Environmental Innovation and Societal Transitions 48 (2023) 100745

Contents lists available at ScienceDirect

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist

Assessing mission-specific innovation systems: Towards an analytical framework

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A R T I C L E I N F O

Keywords:
Challenge-based innovation policy
Transformative change
Societal challenges
Innovation systems
Transitions
Mission-oriented innovation policy
Mission-specific innovation systems

A B S T R A C T

In the currently emerging paradigm of challenge-led and transformative innovation policies, there is increasing attention for addressing urgent societal problems by formulating clear, timebound and ambitious mission goals. Completing such transformative mission's places new demands on innovation systems, as actors and activities need to align around prioritised problem and solution directions. Consequently, new perspectives that support the appraisal of innovation systems' performance are required for determining what hampers change processes, and which policy responses are appropriate.

Following an abductive research approach, this paper aims to develop an analytical framework for assessing mission-specific innovation systems (MIS). We examine three sectoral cases in the mission for a Circular Economy in the Netherlands and propose three analytical steps: 1) a problem-solution analysis, 2) a structural analysis recognising the importance of mission arenas, and 3) a functional analysis addressing directionality provision, coordination, and regime transformation. We conclude with discussing operationalisation and application of the framework.

1. Introduction

There is a rising interest for missions as a means to facilitate societal transformations and, thereby, tackle societal challenges (Foray et al., 2012; Mazzucato, 2015, 2018). This holds particularly for persistent societal challenges labelled as wicked due to their complex, contested and uncertain nature (Wanzenböck et al., 2020). The often state-led prioritisation of societal missions is regarded as a promising approach to mobilise innovation capacities around a shared goal (Mazzucato, 2018). A mission's key characteristic is a measurable, ambitious and timebound objective, suitable for engaging diverse stakeholders in mission governance and in the development as well as the diffusion of innovative solutions (Kattel and Mazzucato, 2018). However, despite missions' soaring popularity, scholars and policy makers are struggling to successfully implement and monitor mission-oriented innovation policies in practice (Hekkert et al., 2020; Janssen et al., 2021; OECD, 2021). A critical problem is the lack of suitable theoretical lenses and tools for determining whether the diverse stakeholders' activities are adding up sufficiently (Mazzucato et al., 2020; Janssen et al., 2022).

Since missions on wicked societal challenges require the transformation of configurations of actors, networks, institutions, and

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https://doi.org/10.1016/j.eist.2023.100745
Received 28 September 2021; Received in revised form 17 May 2023; Accepted 4 June 2023
Available online 8 June 2023
2210-4224/

capabilities (Wittmann et al., 2021), assessing mission progress (and targeting interventions) may benefit from an innovation systems perspective. The Technological Innovation Systems (TIS) framework provides a useful basis in this respect, but its focus on driving a particular technology limit its suitability for solving societal problems (Bergek et al., 2008; Hekkert et al., 2007; Bergek, 2019; Markard, 2020). Therefore, following the example of Hekkert et al. (2020), we adapt the innovation system concept to missions and define a Mission-specific Innovation System (MIS) as: *the network of agents and set of institutions that influence the development and diffusion of innovative technological and social solutions and the transformation of existing production and consumption systems with the aim to complete a societal mission.*

Like other innovation system concepts, a MIS can be regarded as an analytical construct or heuristic for studying the interactions between actors and institutions that in some ways are relevant for the topic that defines the innovation system – in this case a mission. This implies that a MIS can comprise groups of actors involved in various potential solutions for a societal challenge, which might compete or complement each other. How their interplay unfolds is determined by different types of conditions (e.g. financial, infrastructural, legal, cultural) that favour some changes more rather than others. The interplay can also enable those conditions to evolve, within the innovation system (as conceived by analysts) over time becoming more or less suited to accommodate the development and diffusion of promising solutions.

Looking at innovation development and diffusion through a MIS lens should thus help us understand whether and where momentum for change is building up (including which solution or set of solutions), and what is holding it back. However, knowledge on how to apply the new innovation system concept is still in an early phase, as the first studies that rely on MIS thinking have appeared only recently. For example, Jütting (2020) more closely analysed mission-oriented innovation ecosystems, Cappellano and Kurowska-Pysz (2020) made a conceptualisation for a regional MIS, Klerkx and Begemann (2020) applied MIS to the case of agriculture, and Rainville (2022) explored how green public procurement can strengthen MIS activities in the context of municipalities' sustainability ambitions. Still, more empirical studies are needed to shed light on how MIS dynamics unfold; more specifically, what the typical structural elements of a MIS are, and how system functions should be defined to adequately capture processes of MIS building.

The aim of this paper is to develop a theory-informed and empirically inspired assessment framework from a MIS perspective that helps to shed light on societal transformation processes (influenced by innovation development and diffusion processes) for addressing wicked societal challenges. In this paper, we utilise an abductive research design to examine how such an assessment framework from a MIS perspective would need to differ from the TIS framework. Using three sectoral cases related to the Dutch mission of transitioning to a fully circular economy, we examine which essential dynamics the TIS framework cannot account for. In line with the 'back-and-forth' principle of abductive research (Dubois and Gadde, 2002) we rely on additional concepts to adapt the TIS framework in a way that addresses the identified shortcomings. This ultimately renders the outline of an analytical framework consisting of a newly introduced problem-solution diagnosis and an adapted structural and functional analysis (which, besides addressing innovation build-up, also cover the phasing out of existing practices). By highlighting which decisions, processes and structures should be considered when delineating and assessing system transformation using a MIS lens, this paper advances the debate on monitoring societal missions reliant on system transformation using an innovation system perspective.

The remainder of this paper is as follows. In Section 2 we immediately introduce the abductive methodology for framework development, since applying this research approach requires us to later discuss relevant theories (the starting framework and the complementary theoretical concepts) as part of our results. Before presenting those results, Section 3 describes the three sectoral cases in which we have studied actors and activities associated with creating a Circular Economy. Section 4 first substantiates why an innovation system lens could be beneficial in studying societal transitions required for completing transformative missions. Afterwards, the contours of an assessment framework from a MIS perspective are proposed based on transition literature concepts and 'empirical anomalies' (Dubois and Gadde, 2002) the TIS framework fails to address. Section 5 summarises and concludes the paper.

