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Are we in need of a re-conceptualization?**

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Getting to grips with system innovation: are we in need of a re-conceptualization?

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Abstract

To achieve more desirable futures, we need to completely overhaul our current production, consumption, and innovation systems, requiring practices that go beyond merely understanding these systems and their problems. While the necessity for systemic changes to address grand societal challenges is widely supported across diverse schools of thought, systems innovation faces two significant limitations. First, many approaches to systems innovation focus primarily on understanding and mapping systems, seldom enabling robust change towards achieving desirable futures. Second, and relatedly, the literature on systems innovation (SI) is fragmented and built upon different fields with contradictory ontological assumptions—some suggest changes can be strategically planned and managed, while others fundamentally reject this notion. This fragmentation and these ontological contradictions hinder robust actions towards desirable futures by increasing the divide across disciplines, antagonizing the very core principles of system innovation that demand transdisciplinarity. Therefore, the central research question of this paper is: How can the integration and alignment of diverse approaches within systems innovation overcome current limitations and better support the transition towards desirable futures?

In this paper, we argue that the conceptualization of ‘systems innovation’ stems from three distinct approaches that have largely remained unconnected: 1) Research and innovation approaches, 2) Systems thinking approaches, and 3) Societal transition approaches. This paper aims to bring conceptual clarity by offering a comprehensive overview of these fields ultimately arriving at a re-conceptualization of systems innovation. While these different fields have largely developed independently, we find that their alignment facilitates a more cohesive and effective re-conceptualization of ‘systems innovation’.

Keywords

Systems Innovation; conceptual framework; innovation studies; sustainability transitions; systems thinking; transdisciplinary research

1 Introduction

The world is facing unprecedented complex societal problems, from climate change to social inequality, that require innovative solutions to achieve sustainable futures. However, the current approaches to addressing these problems are often ineffective, leading to unintended consequences. Complex societal problems are characterized by their multifaceted nature, stakeholder diversity, and high stakes (Rittel & Webber, 1974; Ackoff, 1971). This highlights the need for a more integrated and comprehensive understanding of enacting systemic change. The need for systemic knowledge and methods to address grand challenges is growing, but literature on systems innovation (SI) is fragmented and built upon different fields.

Scholars across various disciplines have theorized about systemic change to address complex societal problems. Specifically, innovation studies, transitions studies, and systems sciences provide distinct, valuable lenses for understanding the dynamics of complex systems and the potential for transformative innovation (Haddad et al., 2022; Schot & Steinmueller, 2018; Weber & Rohracher, 2012). As a shared concept, Systems Innovation (SI) is an approach to changing societal systems in which a complex societal problem occurs. The OECD (2015) offers two approaches to the concept of systems innovation. First, as a tool, SI is a *“conceptual framework for understanding and managing transitions in response to radical technological and social change”* (p.14). Second, SI, as a phenomenon is considered *“a radical innovation in socio-technical systems which fulfill societal functions, entailing changes in both the components and the architecture of system”* (p.15).

However, the concept of SI remains fuzzy. First, there is extensive literature on sustainability transitions and transformations (Geels, Elzen & Green, 2004). Less attention is placed on how systemic changes (innovations) unfolds and can be steered, which is the focus of SI (Butter, 2002). The interventions required to create systemic change are only explored in specific domains such as policy, economics, and behavior, but barely at the systemic level of generic leverage points (Meadows, 1999; Abson et al., 2017). Second, wicked problems tend to require radical change which has a paradoxical relationship with incremental change (Termeer & Dewulf, 2019). Third, each framework focuses on a different actor of change - policymakers (OECD, 2015), innovators (Midgley & Lindhult, 2021), designers (Ceschin & Gaziulusoy, 2020), or businesses (Dooley et al., 2000). Some frameworks even consider multiple roles for actors of change (Leadbeater & Winhall, 2020). Finally, SI involves many different activities: identifying and understanding systems, predicting the behavior of systems, and devising modifications to that system (Arnold & Wade, 2015). Achieving SI also requires planning, implementing, fostering, evaluating and scaling changes. Innovation, which comes in many forms, is often seen as a driver of system transformation.

