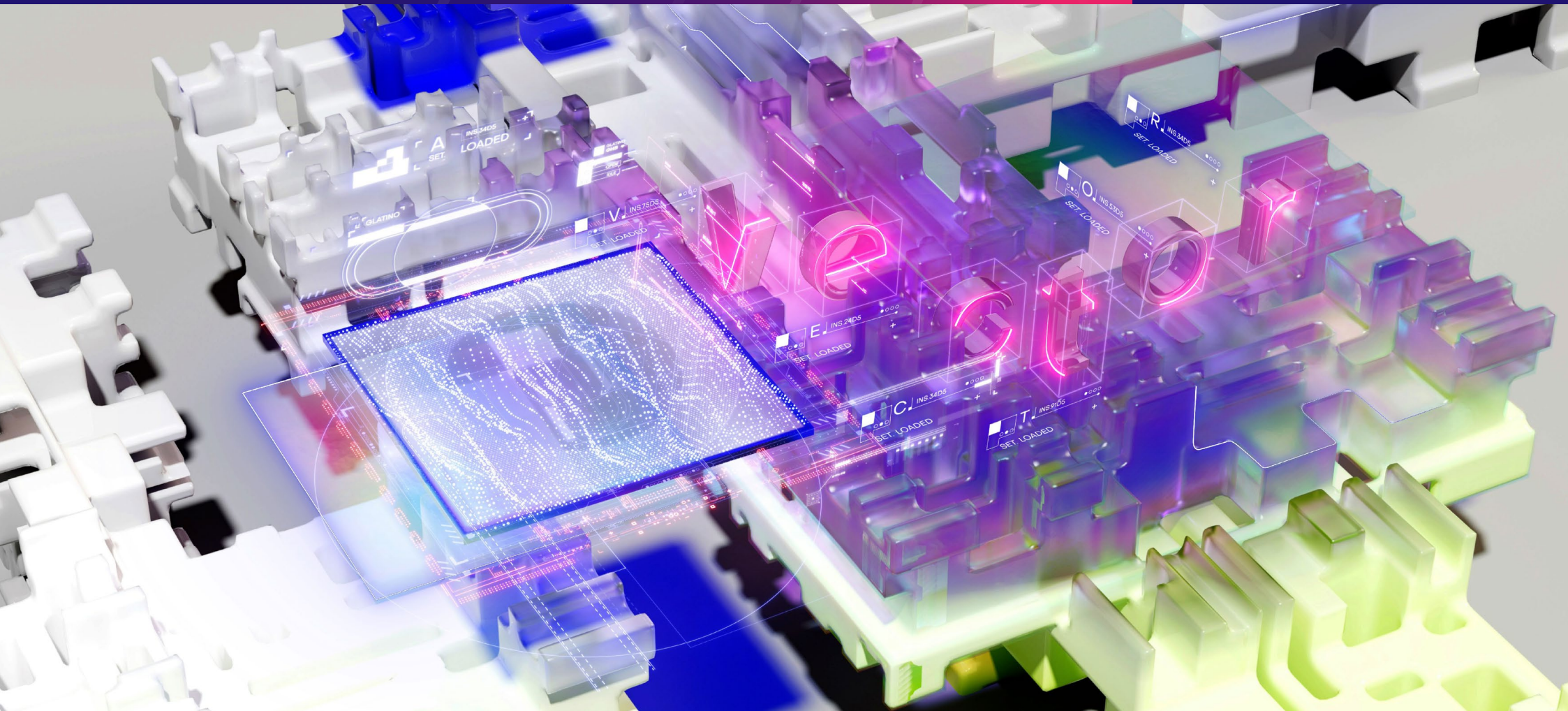
Paper

The power of collaborative systems: building a resilient and adaptive society

TNO Vector
Centre for Societal Innovation and Strategy



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1. Introduction: systems and collaboration

Systems are the backbone of modern societies. Think, for example, of smart cities, where physical infrastructures, digital technologies, and citizens come together to create a more sustainable and prosperous environment. Or, consider the healthcare system, in which medical technologies, lifestyle improvements and patients must work in tandem to enable healthy ageing.