2. Methodology for framework development

2.1. Approach

This paper aims to develop a theory-informed and empirically inspired framework to assess societal transformations specific to missions. To do so we follow an abductive approach, which guides theory development by alternating between inductive and deductive methods (Dubois and Gadde, 2002; 2014). While first popularised in fields like organisational studies and business research (Dubois and Gadde, 2002; Demil and Lecocq, 2010; Van de Ven et al., 2015), abductive reasoning is increasingly found also in the sustainability transitions literature (e.g. Diaz et al., 2013; Sarasini and Linder, 2018; Awuzie and McDermott, 2017). One recent example is the study by Ruggiero et al. (2021), who conducted interviews and used abduction to develop a business model innovation framework that overcomes the 'binary thinking' limitations in existent niche-regime theory.

The abductive approach starts with collecting empirical observations that point at weaknesses of an existing theory or theoretical framework. To address these empirical anomalies, researchers may rely on additional explanations and concepts to come up with a more adequate framework (Dubois and Gadde, 2014). Finding the best possible explanation is a matter of continuously moving back and forth between empirical observations and potentially relevant concepts. This is also referred to as 'systemic combining' (Dubois and Gadde, 2002), which "can be described as a nonlinear, path-dependent process of combining efforts with the ultimate objective of matching theory and reality" (Dubois and Gadde, 2002, p. 556). Rather than generating new theories, for which a fully inductive method is more suitable, this approach is particularly useful for refining existing theories or modifying already available frameworks. The adapted versions should be applicable beyond the specific empirical context (typically case studies) in which the anomalies were encountered.

Fig. 1 visualises how the abductive research process was applied in this study. Our initial reference is the TIS framework (Hekkert et al., 2007; Bergek et al., 2008). The TIS framework serves to assess the development status of a particular technology, based on so-called structural analysis and functional analysis (Hekkert et al., 2011). The structural analysis maps what type of actors are present or missing in the development and diffusion of a new technology, while the functional analysis points at the relative strength or weakness of several key processes ('functions') that determine a technological innovation system's performance.

The vibrant debate on innovation policies oriented towards missions has highlighted salient features of the search and development of solutions for wicked societal challenges (e.g. Wanzenböck et al., 2020; Wittmann et al., 2021; Janssen et al., 2021). Some of these features appear to be not accounted for in the TIS framework, as the latter explicitly focuses on a specific technology rather than challenges for which solution pathways (including non-technological ones) are still contested. What this means for assessing system dynamics has hardly been addressed by the literature, as much of it mostly advances theoretical arguments for why innovation processes should unfold differently – e.g. more coordinated, cross-sectoral and inclusive (Mazzucato, 2018). To understand better in what ways the TIS framework is limited, and how these limitations can be addressed in an adapted analytical framework, more original empirical work is needed.

2.2. Case selection

Following Dubois and Gadde's (2002) guidelines for conducting abductive research, we rely on a single case study with three embedded subcases – i.e. subcases that are situated in the same context. Studying three similar but independent sub-cases allows for analysing variation, and thereby for creating a better understanding of the shortcomings of existing theory. The current study examines the Dutch mission that aims for a 100% circular economy by the year 2050 (Dutch Ministry of Economic Affairs and Climate Policy, 2019). We specifically look at transition dynamics in the plastic packaging, manufacturing, and textile sector. In each of those cases, representatives of different types of organisations (including but not limited to the Dutch government) intended to provide directionality for public and private actors' circular innovation and transformation efforts, with the use of sector-specific roadmaps and by aligning policy interventions.

The Dutch CE mission is an excellent case to study MIS dynamics. Firstly, a measurable and timebound mission goal has been put in place. Second, there is a diversity of solutions' directions (some technological, other social in nature) that may lead to mission completion. Thirdly, these different strategies are expected to overlap, conflict, or compete over attention and resources, resulting in contestation and uncertainty (Hekkert et al., 2020; Wanzenböck et al., 2020).

2.3. Data gathering and analyses

The three subcases have each been studied via a combination of desk and document research, interviews, and workshops. A preliminary assessment of the actors, initiatives and strategies in the sectors was constructed using desk research. Subsequentially, interviews and workshops were hosted to uncover the transition dynamics at play and the functioning of the innovation system. Table 1 lists the number of actors participating in workshops and interviews. For each case, actors from the entire supply chain were involved to guarantee total system coverage. Throughout the results the names of actors and type of organisations are anonymised and used in an aggregated way, in agreement with the informed consent form the interviewees agreed upon.

By analysing the three different circular economy subcases, we obtain insights in which important innovation system actors, activities and interactions are overlooked by the TIS framework. In the search for concepts and perspectives that help to account for these anomalies, we rely on strands of innovation systems and transition literature that seems most appropriate for highlighting identified dynamics. Two important criteria when considering complementary theoretical concepts is that they should provide a meaningful extension to the original TIS framework (based on its identified shortcomings), while maintaining a high degree of logical coherence and parsimony (Dubois and Gadde, 2002).

The next section briefly describes the cases, while more detailed information is provided in the supplementary material. In Section 4, we present the framework that was constructed by combining deductive and inductive research steps. We explain the framework by discussing both the theoretical considerations and the empirical observations that motivated the adaptations to the original framework. Given the iterative nature of our methodology, the order in which these two aspects are presented is not representative of their

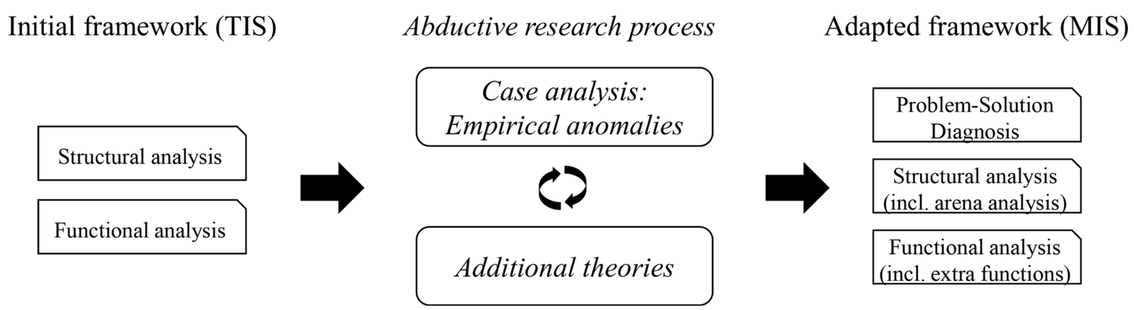

Fig. 1. Visualisation of abductive research design.

