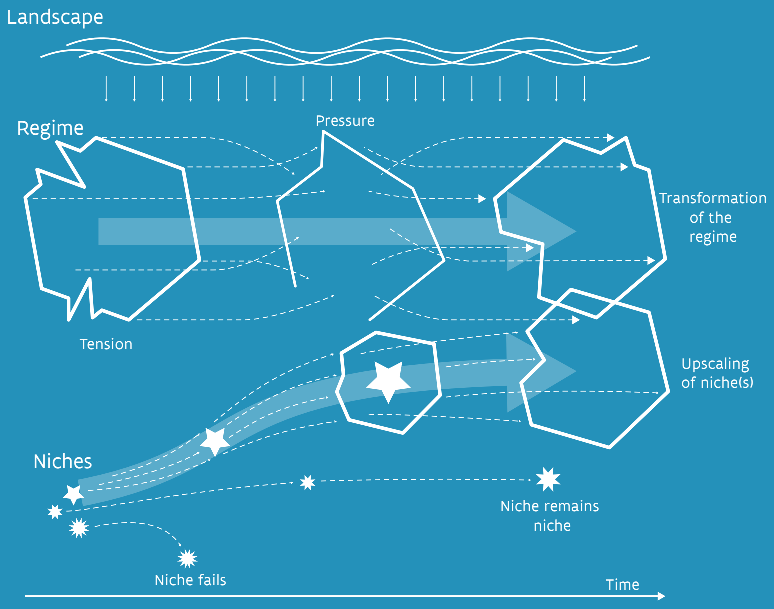
Transition as a result of interactions between regime, niches and landscape

The study of the complexity of systems has developed mainly since the second half of the twentieth century. New insights into the natural sciences on chaotic behaviour and self-organising systems played an important role in this development. Thus, it appears that not only entire ecosystems, but even certain single-celled organisms can, under certain conditions, organise themselves into a system (the organism) based on relatively simple interactions between individual cells. This enables the system to smoothly adapt to changing conditions and even shocks. This complex adaptive behaviour has been identified in many biological and social systems, from termite colonies to financial markets. Based on these insights, systems thinking seeks to understand how societal systems behave when they are exposed to a strong transition impulse, as is the case today.

MULTILEVEL PERSPECTIVE

Research into complex systems and their transitions generally considers change as a co-evolutionary, multilevel process. Dominant regimes within societal systems experience not only internal tension, but also external pressure from the 'landscape'. These can be developments within their own society or impacts from global megatrends. In addition, new niches emerge that challenge the status quo within a societal system, thereby adding further pressure. The complex, multilevel dynamics resulting from this interaction is visually represented in a multilevel perspective.

MULTILEVEL PERSPECTIVE ON TRANSITION



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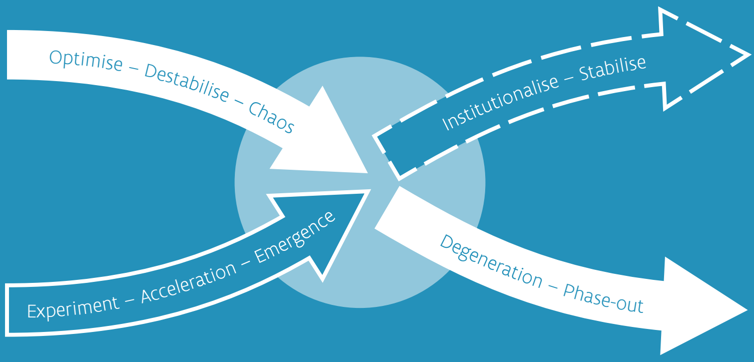
From this perspective, it becomes clear how existing regimes transform themselves under the influence of internal tension and external pressure. At the same time, certain niches gradually develop into new co-regimes. Other niches remain more marginal, or fail and disappear again. Transition is a multi-domain process whereby technological innovation interacts with societal, cultural and institutional changes. Four phases are generally distinguished: an emergence phase; a take-off phase in which the niche innovations begin to destabilise the regime; an acceleration phase with a tipping point for sudden reconfiguration, and finally, the stabilisation of the newly established regimes.

EMERGENCE AND (PARTIAL) DEGENERATION

In recent years, in addition to the attention given to the development of niches, there has also been growing interest in the processes of degeneration within existing regimes during the transition. The combination of both is represented by means a double S-curve (or X-curve).