The fragmentation of these system innovation understandings lacks conceptual clarity and might, perhaps, not be tailored to the complex societal problems of today - with the risk that interventions have unintended consequences (Greco & Long, 2022). Thus, a more comprehensive typology can help in a better understanding and scoping of the problem so that it is clear from which characteristics its complexity arises; it encompasses the different stakeholders, methods, and processes at hand to contribute to systems change. The central research question of this paper is therefore: How can the integration and alignment of diverse

approaches within systems innovation overcome current limitations and better support the transition towards desirable futures?

The main objective of our article is to provide novel conceptual contributions, rather than a bibliometric analysis or systematic literature review. Thus, a focused literature review is more suitable, as it aims to identify relevant research traditions and construct a meta-narrative from them (Snyder, 2019). To answer our research question, we formulated two sub-questions.

We aim to provide conceptual clarity by answering the following sub-research question: *How have systems innovation processes been conceptualized by the three strands of studies (innovation, transition, system)?* We draw upon research & innovation theory to understand the evolution of innovation policy and the shift towards addressing societal challenges. Transitions theory provides insights into the dynamics of socio-technical systems and the processes of systemic change. Systems theory offers both theory and tools for analysing complex systems and identifying leverage points for intervention.

Next, we aim to provide conceptual clarity by answering the following sub-research question: *How can these conceptualizations be used when devising an integrative conceptualization of systems innovation processes toward achieving desirable futures?* By providing a clearer and more comprehensive understanding of systems innovation, this paper contributes to the ongoing discourse on addressing complex societal challenges. Our framework offers valuable guidance for researchers, policymakers, and practitioners seeking to navigate the complexities of systemic change and foster sustainable transitions towards a more just and equitable future.

This paper is structured as follows: section **Error! Reference source not found.** describes the literature where conceptual frameworks have been considered. Section 3 presents the three fields and their conceptualisations of systems innovation. In section 4 we propose a re-conceptualisation of systems innovation that bridges across the different fields. Finally, in section 5 we shortly discuss the implications.

2 Related work

Ours is not the first effort of mapping the conceptual framework space and exploring the interactions between disciplines. Table 1 provides an overview.

Many researchers have attempted to identify and synthesize different theories of sustainability transition studies (Markard, Raven & Truffer, 2012; Falcone, 2014; Ollivier et al., 2018) or analysed their use in specific sectors (see e.g. El Bilali, 2020; Ollivier et al., 2018). Sovacool & Hess (2017) identify 96 conceptual frameworks for sociotechnical change, of which 14 are articulated¹. These theories emphasize one of five categories: human agency and decision-making; (institutional) structures; systems of meaning; and hybrid theories, which apply to all three other categories. They argue that the many different theories

¹ The 14 theoretical frameworks for sociotechnical change are: 1) sociotechnical transitions; 2) social practice theory; 3) discourse theory; 4) domestication theory; 5) large technical systems; 6) social construction of technology; 7) sociotechnical imaginaries; 8) actor-network theory; 9) social justice theory; 10) sociology of expectations; 11) sustainable development; 12) values beliefs norms theory; 13) lifestyle theory; 14) universal theory of acceptance and use of technology (Sovacool & Hess, 2017)

provide a “*rich and useful menu*” (p.742) for the assessment of sociotechnical change from different perspectives. These theories, largely to support research in the field of sustainability transitions, have also been categorized as ‘families’: Socio-technical transitions (STT) and social-ecological systems (SES) (Ollivier et al., 2018). STT groups strategic niche management, multi-level perspective, technological innovation systems, and transition management (Markard et al., 2012). SES consists of Institutional Analysis and Development (Ostrom, 2009) and Resilience Thinking (Holling 1978; Folke et al. 2010). They caution that there may be ontological differences between the frameworks.

Several authors have also attempted to compare and integrate across the fields of innovation studies and sustainability transition studies. Most notably, these contain comparison of systems approaches to innovation and technological change: innovation systems and socio-technical system transitions (Coenen & Díaz López, 2010; Suurs & Roelofs, 2014). Havas, Schartinger & Weber (2023) attempt to integrate the fields together with social innovation theory and outline the common concept of goal-oriented transformative change.