Table 1
overview of the number of actors participating in workshops and interviews for the different cases.

Case	Workshops	Participants per workshop	Interviews	Total actors
Manufacturing	2	15	3	33
Textile	1	13	21	33
Plastics	1	13	12	25

place in the research process. This implies that the empirical sections merely illustrate which observations required adaptations to the model, rather than that they represent some sort of validation.

3. Case descriptions

Circular economy is a term used for economies that fulfil societal functions with a minimal input of resources. This is an attractive strategy since the extraction, production and use of resources leads to many negative effects on the environment (Ghisellini et al., 2016; Geissdoerfer et al., 2017). Also, economies with a high resources' intensity are vulnerable for shocks in resource prices and constraints in supply. Three dominant routes for attaining a circular economy can be discerned, namely *prevention* (avoiding the use of resources, e.g. thinner materials), *life-time extension of products* (e.g. repair, re-use of products and components, refurbish) and *closing the loop* (e.g. recycling, material re-use) (Ghisellini et al., 2016; Kirchherr et al., 2017; Potting et al., 2018; Reike et al., 2018).

In 2019 the Dutch Ministry of Infrastructure and Watermanagement (I&W) proposed its circular economy mission as part of a national effort to complete a total of 25 missions (Dutch Ministry of Economic Affairs and Climate Policy, 2019). Although the ambition to reach a fully circular economy by 2050 is perhaps a utopic image of the future, it is a goal that is easily communicated and clear in its ambition. Already in 2016, the Ministry of I&W asked societal partners to develop concrete plans for achieving a circular economy. As an outcome, roadmaps were produced, with intermediate targets, and concrete steps to realise this envisioned transition, published as the Transition Agendas Circular Economy in 2018.[1] Five Transition Agendas were established, that cover the five most influential and impactful sectors for the Dutch economy, namely; manufacturing, plastics, construction, biomass and food, and consumption goods sectors. The possibilities and challenges for becoming fully circular are subjected to the specific characteristics of each sector. We focused on analysing the dynamics in three of these sectors.

3.1. Manufacturing sector

The Dutch manufacturing sector is a well-developed and capital-intensive sector, harbouring several multinational organisations specialised in producing complex equipment consisting of many parts for healthcare, transportation, energy production, or ICT industry. In a response to the transition agenda, the Dutch manufacturing industry created a task force with industry leaders and governmental organisations, called the "Implementation program (in Dutch: Uitvoeringsprogramma) Circular Manufacturing" (UPCM), to operationalise the goals set in the transition agenda and to develop strategies to complete the mission.

Two dominant routes are visible in this sector. One route is focused on material recycling. Due to many government initiatives in the past, related to waste management, this route is quite mature with clear legislation, dedicated companies involved in waste management and high re-use percentages (over 90%) of easy-to-recycle materials like steel and aluminium or highly valuable materials like copper.

The other route is related to life-time extension of products made by the manufacturing industry. The key idea is that through improved repair, giving products a second life, digitisation and re-use of components, the lifetime of these products can be significantly extended, leading to deep reductions in material use. This route requires fundamentally different business models (like retaining ownership of products through leasing instead of selling) and new relations between OEM's and clients. This route was embraced by a selection of large OEM's that organised themselves in the so-called capital equipment coalition (CEC) .[2] The central idea is that when this front runner group is able to show that they are successful in implementing this route, it will spill over to other actors in the innovation system. While this route enjoys high legitimacy, the diffusion is still very low.

3.2. Textile sector

The textile sector was not granted a transition agenda of its own, like the other cases, but is coordinated and directed under the banner of consumer goods. However, mounting pressure on the sector to show improvements in their sustainability performance motivated the sector to organise itself. Industry organisations Modint and Inretail coordinated sector wide ambitions related to circularity (Hartog et al., 2019). The Dutch Government followed suit by formulating specific circularity ambitions for the Dutch textile sector; in 2030 50% of recycled fibres in new products and 50% of the products brought to market should be recycled, and eventually the sector should be fully circular by 2050 (Dutch Ministry of Infrastructure and Waterways, 2020).

To reach the circular ambitions, three pathways are dominant: 1. reuse through second-hand clothes shops or platforms, and

[1] https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/nederland-circulair-in-2050

[2] https://pacecircular.org/capital-equipment-coalition

recycling through either 2. mechanical or 3. chemical recycling technologies. Mechanical recycling of textiles includes shredding and carding processes to reclaim fibres from the fabrics, while chemical recycling adopts a series of chemical processes to break down the fibres into monomers (Hekkert et al., 2021).

The first route is rapidly gaining traction; entrepreneurs move in, mergers and acquisitions take place, and online platforms are created for second-hand clothing and consumers make frequent use of these platforms. The other two routes show less positive innovation dynamics. Mechanical recycling is in a more mature development stage than chemical recycling, but the uptake of both technologies is low. A major hurdle here is a lack of demand by large clothing brands to adopt these recycled yarns and textiles. The brands in turn indicate that their reluctance is due to limited availability and quality concerns. This results in a typical hen and egg problem. The Dutch government has created a new intermediary organisation, Dutch Circular Textile Valley, to unlock this problem. One strategy is to sign voluntary agreements with clothes producers in which they promise to use more recycled fibres.

3.3. Plastic packaging sector

The circular economy ambitions for the plastic packaging sector did not start in a green field. The sector is already regulated for a long time due to waste reduction policies. For example, already in 2014 the Dutch government drafted extended producer responsibility (EPR) laws holding producers of packaging accountable for the collections and processing of its products (Overheid.nl, 2014). To adhere to these obligations, the sector created and funded an organisation, named Afvalfonds Verpakkingen, to coordinate the collection schemes and allocate the required financial resources for doing so. Moreover, large investments were made to create the infrastructure needed for collection and recycling of the collected waste stream.