The success of such systems largely depends on the degree of alignment between the various elements within these systems, as well as how different systems relate to one another. Increasingly, systems, such as those for water, energy, and mobility, are interconnected and highly interdependent. This makes them vulnerable, but also offers opportunities.

However, successfully collaborating systems remain rare. We are all familiar with the example of streets being repeatedly opened up — first for sewer works, then for fibre optic internet, and finally for tram tracks. But also, the poor implementation of digital technologies across industrial chains, which hampers labour productivity and reduces competitiveness, as was highlighted in the recently published Draghi report and thereof the translation to the Dutch context (Draghi et al., 2024; TNO, 2025).

These examples raise questions about how collaboration within and especially between systems can be organised to tackle complex societal challenges. This paper explores the power of collaborative systems as input for the TNO Vector symposium taking place on June 12 2025. We examine what collaborative systems are and why they are essential, but also which tensions can arise from collaboration within and between systems, and how these might be addressed. We suggest that focusing on the *interconnectedness* of systems is a crucial guiding principle.

The aim of this paper is to highlight the challenges and provide initial insights for identifying the factors that enable successful collaboration within and between systems. In doing so, we offer practical guidance for both the analysis and design of collaborative systems that work.

This paper also serves as an introduction to a series of related papers, covering social and physical systems, digital technologies, and digitalisation. The first paper by Vonk Noordegraaf et al. focuses on social systems and their importance for a healthy, inclusive, and resilient society. The second paper, by Elsman et al., addresses physical infrastructure, vital for urban functioning. The third paper by Mohn and Barbereau discusses how digital technologies can be used to build resilient systems. The fourth and final paper, by Yagafarova et al., explores how digitalisation in the manufacturing industry can contribute to competitiveness.

2. Why collaborative systems are essential

What are collaborative systems?
A *system* can be described as a coherent set of elements that is organised in such a way that it achieves a specific goal—for example, addressing a specific complex societal issue (Meadows, 2008; see also Lazo et al., 2023).

These elements come in various shapes and sizes (see Figure 1). For instance, there are physical infrastructures for mobility, energy, waste, and water, which serve as a shared foundation, particularly in urban areas. In addition, there are IT systems, which function as the – largely invisible – backbone of our society and which are increasingly dominated by a limited number of (foreign) companies. Finally, there are social structures, which form the fabric of societies because they are based on trust, reciprocity, and shared norms.

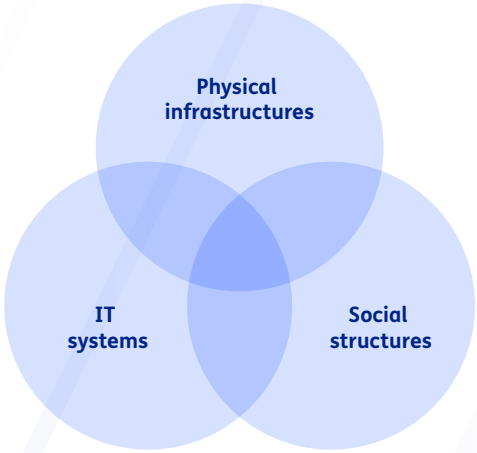
We are particularly interested in a combination of these elements in so-called *socio-technical* systems. These are systems composed of both people and technology, in which these elements interact with one another, and the boundaries of which are often blurred (see e.g. Emery & Trist, 1960; Geels, 2004; Borrás & Edler, 2020).

Many of these systems are *complex* socio-technical systems (see e.g. Righi & Saurin, 2015). Their complexity emerges from, among other things, the multitude of different elements (various technologies, but also different actors), dynamic interactions between those elements, openness to external influences, instability and unpredictability (and the emergent nature of systems as a result), as well as path dependency (i.e. choices made in the past that affect the options available in the present; see e.g. Pierson, 2000; Page, 2006), and the limited overview that actors have of the entire system.