The relationship with system studies is explored to a lesser extent, because of the broad nature of the systems sciences and system methodologies. Rotmans & Loorbach (2009) explain the conceptual underpinnings of complexity theory in transition management, and its key notions of emergence, coevolution, attractors and self-organization. Midgley & Lindhult (2021) investigate the different definitions of systemic innovation in the discipline of technology and innovation management and argue for a contrasting definition in support of the prior definitions. They point out several systems methods, such as the systemic intervention (Midgley, 2000) to provide a more systemic management of innovation. Palmer & Cavicchi (2023) explore several system methodologies and their use to deal with the complexity of system transitions in innovation policy.

Table 1: Reviews and integrations of the three fields

	Innovation studies	Sustainability transition studies	Systems studies
Rotmans & Loorbach (2009)		X	X
Coenen & Díaz López (2010)	X	X	
Markard, Raven & Truffer (2012)	(X)	X	
Ollivier et al. (2018)		X	
El Bilali (2020)		X	
Midgley & Lindhult (2021)	X		X
Havas, Schartinger & Weber (2023)	X	X	
Palmer & Cavicchi (2023)	X		X

3 Key features of systems innovation

This section describes the three fields and how systems innovation is being conceptualised in those fields. Table 2 contains a comparison of how the three fields conceptualise systems innovation.

3.1 System innovation in innovation studies

The way in which science, technology and innovation is analysed and steered via science and technology policy has, over time, developed into different approaches or frames with different models of innovation supporting these frames. For this conceptual paper, we explore these different approaches, which are R&D systems, innovation systems and transformative change (Haddad et al., 2022; Schot & Steinmueller, 2018; Weber & Rohracher, 2012).

The R&D systems frame is focused on innovation for growth, prosperity and future earning capacity (Schot & Steinmueller, 2018). This frame for innovation and innovation policy was born after World War II over the emergence of modern economic growth thinking next to concerns about the future of the industrially developed economies. Within this frame, science, technology and innovation were seen as important as they hold the potential for (future) prosperity, economic growth and competitiveness. As a result, it was seen as legitimate that the state could and should play an active role in stimulating science, technology and innovation via policies. Until the 1980s, the government's innovation policy thus mainly tried to entice companies to invest more in research and technology development through subsidies, tax benefits and protection of intellectual property (Arrow, 1962; Nelson, 1959). The legitimization for this policy was the principle of market failure: companies will, for their own reasons, invest less in research and development (R&D) than is socially desirable, because others benefit from the results (Schram, Verbon & Van Winden, 2004).

The (national) innovation systems frame emerged during the 1980s (Lundvall, 1992; Nelson, 1993). In this frame, innovation is seen as an interactive, non-linear process in which companies 'interact' with a multitude of other organizations - universities and knowledge institutions, other companies, etc., in what is called the 'innovation system'. An innovation system is a socio-technical system in which a network of actors interacts with each other to realize innovation (Suurs & Roelofs, 2014). The focus of innovation systems is to make the most of an existing or emerging innovation system by analysing and supporting mechanisms and system functions that lead to successful innovation (Hekkert et al., 2007). In this context, the government's main role is to repair so called system failures that hinder the creation and application of knowledge, for instance because certain actors within the innovation system are absent, or necessary interactions between actors are underdeveloped (Klein Woolthuis, Lankhuizen & Gilsing, 2005). Innovation policy thus focused more on connecting parties in the innovation system, in particular by encouraging public-private partnerships between knowledge institutions and companies.

The third framing of innovation emerged in the 2000s and emphasized a broader view on economic development, in which creating economic growth should not be at the expense of broader well-being concerns (Haddad et al., 2022; Kuhlmann & Rip, 2018). As societies and economies are increasingly confronted with major societal challenges of increasing wickedness (i.e. climate change, unaffordable healthcare, biodiversity loss, circular economy, renewable energy etc.), the realisation emerged that these challenges are, in part, the result of our existing socio-technical systems and the earlier economic growth-focused innovation policies (Mazzucato, 2018; Schot & Steinmueller, 2018). That is, current interventions and instruments, based on concepts of market and/or system failure, do not ensure that the necessary innovations are initiated that address urgent societal challenges. Consequently, there is increasing attention