The CE mission changed the rules of the game. The existing focus on recycling led to low quality recycled plastics streams that could only be used for low quality products like park benches and road posts. The CE mission requires the sector the produce high quality recycled materials that can be re-used in the packaging sector itself. Also, it steered towards prevention and re-use of complete packages like containers and bottles. It proves to be quite difficult to get the sector out of its low-quality recycling routines.

4. Towards an analytical framework

The concept of innovation systems is a popular heuristic for studying the dynamics that come into play when different actors and institutions are implicated in bringing about novelty. Edquist (2005) defines an innovation system as “all important economic, social, political, organisational, institutional and other factors that influence the development, diffusion and use of innovations” (p. 182). The innovation system is thus an analytical construct to describe and appraise the totality of factors and actors that, knowingly and unknowingly, contribute to the development and diffusion of innovation. Taking a comprehensive view, that stretches well beyond just science production or market mechanisms, serves to understand how a broad range of activities and conditions influence each other.

In order not to become too comprehensive, it is important to clearly delineate the innovation system under study. Over the years authors have done this according to different boundary dimensions, resulting in research streams on national innovation systems and regional innovation systems (e.g. Cooke et al., 1997; 1998), sectoral innovation systems (Breschi and Malerba, 1997), and technological innovation systems (Hekkert et al., 2007; Bergek et al., 2008). However, none of these boundaries seem appropriate for studying development and diffusion activities relevant for addressing a particular societal challenge as captured by a mission. We therefore propose to cast the net by considering all actors, organisations, institutions, networks and technologies that play a role in driving solutions that may contribute to mission completion. Together this constitutes a mission-specific innovation system (MIS).

A MIS is not an institutionalised network that starts to emerge when a mission is launched, but merely a lens for studying how well already existing actors, institutions and networks are geared towards delivering on a real or imaginable mission goal. Obviously, this can change as actors and institutions start to respond to the strong prioritisation of a collectively shared goal, but a priori there are no presuppositions regarding e.g. how connected or fragmented the actor structure is, nor how engaged actors are with a particular mission or the concept of missions. It is very well possible that in a MIS many actors are exclusively concerned with driving or hampering a particular solution – possibly without even realising how it relates to addressing a given societal challenge. One important analytical implication is thus that in order to define the boundaries of the MIS corresponding with that challenge, it is key to first understand what solutions and thus what actors are of relevance.

In our proposed analytical framework, we therefore start with a *problem-solution diagnosis* (Section 4.1), which consists of mapping the problem(s) a mission aims to tackle and the solutions that are deemed viable and legitimate to do so. Subsequently, we follow the TIS literature and continue with assessing the *structural dimensions* that make up an innovation system (Section 4.2) and highlight the *systemic processes* (Section 4.3) contributing to a well-functioning innovation system (Hekkert et al., 2007; Bergek et al., 2008). For both analytical building blocks, we propose adaptations to the typical structural elements and the functions of the innovation system. Moreover, for all building blocks we argue which theoretical arguments and empirical observations motivate our proposal for how to turn the TIS framework into a MIS framework. Relying on our cases we highlight examples of what type of dynamics to consider when appreciating developments in a MIS. Section 4.4 summarises the proposed outlines for the resulting MIS assessment framework.

4.1. Problem-solution diagnosis

4.1.1. The need for a problem-solution diagnosis

How exactly the mission and proposed solutions are defined and framed delineates the innovation system that aims to complete the mission. To grasp this, we introduce the problem-solutions diagnosis as the first analytical step in assessment from a MIS perspective.

A TIS describes change in one specific technological domain and is characterised by periods of high and low directionality. This is captured by the system function 'guidance of the search', which specifies the level of convergence in perceptions and priorities regarding possible development paths (Hekkert et al., 2020; Negro et al., 2012, 2007). A MIS, however, holds multiple dynamics related to directionality, which cannot be accounted for by the original TIS framework.

First, a MIS pertaining to a particular societal goal is more directed than a TIS centred around technologies for which the economic and societal value might not be clear from the outset. In fact, having a clear timebound and urgent societal objective is precisely what constitutes the promise of missions to have a mobilising and aligning effect (Janssen et al., 2021). Both the literatures on mission-orientated innovation policy (Mazzucato, 2018) as well as on transformative innovation policies (Weber and Rohracher, 2012; Schot & Steinmueller, 2018; Schot and Steinmueller, 2019) argue that strong directionality is crucial for allowing dissimilar stakeholders to explore how they can complement each other in overcoming the inertia stemming from interdependencies in the existing production-consumption system. This is also reflected in recent work on 'transformative outcomes' (Ghosh et al., 2021; Molas-Gallart et al., 2021), which underlines the importance of clear directions for creating synergies in developments that challenge the status quo.

Second, a MIS is likely to be characterised by the presence of multiple solution directions that may contribute to the completion of the formulated mission. In early phases of pursuing a mission it is unclear which technologies, initiatives or solutions will contribute to the mission and the focal societal problem. While analysis and consultations can help to create an overview, and thus provide a basis for comparing the potential and feasibility of different solutions, new unexpected solutions might keep emerging during the pursuit of a mission. This poses problems of uncertainty rather than of missing information (Wanzenböck et al., 2020), which can be addressed via tentative governance (Kuhlmann et al., 2019) and leaving sufficient room for bottom-up experimentation (Bergek et al., 2008). Moreover, different solutions could propagate diverging and conflicting claims and values, which may result in high contestation within the innovation system (Wanzenböck et al., 2020). Dealing with this contestation is especially complex when technological innovation trajectories should be complemented by socio-institutional solutions like behavioural, economical, organisational and institutional change (Mazzucato, 2016; Wanzenböck et al., 2020; Hekkert et al., 2020). Which (combinations of) top-down or bottom-up solutions actors will push forward depends on the focus and framing of the societal problem at hand and the expertise, power and interest of key stakeholders (Janssen et al., 2021). It is important to note that different solution directions may have different interactions. Sandén and Hillman (2011) define interaction as overlap in the value chain of alternative solutions, which can be characterised by a symbiotic, neutral or competitive relationship.