An example of a complex socio-technical system is the financial system. It is highly dependent on digital technology, but also on a wide range of diverse parties. The interaction between that technology and those parties can, as we witnessed during the global financial crisis (2008–2011), have unpredictable consequences and destabilise the system—also because none of the parties have a complete overview of the system. The same applies, for example, to the energy system (see e.g. Van der Steen et al., 2024).

The interconnectedness between systems is crucial to deal with the challenges we face as a society: climate change, digitalisation, an ageing population, geopolitical tensions, and social inequality, to name a few. Because these challenges transcend individual systems, alignment between separate systems is crucial. For example, climate adaptation requires coordination between water management, mobility, sustainability, and urban development. Digital resilience demands the involvement of and interaction between countries, companies, and citizens across system boundaries.

Figure 1: Different elements of systems



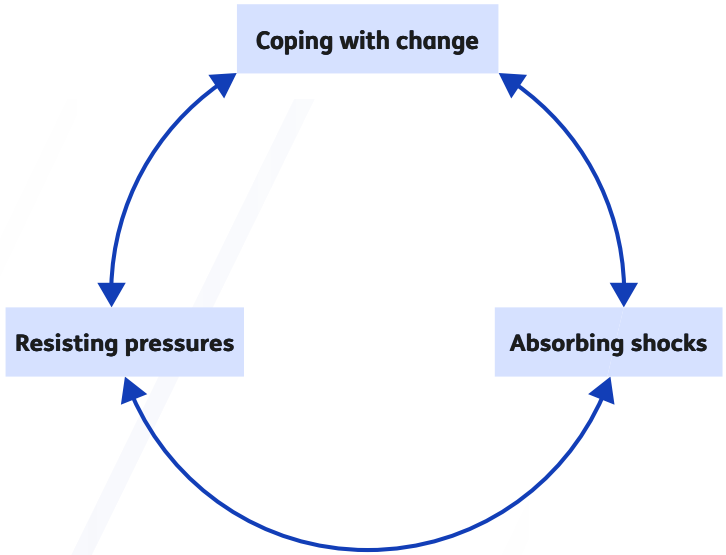
The benefits of collaborative systems

In what we refer to as collaborative systems, the resources and capabilities of individual systems are effectively bundled to create a new overarching system — a 'system of systems', as systems engineers would call it. This overarching system is better equipped to tackle complex societal challenges than the sum of its constituent systems (e.g. DeLaurentis & Callaway, 2004). The bundling goes beyond mere coordination; it involves integration — not only of technical systems such as those for mobility, electricity or IT, but also of organisational structures, legal frameworks, and underlying norms and routines.

Successful collaborative systems offer significant benefits (see Figure 2), to begin with in terms of *resilience*. Collaboration within and between systems can help society to become better able to absorb shocks and return to a desired level of functioning (e.g. Duit et al., 2010). Collaboration can also improve society's ability to resist pressures that threaten the functioning of systems. By exchanging functions, systems can continue to perform at a minimum level.

Moreover, collaboration within and between systems can contribute to the *adaptability* of society. Besides the efficient and effective functioning of individual systems, the inherent uncertainty in system integration demands flexibility, experimentation, and learning — all necessary to cope with change (e.g. Duit & Galaz, 2008; Lazo & Tjokrodikromo, 2022).

Figure 2: Benefits of collaborative systems



3. Which tensions are created by collaboration within and between systems

A fragmented approach

The need for coordination and integration does not automatically mean that systems are actually approached in a integrated matter. On the contrary, efforts toward sectoral optimisation often result in a fragmented approach. Complex problems are broken down into parts, with responsibility for solving them assigned to separate organisations. These organisations then apply familiar interventions within their own vertical silos or horizontal chains (e.g. Crosby et al., 2017).

The consequences of such fragmentation are becoming increasingly evident. Within systems, problems arise when social and technical elements are not well aligned, leading to ineffectiveness and injustice. Problems also occur when tasks and responsibilities are poorly distributed across a chain, resulting in confusion or conflict between actors. A lack of cooperation between different elements of a system can ultimately lead to system failure.