towards innovation policies that address major societal challenges, whereby the concept of transformation failure is becoming a rationale for government intervention (Weber & Rohracher, 2012). Transformation failure assumes that fundamental, systemic changes in our systems of production, consumption and innovation are necessary to achieve a new design of the entire system of production, consumption and innovation that enables a socially desirable transition in the longer term. Thus, systems innovation focuses on the transformation of socio-technical systems – rather than the strengthening of existing or emerging innovation systems as they are largely seen as unfit to address societal challenges: it is time to articulate more forcefully and to experiment in practice with a framing for science, technology and innovation that emphasizes “socio-technical system change” (Schot & Steinmueller, 2018) of those systems (i.e. around energy, mobility, food, water, healthcare, innovation, etc.) that make up the backbone of our modern societies (Grin et al., 2010).

Systems innovation goes beyond the application of system concepts in the analysis and organization of innovation. The innovation system approach recognized the systemic character of innovation rather than the linear models of innovation (Schot & Steinmueller, 2012). The goal of policy is to improve the functions or structures of innovation (Hekkert et al., 2007). However, the innovation system approach does not address transformation failure (Weber & Rohracher, 2012). Transformative innovation policy may be considered the most recent policy effort to integrate the innovation system approach with the wickedness of societal issues (Diercks, 2019). In this framing, SI goes beyond ‘conventional’ product and process innovation to include a combination of changes in markets, user practices, regulations, infrastructures and cultural meanings to change societal needs and offer new ways in which our current systems fulfil those societal needs (Butter, 2002; Lazo et al., 2023; Tukker, 2005).

Another conceptualization of systems innovation is that it emerges from actors in the innovation system using systems thinking, methods and tools (or enabling other actors to use those) (Midgley & Lindhult, 2021). The nexus of change becomes the person, their practice, methods, and capabilities, and as such, system methodologies have emerged in innovation policy (De Vicente, 2016; Matti et al., 2020; Brodnik et al. 2021).

3.2 System innovation in sustainability transition studies

We discern societal transition approaches and their development over time. Transition studies is in itself an interdisciplinary field that strongly builds on the tradition of system thinking – albeit with a clear focus on addressing sustainable environmental development. Over time, this perspective has widened with the introduction of socio-technical transitions (STT) theory which is engaged with systems composed of people and technologies interacting (Soliman & Saurin, 2017). STT helps thinking about the role of technology in society not merely as technological systems or social systems, but as their combination (Geels, 2004).

The multi-level perspective (Geels, 2004) is an important transition framework and provides a way to describe the dynamics between processes at different levels in the complex socio-technical system, and how innovations can change the socio-technical regime. These dynamics include *macro* factors: the ‘landscape’ or wider context that slowly changes. *Meso* factors: the socio-technical system, or regime. And *micro* factors, or those factors that arise in “*secluded margins within the socio-technical system*” called *niches* (Geels, 2004) where

niche actors develop new innovations with the potential to influence the regime at the meso level.

The concept of systems innovation (SI) has emerged as a key component of socio-technical transitions (STT) theory in the sustainability transitions literature. Geels, Elzen & Green (2004) define systems innovation as “*a transition from one socio-technical system to another*” (p.2) and the term is often used interchangeably with the terms “*transition*” or “*transformation*”. Often, SI includes a combination of changes in markets, user practices, regulations, infrastructures and cultural meanings (Geels, 2005) in order to change societal needs and offer new ways in which our current systems fulfil those societal needs (Butter, 2002; Tukker, 2005).

While earlier studies primarily had an environmental and sustainability focus, we find that over time, the systems of interest has broadened to those with societal functions like housing, energy provision or healthcare (Geels & Kemp, 2000). In those systems, SI occurs at various levels simultaneously, from company and network to macro and landscape levels, and involve major and complex technological and structural changes (Butter & Montalvo, 2004).