DOUBLE S-CURVE (X-CURVE)



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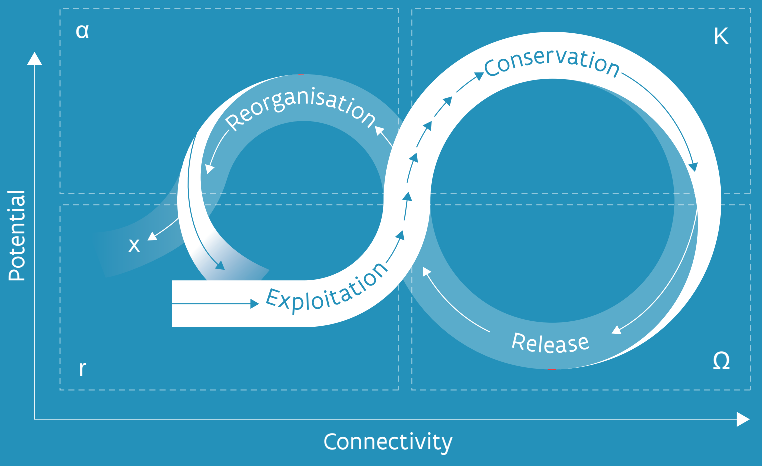
The ascending curve represents the development of new niches to regimes. After a period of experimentation, new emerging niches go through a phase of acceleration and emergence. When they have sufficient potential to offer answers to societal needs, they eventually become institutionalised and stabilised into new (niche) regimes. The descending S represents the degeneration of (parts of) the existing regime. If optimisation no longer allows the regime to withstand the external pressure and internal tensions, a phase of destabilisation sets in. If this pushes the regime into a far-from-equilibrium state, it may end up in a critical state. This state is situated at the boundary of chaos, where minimal disturbances can give rise to major changes ('tipping'). In some cases, this can lead to degeneration and phase-out; a recent example being the rapidly falling sales of diesel cars following the emissions scandals in the automotive sector and the increased attention for the health effects of particulate matter. This has led to a rapid shift away from diesel cars, which could suggest a possible degeneration and eventually a phase-out of diesel passenger cars.

Degeneration of the existing regime does not always take place in societal transitions. In most cases, it is a reconfiguration of the regime or the prevention of niches that temporarily develop into co-regimes. 'Co-evolution' is a term that more aptly describes the complex change in regimes and niches within a system in transition. It obviously depends on the societal system under consideration and its transition dynamics.

PANARCHY

The concept of panarchy refers to the structure of systems as a constellation of interacting adaptive cycles on different scales. According to this vision, the life cycle of a system consists of four successive phases: rapid growth (r), consolidation (K), release (Ω), and renewal , **α**. This is visually represented by a lemniscate or lazy eight.

THE 'LAZY EIGHT'



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The horizontal axis of the figure represents the connectivity between the components and actors in the system. Low connectivity means that elements are loosely connected, i.e. more flexible and more sensitive to external impulses. The vertical axis refers to the resources that are stored within the system and that help determine the system's change potential. These may be raw materials and energy, but also knowledge, financial resources and human capital.

In the 'rapid growth' phase of the cycle, elements from the system have the possibility to take in disturbed parts of the system. In the consolidation or K phase, additional energy and material is stored in the system. The interconnectedness of the system's elements increases and new elements find it harder to find their place in the system. The growth rate gradually slows down and the system becomes rigid. It thus becomes more stable, but only within a narrower spectrum of external variation. The system becomes increasingly less resilient to external, high-impact shocks. Sooner or later, a powerful disturbance will exceed the system's resilience, thereby disrupting connections and releasing energy and matter (Ω phase). A period of uncertainty and renewal then sets in (α phase). New or smaller elements in the system find their place and are tested.

In the 'lazy eight', two loops are therefore distinguished. The front loop comprises the process of growth and stability, the rear loop that of 'creative destruction' and reconfiguration. This model suggests a rather sequential process whereby a rigid system is broken down before anything new can grow.

Adaptive cycles can manifest themselves on different scales and also influence each other from these different scales. Each scale of the hierarchy follows its own adaptive cycle that interacts with the scales below and above it. These interwoven cycles are called a panarchy. The functioning of these cycles and their interaction determine the viability of a system.

This theory provides interesting insights, such as the existence of traps that indicate undesirable system equilibriums. In a 'poverty trap', for example, a system remains in a state of low interconnectedness and low resilience for a long time. Available resources, if present at all, cannot be mobilised for change. The 'poverty trap' concept has helped to better understand persistent poverty in complex and socio-ecological systems. A 'rigidity trap' occurs when a system is in a stable state of high interconnectedness and many stored resources and energy. External shocks can abruptly disturb this equilibrium. In socio-technical systems, rigidity traps are often connected with a deeply embedded and expensive infrastructure, examples being the natural gas or electricity grid and our comprehensive road infrastructure.