4.1.2. Illustrations of what to diagnose

A multitude of trajectories: In all three cases a well-communicated mission provided some directionality to actors in the innovation system, like the goal of having 100% circular textiles in 2050. Similar missions were formulated for plastics and manufacturing industry. Such goals sparked many new initiatives, experiments, business models and coordination structures. The missions are on one hand clear in quantitative terms (e.g. x% material reduction) and time bound. On the other hand, 100% circular does not seem to be practically feasible, and it remains unclear how a 100% circular industry will look like. The missions therefore excelled in creating momentum, enthusiasm and pressure for change, but did not provide very strong directionality on how to get there. As this might severely hamper mission progress, this observation emphasises the importance of examining which problem interpretations are being considered, and how much support they enjoy.

Regarding the legitimacy of possible solutions, our empirical cases show that different solution directions are legitimised through different rationales and logics. In the case of plastic packaging, industrial players are advocating a focus on mechanical recycling technology as it keeps current production and consumptions systems largely the same and therefore requires very few adaptations on their side. They leave associated problems to actors like municipalities and recyclers. Other actors like NGOs push for a much more radical strategy like product reuse due to the very large effects on improved material efficiency. Consumers would return packages to the retailer and the producer uses these packages for refilling. It is important to understand these rationales for MIS assessment as they explain contestation and competition between solution directions for similar problems. By mapping the rationales, for instance through desktop study and later verification by stakeholders (like in the workshops conducted for this study), the focus of the innovation system towards specific solution directions can be displayed. Such an analysis provides potential explanatory value when reflecting on solution direction performance within the MIS.

Another issue for this diagnostic step relates to the type of solutions an analysis using a MIS lens should monitor. Our cases show ample attention for pure technological solutions like chemical recycling in the case of textiles and mechanical recycling technology in the case of packaging. However, also solution directions that depend on behavioural and institutional change have been explored, e.g., reuse of clothing and new business models for lifetime extension of capital equipment. While these routes can be identified as separate solution directions, it is important to also consider especially the linkages to different types of innovation. Even if there is a prominent place for technological innovation, it is likely that their success depends on complementary change processes which should thus be capture as well.

Interaction amongst trajectories: In our cases we observed all three forms of interaction as proposed by Sandén and Hillman (2011). In the case of circular plastic packaging there is a competitive relationship between the route that focuses on prevention and the route that focuses on material recycling. In the case of prevention, producers search for very light packaging solutions with excellent packaging characteristics like moisture control or breathability. They then quickly turn to plastic laminates. For recycling however, these laminates are bad news. It is impossible for recyclers to turn laminates into high quality recyclate as they require packages from mono materials to do so. We also observed a neutral relationship, as the solution trajectory of reusing packaging can easily co-exist with a recycling strategy. Companies can aim for minimal use of packaging material through reuse and then focus on recycling of whatever waste is left. Yet, while theoretically and technically the solution pathways are not conflicting, we do observe that the recycling pathway draws all the attention and financial resources at the expense of the other solutions directions.

In the case for a circular textile sector, two recycling technologies emerged as solutions trajectories showing symbiotic interactions, namely mechanical and chemical fibre recycling. These trajectories both benefit from a shared collection infrastructure. Both forms of recycling lead to a different type of recycled material tailored for non-competing market segments.

We also noted that solution directions strongly differed in technological versus socio-institutional solutions. The textile case showed attention for complex technology related to chemical recycling, while sharing of clothes via platform is mainly a behavioural innovation supported by generic ICT technology. Important to note is that technological options deem to receive more policy and sectoral attention than the socio-institutional solutions in the textile sector. The same holds for the plastic packaging sector, where recycling was favoured over solutions like the re-use of packaging. Only in the manufacturing industry, significant attention was paid to new business models that required significant socio-institutional change.

4.2. Structural analysis from a MIS perspective

4.2.1. Introducing the mission arena

In research based on the TIS framework, structural analysis consists of examining the actors, networks of agents, organisations and set of institutions that are involved in developing and diffusing innovations belonging to the technological trajectory that is being studied. Such an analysis should reveal, for instance, which share and sub-set of potentially relevant actors is involved, and how they are interacting with each other (Hekkert et al., 2007; Bergek et al., 2008).

However, as becomes clear also from our empirical analysis, conducting a regular structural analysis is insufficient for understanding how well an innovation system is on track for delivering on a mission goal. As noted, the problem with wicked societal challenges is that there are multiple possible solutions that do not necessarily evolve within the same trajectory. The various solutions might hinder each other by competing for resources. Moreover, synergies between complementary solutions are unlikely to emerge without coordinated attempts to unleash mutual reinforcements between solutions that are being developed in parallel, rather than consecutively. Essential for the success of a mission is therefore that it prioritises some solutions, while disregarding others. Once it is clear which problems and solutions are being considered (see previous section), the structural analysis of a MIS should shed light on the process of convergence. With directionality being a distinctive feature of missions (Mazzucato, 2018; Wanzenböck et al., 2020), the ability of a MIS to effectively address societal challenges is believed to be larger when there is less contestation around which innovations to support (Salas Gironés et al., 2019; Salas Gironés et al., 2020; Janssen et al., 2021; Parks, 2022).

To make the MIS assessment framework suitable for studying contestation and alignment, we propose to distinguish two types of structures. One can be referred to as a MIS' *performance structure* (Janssen et al., 2020), and comprises the broad set of actors, networks, technology, and institutions involved in the actual development and diffusion of various solutions. This entails all organisations that would also be captured when studying a technological innovation system. However, in the case of MIS multiple TIS that could contribute to completing a mission need to be mapped, as well as actors working on non-technological solutions. Mapping such organisations and their interrelations should already reveal something about the momentum the mission is building. Relevant in this respect is also the balance amongst private versus public actors, newcomers versus incumbents, and involvement of NGO's and users.