While transition research thus presents societal transitions as the systemic reconfiguration of socio-technical systems, very recent studies have emphasized that they primarily emphasize innovation and built-up, over breakdown, decline or phase-out processes (Hebinck et al., 2022), that might change the systemic assumptions of current socio-technical systems that largely maintain unsustainable practices. Only more recently, we therefore see the surfacing of a more explicit system innovation conceptualisation in sustainability transition studies. These studies also question the extent to which the systems innovation effectively addresses wicked problems. For a long time, the shift from coal to natural gas – through the use of gas fields in Groningen - for residential heating in the Netherlands was considered a sustainable system innovation, with the benefits of lower pollution and greater comfort (Rennings, Hemmelskamp & Hitchens, 2001; Correljé & Verbong, 2004). But, given the many earthquakes, resulting in the shutdown of gas extraction in 2023, the question is to which extent we can speak of a ‘system innovation’ if there are such (unintended) consequences.

3.3 System innovation in systems thinking studies

System thinking approaches have also developed over time. System thinking refers to “*thinking and acting using system concepts and designing/using systems-methodological processes to support the systemic thinking and action of others, so they too can innovate*” (Midgley & Lindhult, 2021, p.656). As such, the ‘systems concept’ is a tool for critical thinking, helping people to include multiple perspectives, values, power, and conflicts which play out in stakeholder relationships and are important to systems innovation (Cabrera et al., 2022; Midgley & Lindhult, 2021).

Since the 1950s, several systems thinking approaches have emerged. Traditionally, systems thinking constitutes several methodologies to bring systems into perspectives. To account for these approaches unsuitability for ill-structured ‘real world’ problems, ‘soft systems thinking’ was developed. Later on, critical systems thinking methods have been developed for practitioners to reflect also on their assumptions and beliefs, and to choose adequate methods for the problem situation at hand (Jackson, 2019). More recently, a fourth wave of systems

research has emerged which focuses on the universalities across domains, and how system thinking skills can be improved for better problem solving (Cabrera et al., 2022; Jackson, 2019), like in societal transitions and transformations.

When conceptualising system innovation, we find that more attention has been given to defining systems than to defining their innovation. A system is “*a set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviours, often classified as its ‘function’ or ‘purpose’*” (Meadows, 2008, p.12). It is more than the sum of its parts and cannot be divided into independent parts (Ackoff, 1971). A system has an environment which consists of all variables which can affect the system’s state. System studies also sees different views on the ‘realness’ of systems (Ison, 2018). On one side of the spectrum, the system is an ontology, a description of an actual phenomenon in the world - for instance, in systems engineering, systems analysis, system dynamics. On the other hand, systems are epistemologies, a ‘lens’ through which to view the world or critically assess how the world is viewed – such as in soft systems thinking (Checkland, 1985) or critical systems thinking (Flood & Jackson, 1991; Ulrich, 1983).

Although the term ‘innovation’ is rarely used in systems studies, we can understand it as systems change towards a certain goal – based on the way it is used in sustainability transitions. Such a system may be called ‘purposeful’ (Ackoff & Gharajedaghi, 1996). This is different from goal-seeking, where a system (such as a thermostat or servo motors) uses information and communication to adapt its state to maintain a certain goal. To characterize system change, systems studies distinguish between *leverage* (focused on the mechanics) and *intervention* (focused on the achievement of a certain goal). Leverage points emerged in the field of system analysis (incl. system dynamics) and describes a categorization of 12 types of places in systems where a “*small shift in one thing can produce big changes in everything*” (Meadows, 1999, p.1). The objective of an analyst is to find these leverage points and devise intervention points that make use of this leverage to create desirable change (Murphy, 2022).

Table 2: Five key concepts and the different orientations of innovation studies, sustainability transitions and systems sciences

	Innovation studies	Sustainability transition studies	Systems studies
System	Network of organisations, technologies, services and value exchange relationships, often captured in ‘innovation system’, various types of ‘ecosystems’, or the ‘socio-technical system’	<i>Socio-technical</i> (people and technology interacting) or <i>socio-ecological</i> (people and nature interacting). The system of interest is a function of society (e.g. the housing system, the energy system)	A coherently organized set of interconnected elements or parts that produces characteristic behaviours, functions, or purposes. Systems can be viewed as either ontological descriptions of actual phenomena or epistemological lenses through which to critically assess the world.
Goals	Improving the functions or structures of innovation systems. Increasingly oriented towards addressing wicked problems with innovation systems	Explicitly aimed at addressing complex, wicked problems – in particular climate change.	Purposeful, distinct from simple goal-seeking behaviour. Systems change towards a desired goal or purpose.
Actors	Business, policy maker, intermediaries	Policy maker, ‘niche’ actors (e.g. entrepreneurs)	Practitioner and analyst, incorporating multiple perspectives among stakeholders