Even when collaboration *within* systems is well organised, this does not guarantee that connections *between* systems function properly. Sometimes there is no collaboration at all; in other cases, friction arises. Precisely at the interfaces between systems — and the various transitions that (must) occur simultaneously within those systems — the need for systems governance manifests itself.

Challenges of collaboration

To be sure, collaboration within and between systems does not automatically lead to better solutions for societal problems. While the "collaborative advantage" is often clear on paper (Huxham & Vangen, 2005), successful collaboration in practice is notoriously difficult to organise (e.g. Bryson et al., 2015; Waardenburg et al., 2020).

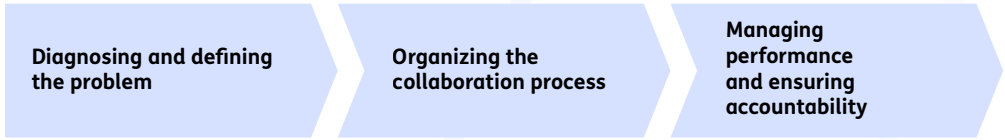
It starts with creating a shared definition of the problem at hand. For example, climate adaptation is viewed differently from the perspective of water management than from the perspective of mobility. On top of that, organisations in different systems not only have divergent perspectives and interests, but also often speak entirely different languages.

A next hurdle is organising the collaboration process itself. This is partly a strategic issue: how do you get different organisations in the same room, for example in the preparation of a regional investment agenda, and who takes responsibility for implementation? To support organisations in working across domains and breaking through silos, TNO developed the UNLOCK method, which centres on systems thinking and transdisciplinary collaboration.[1]

But organising the collaboration process is also a very practical matter: how do you ensure interoperability? There is a great need for seamlessly connected technologies and infrastructures is great. Linking systems and connecting them through digitalisation is anything but straightforward. Existing and new systems are not often interoperable and must be adapted, which takes time and costs money. Standardisation can offer solutions, but often comes at the expense of systemic flexibility.

Finally, there are challenges around managing collective performance and shared accountability. A recurring issue in collaborative systems is that costs and benefits are usually unevenly distributed: the costs of collaboration are incurred in one place, while the benefits are realised elsewhere. As a result, key parties for problem-solving lack a clear incentive to invest, which hampers collaboration. TNO's work on collaborative business models focuses, among other things, on overcoming this mismatch.[2]

Figure 3: Challenges of collaboration within and between systems



1 See Unlock System Transitions | TNO
2 See Collaboratieve Business Modellen voor Transitie | TNO

Complicated and sometimes even undesirable

Because cooperation within and between systems is so complicated, and often leads to new problems, the first question that should always be asked is to what extent an integral approach is really necessary. For security problems, such as organized crime, integral cooperation is regularly initiated immediately, without first reflecting on the need for it. Sometimes a light form of coordination or exchange of information (to understand influences on one's own subsystem, for example) is already sufficient.

Apart from the complexity involved in cooperation, it is also good to remain critical of terms such as 'system' and 'integration'. A systemic approach and integrality have almost become a holy grail in the Dutch administrative landscape (Frissen, 2023). The pursuit of cross-system cohesion, however well intentioned, may sometimes be at odds with the diversity of society and the corresponding need for specialization and differentiation.

Indeed, a certain amount of fragmentation and redundancy within and between systems may be useful at all (Groenleer, 2016). Instead, the risk of failure in complex systems can be increased by too tightly coupling the various elements of those systems (Perrow, 2011), as we have witnessed during the COVID-19 pandemic. Therefore, in a pluralistic society and uncertain world, the costs of fragmentation, duplication and overlap must be weighed against their benefits in the form of, for example, higher levels of reliability, innovation and learning, and responsiveness.

4. From fragmentation to systems power

In most cases — without assuming full control or striving for perfection — it is desirable to harness the power of collaborative systems. But how can this be done? We focus on three interrelated mechanisms for achieving systems strength: analysis, collaboration, and leadership (see Figure 4).

These mechanisms are also discussed in the other papers mentioned earlier — sometimes tailored to the specific systems studied; in other cases they are presented in a more generally applicable manner.