The second structure consists of the collection of actors that deliberately formulate, operationalise, and govern efforts to support the mission. This central structure, which is responsible for defining the boundaries of a MIS, has been labelled the mission arena (Wesseling and Meijerhof, 2021) or the *programming structure* of the MIS (Janssen et al., 2020). The concept of arena highlights the political and contested nature of this directing and coordinating governance process, as various actors -public, private, and other -have interests in the rate and direction of transformative systems change. After all, there are many mission solutions, each with societal benefits and actors' sunk investments, that can be aggregated in solution pathways, that require direction and coordination. Particularly incumbent actors are known for their vested interests and powerful means to defend the status quo (Maguire and Hardy, 2009; Smink et al., 2015; Wesseling et al., 2014). Determining what governance structure to employ and what stakeholders to invite into (or exclude from, in as far that is possible) the mission arena's negotiation processes, is a first strategic decision (Wesseling and Meijerhof, 2021). Transition and mission scholars advocate to empower 'the willing' in such arenas and to be careful with powerful incumbents, lest they dominate the arena (Christoff, 2006; Kattel and Mazzucato, 2018; Wesseling et al., 2014; Loorbach, 2010). At the same time, there are also instances in which precisely incumbents and other mainstream actors can provide the resources required for effectuating large-scale diffusion and system transformation (Geels, 2021). The possible occurrence of tensions or complementarities between change agents and such mainstream actors may depend on the type of mission, as the JIIP report (2018) suggests that 'transformer' missions are in more need of newcomers to challenge vested interests, while 'accelerator' missions may require incumbents' complementary assets to ramp up diffusion processes. The nature of the mission is likely to determine how well a programming structure is able to provide directionality, as 'transformer' typically face more uncertainties regarding possible future states and how to get there. Finally, possibilities to give clear directions also depend on issues like leadership and agency. If one actor holds a natural position to lead the way, it might be easier to set directions than when agency is distributed over a variety of actors with different interpretations of what the problem is and which solutions qualify for solving it (Pel et al., 2020). Our empirical analysis shows that the Ministry of I&W had perhaps a visible role in formulating a mission, but actually the latter emerged from a broad stakeholder consultation. Also, after the launch of the mission goal, stakeholders with dissimilar views kept influencing the framing of the mission and (thus) how it is being received.

In sum, identifying which actors are decisive in shaping a mission's directionality, and what tensions this creates, is an important step in assessing a MIS' potential to mobilise and align actors around a shared goal (and thereby advance progress towards it). Such insights also reveal intervention opportunities, especially as we start to learn more about strategies for overcoming coordination challenges – e.g. via demand articulation (Parks, 2022).

4.2.2. Illustrations of what to study in a mission arena

More detailed considerations on why to study mission arenas, and what to look out for, follow from examining the sub-cases embedded in the Dutch attempt to create a Circular Economy. To achieve the mission goal, the Dutch government together with industry representatives' joined forces in creating sector specific so-called Transition Agendas to guide the envisioned transition. At various points in time, both actors that could gain or lose from the transition, tried to get involved to steer the operationalisation of the goals set in the transition agenda.

Incumbency strategies: A recurrent finding in our empirical analysis is that the CE mission threatens current institutions, thereby inviting defensive incumbency strategies. Since incumbents can severely impede mission progress, either by not collaborating or by actively deterring change, structural MIS analyses should help to estimate the impact and persistence of possible resistance. This involves investigation of how incumbents are organising themselves, and whether they take an anticipatory or a responsive approach to influencing what direction of change the mission arena is converging on.

In the case of *plastic packaging*, actors operating in the mission arena (mainly the government, knowledge institutes and industry partners) became aware that the current system that is dominated by mechanical recycling is not delivering high quality recyclate that can be used as input for new packaging. An obvious solution would be to create separate plastic flows with separate collection systems (socio-institutional change) as this had proven to be very successful for PET bottles. However, according to the actors active in the mission arena, this would require too many changes in current production and consumption systems and consequentially, some of these incumbent actors operating in the performance structure responded with an alternative strategy: investing in improved recycling technology and even chemical recycling where plastics are broken down into small molecules that can be used as feedstock for plastics production. Due to their successful lobby, the mission arena's current solution direction is setting its focus on these technological solutions and the Dutch government has freed massive resources to finance these developments. Even though recycling was not deemed the best solution to the mission, it best matched the current industry's practice.

On the contrary, established actors from the *manufacturing* sector were experimenting with circular strategies already prior to the mission. This led a group of large OEM's, united in the so-called capital equipment coalition (CEC), to embrace the slowing the loop route. Establishing the coalition was an intentional effort to steer circularity directions, built on the premise that innovations successfully implemented by this front runner group will also guide other MIS actors. By not waiting for other organisations to dominate the mission arena, the parties united in the CEC maintain more control over which solution directions are being considered as feasible and legitimate. If indeed also other parties from the performance structure line up with these directions, the MIS is more mature – and ready for acceleration – than when powerful actors have yet to form their potentially opposing strategy. Hence, the contrasts between the cases underlines the importance of understanding incumbents' position in relation to solution directions emerging from the mission arena.

Under- and over-representation: To determine the level of commitment and resolved controversies, the structural analysis step in MIS assessment ideally also sheds light on which parties are under- or overrepresented in the mission arena in which mission-centred coordination takes place. Such an analysis should be able to point at undesirable situations in which influential actors, like incumbents, try to escape responsibilities by only prioritising solutions that require actions from actors, like start-ups, not represented in those structures, or, reversely, when represented actors only consider solutions beneficial to them.

We observed that the *manufacturing industry* representatives dominating the mission arena favour and push new business models enabled by digitisation (which fits their own new business models), while at the same time making overall mission success dependent on the recycling sector that is not represented in their agenda. To account for such unallocated responsibilities, structural MIS analyses should examine the governance of the programming structures through which mission arena actors steer change processes, in particular when it comes to power distributions and resulting negative effects (rent-seeking) as well as positive effects (capacity to mobilise and align with others).

One example of a programming structure is found in the case of *textiles*, in which a new organisation – The Dutch Circular Textile Valley - was formed to coordinate innovation activities related to circular ambitions. Voluntary agreements were made with the sector (e.g. the Denim Deal) to stimulate producers to start using more recycled material in the production process of clothes (Dutch Ministry of Infrastructure and Waterways, 2019). The fact that mission arena actors managed to agree on this, suggests that in principle (in as far as the agreements are enforced) there is less need for regulatory interventions. In other words, whether observed absence of such regulatory interventions indicates a weak MIS, or rather a strong one, very much depends on the mission arena's own ability to get commitment for desirable behaviour.