MODELS AND THE ACTUAL COMPLEXITY OF TRANSITIONS

Each of these models and visualisations of transitions provides a highly simplified schematic view of a highly complex, dynamic set of interactions. Transitions follow pathways that can be comprehensibly represented with these models, but which in reality are much more layered and chaotic than can be depicted with the models. Each of these models nevertheless provides us with useful insights that help us in our search for environmental solutions from a systemic approach. In this search, it is important to identify which models are best suited for understanding the system and the transition and taking policy-based action.

Surprising and undesirable behaviour of systems

Models can help us gain a better insight into complex systems. We would, however, be wrong to assume that we can simply control the dynamics of complex systems. Our capacity to understand complex systems is limited anyway. Moreover, our cognitive apparatus is limited by all kinds of biases that can lead us to suboptimal choices. In decision processes, this is referred to as bounded rationality, a consequence of the combination of complexity, cognitive limitations and scarcity of time and resources.

Complex systems should therefore preferably be organised, so that they are able to autonomously deal with incentives for change. Systems must be able to adapt to changing conditions and, at the same time, minimise the risk of having to face sudden and fatal changes. In other words, they must be able to learn efficiently. If systems do not learn, they will eventually facilitate undesirable system dynamics or system failures. These are summarised and designated as 'system archetypes'.

Unwanted system behaviour can take various forms. Some of the most relevant ones are briefly discussed below.

- Lock-in keeps the system running at an undesirable level of performance. Stability is maintained by various feedback mechanisms. Important investments committed to infrastructure are a form of lock-in, but so is the entire policy that is founded on existing and dominant regimes and, as such, are not adapted to new niches.
- 'Erosion of goals' is a variant on lock-in that gradually pushes the system to lower levels of performance. Due to a negative perception of previous results, the objectives are adjusted downwards. A reinforcing feedback loop is created whereby deviation from the desired level of performance leads to a downward adjustment of that level. Thus, the performance of a public transport system can continue to decline over a longer period of time. Operators and users will eventually adjust their expectations.
- The so-called tragedy of the commons manifests itself when users of an exhaustible, shared resource can benefit from its usefulness much sooner than they experience the disadvantages of over-exploitation. This eventually leads to exhaustion and therefore to a drastic decline in its usefulness for all users. Congestion problems in the mobility system are a typical example: each user optimises their own use of the available road capacity, but the cumulative effect leads to long delays caused by congestion.
- 'Pursuing wrong goals': a system can incline towards an undesirable level of performance if the indicators provide incomplete control information or are not properly conceived. It can thus be argued that our environment is increasingly under pressure because the success of a society is measured in terms of economic parameters such as growth and GDP.

Systems can also exhibit behaviour that is not necessarily undesirable but still surprising, such as:

- 'Presence of limiting factors': each system inevitably clashes with limits or constraints in terms of resources or flows. Often, however, it is not exactly clear where these limits are situated and how they affect the dynamics of the system. This can lead to surprises. An example regards the various oil peak predictions, i.e. the point at which oil production will decline.
- 'Delays': system effects may take quite some time to manifest themselves. This dynamic may conflict with the expectations of actors that have to deal with it and can also lead to belated reaction. Climate change is a process that manifests itself as a result of greenhouse gas emissions, but only over a longer period of time. As a result of this delay, humanity will have to take into account the possible consequences of an overshoot of emissions.

Surprising and undesirable properties are not characteristics of actual systems, but of the way in which people interact with those systems. They are based on our bounded rationality. People inevitably act from a limited perspective and on incomplete information. It is a system structure and behaviour that remains hidden to human actors and therefore can lead to dysfunctions. Thinking in terms of system archetypes helps us interpret unexpected and undesirable transition dynamics.

From insight in system behaviour to action perspectives

Research into the transition to more sustainable societal systems has significantly gained in importance over the past decades. It investigates how large-scale changes in societal systems can be initiated and controlled, the aim being to facilitate the finding of solutions to urgent challenges in the field of sustainability. This involves not only technological innovations, but also shifts in power relations, culture and world views, behavioural practices and social structures. Transition research seeks not only to better understand, but also to assist actors (including the government) in practice in order to reverse the current situation and initiate structural, sustainable change. It offers perspectives for action to initiate, orient and accelerate the desired transition.

However, our capacity to understand complex systems appears to be limited. Systems research teaches us that, rather than trying to control complex systems in detail, we should design and configure them so that they are capable of dealing themselves with triggers for change. It is important that societal systems are able to learn efficiently, so that they can adapt to changing and unforeseen circumstances. This will minimise the risk of them having to confront sudden, disastrous changes. Studying the behaviour of systems therefore does not produce a ready-made blueprint for very specific, targeted interventions. Instead, it offers a reflective framework to identify the pillars that are of special interest in the transition process from a system reconfiguration perspective.