Interventions	Orchestration and experiments to improve the system functioning, articulating new goals for science, technology and innovation.	Product, process innovation and social/societal innovations (markets, user needs, regulations, infrastructures, cultural meanings)	Purposeful actions by an agent to create change. Intervention points making use of leverage points.
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4 A re-conceptualisation of systems innovation

We thus find that within the three different fields of study, distinct pathways led to a focus on system innovation (see Table 2). Given their conjunction, we argue that it is time to re-conceptualise system innovation in light of today’s societal challenges. Thus, we define systems innovation as *the combination of innovations (in its broadest sense) that, over a certain period of time, change the elements, structures and interactions of systems, to achieve a certain goal*. While each strand provides a different theory, the underlying elements are depicted in Figure 1. We will discuss each element next.

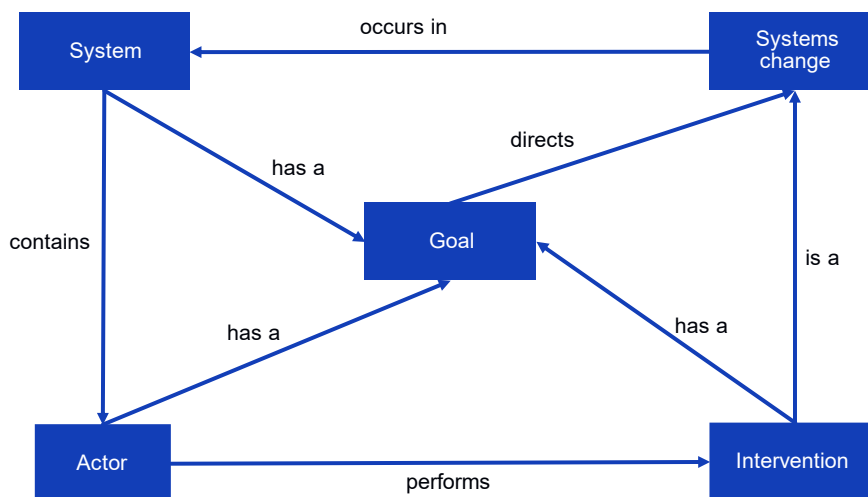


Figure 1: A conceptual model of Systems Innovation

4.1 System and scope

A system is a coherently organized set of interconnected elements or parts that produces characteristic behaviours, functions, or purposes (Meadows, 2008). This concept is fundamental to various fields including the ones being examined, but also biology, philosophy, medicine, engineering. In research and innovation approaches, a system tends to refer to a network of organizations, technologies, services, and value exchange relationships. In sustainability transitions, a system is often viewed as a socio-technical or socio-ecological system, where people, technology and nature interact. The scope is often functions of society such as housing or energy (Geels, 2005).

Across all three fields, the concept of a system involves understanding the relationships and interactions between different components. Systems are often viewed as complex and dynamic and involve multiple stakeholders and actors. The main differences are that research and innovation approaches focus on the innovation process, transition approaches tend to focus on sustainability, while systems theory provides a general framework for understanding

complex systems. Understanding the concept of a system and the ability to critically assess its boundaries is crucial for analysing and addressing complex problems.

4.2 Goals

In systems innovation, the intentional direction of innovation, transitions, or systems change is often aimed at addressing complex, wicked problems. Goals and purpose guide efforts of many parts in the system (such as stakeholders) towards desirable outcomes. Examples include innovation systems addressing climate change, transitions tackling complex problems, and systems change transforming towards a desired state or outcome.

While research & innovation approaches focus on improving the functioning of innovation systems, transition approaches focus on systemic re-configurations over longer periods of time, and systems theory focuses on an understanding and predicting of the system behaviour.