With respect to the issue of underrepresentation it should be noted that in all three cases, the government itself had only a minor role in shaping directions. Much of the coordination tasks were assigned to the so-called transition teams that oversaw drafting and executing transition agendas. These teams contain representatives of science, industry, and society, who regularly interact with the highest level of the ministry responsible for CE policy. Based on the transition agendas, the Dutch government started to implement a wide range of targeted instruments and kickstarted various initiatives. The effect of these actions, informed by bottom-up signals communicated via transition teams, is likely to differ from situations in which the government itself is the most vocal actor in a mission arena. After all, when governments aim for overly ambitious goals, there is a risk that few actors engage in serious attempts. This implies again that MIS assessments benefit from appraising carefully who has been the driving force behind shaping a mission and corresponding policy support. It is an open research question whether top-down mission formulation is better or worse in creating favourable MIS dynamics than bottom-up mission formulation.

4.3. Functional analysis of MIS

We propose a set of functions tailored to assess the programming and performance of different solution trajectories in a mission-specific innovation system. In the studied cases we observed the TIS functions proved useful in mapping (parts of) the observed dynamics, but fall short in assessing dynamics regarding problem- and solution directionality, coordination and the transformation of existing regime structures and practices. Below we first describe how the TIS functions can be reinterpreted to address such overlooked MIS dynamics, after which we propose a list of mission-specific innovation system functions.

4.3.1. Providing problem- and solution-directionality

The dynamics within a mission-specific innovation system are focused on selecting and aligning directionality efforts, across sectors and domains, to jointly contribute to the completion of the focal mission. Shaping directionality is not merely a key process describing the performance of the innovation system, but it also creates, drives, and forms the innovation process itself (Weber and Rohracher, 2012).

As building momentum around one or more directions lies at the heart of a MIS, we argue a single function, in TIS literature described as guidance of the search, cannot represent this fundamental aspect. Understanding interaction among functions is of essence in the comprehension of an innovation system (Bergek, 2019). Therefore, we argue the original function *guidance of the search* should be extended in two ways.

First, as missions emerge around problems, the actors in the innovation system need to develop a common perception and prioritisation of the problems addressed by the focal mission. If the mission aims to tackle problems which do not resonate, are not adequately understood, or are deemed unimportant by the actors, this will hamper the commitment to the mission goals and, herewith, the intended transition. Therefore, activities need to be undertaken by actors in the innovation system influencing other actors' perception of urgency, comprehension and opinion of the societal problems addressed by the mission. Wanzenböck et al. (2020) coined this process creating *problem-directionality*. We will use this notion to describe the convergence of narratives supporting the mission. Narratives can be understood as stories that explain a situation, present a problem that disrupts the order in that situation, and provide a resolution for solving the problem – and thus re-establishing the order (Bushell et al., 2017). Recently narratives have gained attention in the transition literature, for instance in relation to discourse formation, empowerment, alternative economies and societal transformation (e.g. Wittmayer et al., 2019; Pel et al., 2020). Inspection of different narratives in the societal discourse may shed light on opinions held by different actors affected by the problem, value to be gained by resolving the problem, and consequences of maintaining the status quo. These narratives can be inspected by reviewing media or marketing output, corporate strategy, research agendas and public policy agendas addressing the focal societal problem. Efforts for providing problem directionality can be undertaken by any (type of) actor in the innovation system, although actors involved in the formulation of the mission might be more inclined to do so.

Second, even after reaching general consent on the importance of the societal problem, actors will propose divergent solution trajectories (Hekkert et al., 2020; Wanzenböck et al., 2020). Moreover, typically a MIS is characterised by such multiple contesting solutions with a technological, behavioural or socio economical nature. Again, these potential solutions might be contesting, complex and uncertain. Actors, like governments and entrepreneurs, will try to reduce the level of wickedness by creating narratives regarding the potential contribution of a specific solution trajectory to solve the focal problem(s). Therefore, actors active in the mission arena will undertake actions aimed to creating positive expectations for specific solutions, publish strategic literature or launch (marketing) campaigns illustrating the contributions of a solution to the focal mission. Wanzenböck et al. (2020) called this process provision of *solution-directionality*. We will use this notion in our analytical framework to map the rise of solution trajectories, through their according narratives, by reviewing the societal discourse.

The relation between system performance and directionality was visible in all studied cases. For example, in the plastic case, actors indicate they are lacking problem-directionality as they are disputing on which problem to tackle, either waste accumulation or material loss. In all cases actors are investing in different solutions aimed at solving similar problems displaying different (contesting) solution-directionalities. We suggest capturing these dynamics by expanding the function *guidance of the search* into *providing problem directionality* and providing *solution-directionality*.

4.3.2. Coordination

We previously argued MIS has an increased need for coordination to manage the strong directionality throughout the system resulting in various bottom-up, often contesting, solution trajectories. Absence of coordination is expected to result in suboptimal or no decision-making at all. Therefore, the level of coordination strongly effects the performance of the MIS and should be described as an innovation system function itself, called coordination. Coordination thus addresses the system's ability to involve and empower actors, and in turn actor's ability to structure, shape and mobilise the innovation system resolving contestation by creating alignment of the multiple technological and socio-economical solution.

The function coordination can be assessed by mapping the actions of actors to form narratives regarding the solution trajectories. Actors engaged with a specific trajectory will propagate its relevance by creating developmental roadmaps and foresight analyses portraying its value. In doing so, actors might claim a central role in the transition process by committing themselves to the mission and mobilising others to follow suit, resulting in coalitions pushing a solution. This role can be fulfilled by any type of actor or a consortium of actors. Actors, like governments and sectoral organisations, could perform likewise activities in the alignment of different trajectories. Comparing forecasts, merging developmental roadmaps, and the formation of coalitions aimed at pushing the transition as a whole might create synergies among different trajectories and their associated actors, accelerating the transition.

Coordination is yet unaccounted for in classic TIS literature. The original system function *Guidance of the search,* discussed above, does cover expectation setting and the process of selection (Bergek, 2019; Bergek et al., 2008; Hekkert et al., 2007). Selection among technological variation, however, does not resemble selection among directionalities with a technological, organisational, or social nature. Moreover, in MIS, it is not a given that selection is the required process; multiple solution trajectories could be required to accomplish the focal mission. Whether to select or combine solution trajectories is something that needs to be assessed on an ongoing basis, as there can be development in those trajectories as well as in how the problem itself is understood. Especially for 'wicked' societal challenges, characterised by uncertainty, complexity and contestation, there is a need to go beyond first-order learning (e.g. how are solutions developing?) and instead organise second-order learning activities that question the chosen (governance) strategy itself (e.g. are the solutions fit for purpose?) (Renn et al., 2011; Wanzenböck et al., 2020). Ensuring such reflexivity places demands on coordination as well, in terms of the information that needs to be gathered as well as the capacity to interpret it and reach conclusions on possible strategy adjustments - e.g. when it comes to balancing programmatic solution development with maintaining space for new problem interpretations and solution directions (Voß et al., 2009; Weber and Rohracher, 2012; Avelino and Grin, 2017). Therefore, we argue that guidance of search restricted to technological expectation management is insufficient for a MIS framework, and should be complemented with key processes of validation, comparison, structuring and alignment of potential solutions.