From understanding systems through analysis...

To build successful collaborative systems, the first step is to better understand the interactions within and between systems. By critically analysing systems, insight can be gained into these interactions. For this, various methods can be used, such as the Vital Systems Method developed by TNO for urban contexts.

With the help of the Vital Systems Method, it becomes possible to visualise how systems are interconnected, which systemic dependencies exist, and where vulnerabilities lie. It also helps identify opportunities for, for example, urban development.

The method provides municipalities — as coordinators of the urban environment — with a concrete tool for cross-system collaboration.

...to organising collaboration based on that analysis...

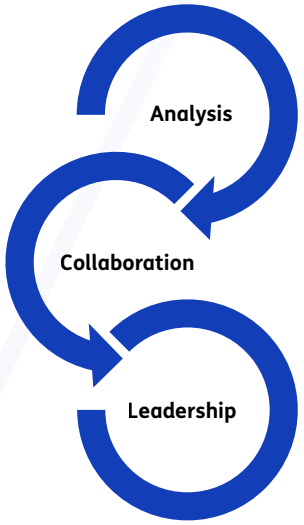
A second way to achieve systemic power is by bringing together the elements of different systems. This is not just a technical challenge — such as linking physical and digital infrastructures — but also a social one. It involves strengthening the social fabric between systems and the underlying connections, particularly the trust between actors (see also Groenleer, 2024). Institutions and ecosystems play an important role in this.

The Vital Systems Method can also support this second step. Based on the analysis, it becomes possible to identify which alignments and collaborations are needed — both within and beyond the municipality (as central actor). The network can then be formed, a governance structure established, and innovation orchestrated — for example using TNO's Acceleration Compass.[3]

The method also helps identify gaps in existing knowledge and organise learning through experimentation, including making adjustments and steering where necessary.

This also relates to capacity building for collaboration between systems. To effectively use the available tools, actors need to possess the right skills.

Figure 4: Interconnected mechanisms for achieving systemic power



...and exercising Integrative Leadership for system analysis and action

What does this require from leaders or, rather, those assuming positions in which they may exercise leadership? First, a collaborative and adaptive mindset. But also a commitment to the process — especially when it goes against the grain — and a willingness to work on issues that are not directly part of their organisation's "core business" (and often not of any single organisation). For success in systemic collaboration, these conditions are necessary, but they are not sufficient.

The same applies to leadership. The type of leadership needed to move from fragmentation to systems power is often referred to as integrative leadership (Crosby & Bryson, 2010). Leaders in collaborative systems are expected to bring together diverse groups and organisations in a semi-permanent way, across sectoral boundaries, to solve complex societal problems and contribute to public value.

This type of leadership requires, among other things, building support across system boundaries, managing differences between divers parties., handling conflict in a productive manner (e.g. through reframing), and actively accounting for decisions to a wide range of stakeholders — not least to society itself.

3 See: Orchestrating innovation: samen innovatie aangaan - TNO Vector; Acceleration Compass: nieuwe methode om innovatie te versnellen - TNO Vector

5. Instead of a conclusion: interconnectedness as guiding principle

Collaborative systems are the foundation for broad prosperity and sustainable growth. Collaboration within and between systems — increasingly enabled by digital technologies — can contribute to improving the efficiency and effectiveness of systems, reducing operational costs, and enhancing the quality of decisions made across systems. Such collaboration is not a "nice-to-have", but a "must" for building a resilient and adaptive society.

At the same time, collaboration is not self-evident. While societal challenges demand cross-system coordination, systems often remain siloed, driven by technological "quick fixes" and sectoral optimisation. To achieve collaboration, investments are needed — not only financial and technological, but also in relationships, trust, and people's mindsets and skillsets. It is precisely in these areas that gaps often remain.

Ultimately, of course, it is not the systems themselves that collaborate, but the actors within them — or more accurately, the people. Increasingly, these individuals need to work together on concrete challenges, in multidisciplinary teams, across system boundaries. This requires a form of leadership that brings together actors with diverse perspectives, interests, and capacities, while also paying attention to the performance, uncertainty, and limitations of collaborative systems, as well as and the drawbacks risks of integration.