4.3 Change processes and dynamics

Systems innovation focuses on transformative change. Change processes entail multi-level and multi-actor interactions and co-evolution of various system components, going beyond incremental adjustments. Research & innovation approaches see a shift from focusing on individual innovations to transforming entire systems, such as transitioning from fossil fuels to renewable energy. Sustainability transitions theories explain the long-term dynamics of change, like the shift from horse-drawn carriages to automobiles, highlighting the interplay between the broader context, existing systems, and emerging innovations. Systems theory provides tools for understanding these changes, such as leverage points, to identify effective intervention strategies for achieving desired outcomes.

While research & innovation approaches emphasize diffusion and interdependencies between technologies and knowledge, sustainability transitions approaches aim to understand and make use of long-term dynamics at multiple levels, while systems sciences offer tools for analysing and intervening in complex systems. Although the three fields differ in their specific focuses and methodologies, they share a common ground in understanding complex systems and their change processes. They all recognize the interconnectedness of system elements, the importance of feedback loops, and the role of human agency in driving change.

4.4 Actors

Actors including policymakers, entrepreneurs, designers, practitioners, and analysts are key in the transformation of complex socio-technical systems. Their roles range from developing and implementing innovations to shaping policies and facilitating stakeholder engagement. In research and innovation approaches, the focus is on businesses, policymakers and intermediaries, who play a crucial role in steering science, technology, and innovation. Businesses develop new products and processes, while policymakers create the enabling environment for innovation. In sustainability transitions theory, policymakers and 'niche' actors, such as entrepreneurs, are considered central to driving socio-technical transitions. Policymakers (who are regime actors) create the conditions for niche innovations to emerge

and scale, while niche actors develop and experiment with new solutions. Within systems theory, practitioners and analysts are the main focus, as they use systems thinking and methodologies to support systemic change. They incorporate multiple perspectives, values, and conflicts among stakeholders to facilitate systems innovation.

Across these three fields, the common thread is the recognition that systems innovation requires the coordinated efforts of diverse actors, each playing a unique role. However, the specific focus and emphasis on different types of actors may vary depending on the theoretical lens. In research and innovation approaches, businesses develop new products and processes which create new interdependencies, while policymakers create the enabling environment for innovation. In sustainability transitions, the focus is on the multi-level dynamics around policymakers and niche actors, such as entrepreneurs. Systems thinking is focused on practitioners and analysts, who use system methodologies to support systemic change, incorporating multiple perspectives and addressing conflicts among stakeholders.

4.5 Combination of interventions

Combinations of interventions (including technological and social innovations), which involve the integration of purposeful actions or changes at multiple levels in the system, require a diverse set of actors working together to create systemic change. Many different constellations of actors (Kuhlmann & Rip, 2018) contribute to the development and implementation of new ideas, technologies, or policies that can address complex societal problems. They experiment with new technologies and social arrangements, challenge existing structures, and promote collaboration across different levels of the system, ultimately driving innovation, systemic changes, and purposeful actions towards a more sustainable and equitable future.

The fields recognize the multitude of interventions or changes that make up a transformation. For instance, incremental innovations are often necessary to facilitate radical innovations (Twomey & Gaziulusoy, 2014). However, differences emerge in their focus, with research and innovation approaches emphasizing technological development, sustainability transitions theory focused on institutional change, and systems theory preferring systems thinking and design.

5 Discussion

We review three fields that touch upon system innovation and attempt to integrate their conceptualisations. Innovation studies, sustainability transition studies and systems studies are all moving towards understanding and creating change to address complex societal problems. By integrating these perspectives, we gain a comprehensive understanding of change processes and dynamics, enabling us to navigate the complexities of systems innovation and foster sustainable transitions.

While the specific roles and approaches may differ, they all share a common goal: fostering positive change within complex systems. Understanding the nuances of each perspective and the similarities and differences between them allows for a more comprehensive approach to tackling societal challenges. By combining insights from these diverse fields and engaging a

broader range of key actors, we can increase the likelihood of successful system transformations that benefit both current and future generations, ultimately leading to more sustainable and desirable outcomes.

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