A key recommendation for better harnessing the power of collaborative systems is therefore to focus on interconnectedness as a guiding principle, and to remain aware of the ambiguity of collaboration. Collaboration within and between systems is not always neat and tidy. It is just like with a tapestry: if you look at it from the back, it may seem messy, with tangled threads and loose ends. But if you look from the front, you see the patterns that emerge from weaving those threads together.

References

Borrás, S., & Edler, J. (2020). The roles of the state in the governance of socio-technical systems' transformation. *Research Policy*, *49*(5), 103971.

Bryson, J. M., Crosby, B. C., & Stone, M. M. (2015). Designing and implementing cross-sector collaborations: Needed and challenging. *Public Administration Review, 75*(5), 647-663.

Crosby, B. C., & Bryson, J. M. (2010). Integrative leadership and the creation and maintenance of cross-sector collaborations. *The Leadership Quarterly, 21*(2), 211-230.

Crosby, B. C., 't Hart, P., & Torfing, J. (2017). Public value creation through collaborative innovation. *Public Management Review, 19*(5), 655-669.

DeLaurentis, D., & Callaway, R. K. C. (2004). A system-of-systems perspective for public policy decisions. *Review of Policy Research, 21*(6), 829-837.

Draghi, M., et al. (2024), *The future of European competitiveness.*

Duit, A., & Galaz, V. (2008). Governance and complexity—emerging issues for governance theory. *Governance, 21*(3), 311-335.

Duit, A., Galaz, V., Eckerberg, K., & Ebbesson, J. (2010). Governance, complexity, and resilience. *Global Environmental Change, 20*(3), 363-368.

Emery, F. E., & Trist, E. L. (1960). Socio-technical systems. *Management science, models and techniques, 2*, 83-97.

Frissen, P. (2023). *De integrale staat. Kritiek van de samenhang.* Boom.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy, 33*(6-7), 897-920.

Groenleer, M. (2016). *Redundancy in multilevel energy governance: Why (and when) regulatory overlap can be valuable.* Available at SSRN 2865683.

Groenleer, M. (2024). *Op zoek naar verbinding: Relatietherapie voor het Openbaar Bestuur (ROB).* Lezing uitgesproken bij het afscheidssymposium van Han Polman als voorzitter van de Raad voor het Openbaar Bestuur, 10 oktober.

Huxham, C., & Vangen, S. (2005). *Managing to collaborate: The theory and practice of collaborative advantage.* Routledge.

Lazo, C.B., & Tjokrodikromo, T.S. (2022). *Adaptive governance for transitions and transformations: definition, characteristics and methods*, TNO paper.

Lazo, C.B., et al. (2023). *Systems innovation concept map*, TNO paper.

Meadows, D. H. (2008). Thinking in Systems: A Primer. Chelsea Green Publishing.

Page, S. E. (2006). Path dependence. *Quarterly Journal of Political Science, 1*(1), 87-115.

Pierson, P. (2000). Increasing returns, path dependence, and the study of politics. *American Political Science Review, 94*(2), 251-267.

Perrow, C. (2011). *Normal accidents: Living with high risk technologies.* Updated edition. Princeton University Press.

Righi, A. W., & Saurin, T. A. (2015). Complex socio-technical systems: Characterization and management guidelines. *Applied Ergonomics, 50*, 19-30.

TNO (2025). Het Nederlandse concurrentievermogen in het licht van het Draghi-rapport.

Van der Steen, M., Otto, M., Hill, R., Oosterloo, S., Ganzeboom, Q., Kuipers, G., Woestenburg, A., & Groenleer, M. (2024). *Breder denken, anders doen. Naar een nieuwe institutionele balans voor het energiesysteem van de toekomst.* NSOB.

Waardenburg, M., Groenleer, M., de Jong, J., & Keijser, B. (2020). Paradoxes of collaborative governance: investigating the real-life dynamics of multi-agency collaborations using a quasi-experimental action-research approach. *Public Management Review, 22*(3), 386-407.

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