We observed that the presence or absence of coordination strongly affects system performance in the studied cases. Actors in the textile sector, for example, did initially lack coordination as a governmental roadmap, in the form of a dedicated Transition Agenda, did not exist. The textile sector alternatively started coordinating itself by forming coalitions and creating covenants pushing for circularity and sustainability objectives, eventually resulting in momentum among entrepreneurial actors. Another example illustrating the significance of coordination can be found in the plastic packaging case. Although a clear strategy, in the form of Extend Producer Responsibility schemes, was present, coordination effort did not align and fluctuated over different municipalities. This obstructed mission completion and is hampering the transition to a circular economy, clearly showing the need for coordination for system performance. Hence, it seems justified to dedicate a separate function to coordination (Table 2). While virtually all kinds of actors can play a role in coordination, especially intermediary agents (like Dutch Circular Textile Valley in the case of textiles) may be of importance here. By facilitating or even orchestrating interactions, intermediaries can contribute to the alignment and momentum building that are so essential for profound system transformations (Kivimaa et al., 2019).

Table 2
Overview of the proposed innovation system functions to assess mission-specific innovation systems.

Programming functions	
Providing problem directionality: Actions aimed at creating consensus regarding the urgency of the focal mission and the level of prioritisation over other societal problems. **Providing solution directionality:** Actions aimed at providing insight in viable solutions, aligning expectations regarding solutions or strategies to ultimately converge around solution directions. **Coordinating the transition:** Monitoring solution potential and progress to coordinate and structure solution directions, according to learned lessons. Creation or rise of coordinating actors or groups via platforms, intermediaries, or transition teams to provide validation, comparison, and structuring of transition routes.	
Performance functions *Innovation side*	*Destabilisation side*
Knowledge development: Learning by searching and by 'doing', resulting in development and better understanding of new technical and social knowledge on innovative solutions, through R&D, social research, and behavioural science research.	**Unlearning:** Likewise activities, but for knowledge development regarding societal problems caused by practices that hamper possible solutions; unlearning practices that obstruct mission completion.
Knowledge diffusion: Stakeholder meetings, conferences, governance structures, public consultations, mission progress reports and other forms of disseminating technical and social knowledge for innovative solutions.	**Knowledge network break-down:** Deconstructing knowledge-sharing networks on practices obstructing mission completion.
Entrepreneurial experimentation: Experiments with (clusters of) solutions to enable learning; entering markets for novel solutions; engaging in business model innovation to foster the diffusion of solutions.	**Restriction of experimentation:** Limit innovations reinforcing the regime; experiment with destabilising actors, institutions, and technologies that support mission-obstructing practices.
Market creation: The formation, protection and generalisation of (niche) markets and demands for practices, guidelines and standardised solutions.	**Market destabilisation:** Diminishing or removing regulatory or financial advantages for existing practices and technologies that obstruct the mission.
Resource mobilisation: Allocating financial, human, material, and infrastructural resources to support development and diffusion of solutions.	**Resource withdrawal:** Reallocating resources and supportive physical infrastructure away from practices that obstruct mission completion.
Creating legitimacy: Creation of a supportive socio-institutional environment for solutions that contribute to mission completion, through raising awareness for the mission and solutions and lobbying for resources and supportive policies in line with the mission.	**Challenging status quo:** Question the desirability of practices obstructing mission progress by raising awareness for the societal problems; lobbying against institutions supporting undesirable practices; mitigate power and access of incumbents' lobby.

4.3.3. Regime transformation

Although innovation system and transition literature has gained widespread acceptance in addressing long-term change, it has been often criticised for lacking an operationalisation for processes of regime change (Fuenfschilling and Truffer, 2014; Markard et al., 2012). Regimes represent "semi-coherent set of rules that orientate and coordinate the activities" (Geels, 2011, p. 5) of the actors that are active in a system. According to an institutional conceptualisation, regimes represent the 'rules of the game' that determine possibilities for emerging solutions to develop and diffuse. Depending on how regimes are configured, they harbour a certain level of transformative capacity (Fuenfschilling, 2019). In case possible solutions for a societal problem are in tension with a regime, it becomes important to alter it – via pressures from either within or outside the regime (Turnheim and Geels, 2012; Runhaar et al., 2020).

Markard (2020) argues regime change is especially relevant in (T)IS-frameworks when applied to sustainability transitions, as the phase-out of 'unsustainable' technologies is of crucial importance. We argue the same holds for MIS applied to societal transformation. So, activities in a MIS are not only about setting a desired direction of change and coordinating the alignment of a broad range of actors and their stakeholders, but also about challenging or transforming the current regime (Schlaile et al., 2017). Secondly, Markard (2020) foresees a pitfall for the TIS in describing regime change as it focusses on technology mostly and potentially misses relevant social, organisational and institutional dynamics. The wider scope of MIS counters this pitfall and could prove more useful in operationalising regime change.

Vested interests or system-wide path dependencies present in the sector will strongly influence the direction of the innovation system and should be accounted for by managing or accelerating the mission progress. Regime transformation therefore played an important role in the studied cases. Looking at the case of textiles, we noticed tensions between innovative activities by entrepreneurs and reluctant attitudes of large fashion companies unwilling to adopt innovative textiles based on recycled content. At the same time, front-runner incumbents made deals with the Dutch government, to increase the share of recycled content in their products. Also, in the other cases we observed that incumbent actors were forced by the new missions' objectives to complement their current value creation strategies with the proposed circular principles. Therefore, we extend the system functions with a transformation and destabilisation perspective to incorporate *regime transformation.* We operationalise transformation by making a distinction between novelty creation and destabilisation functions. MIS actors can transform by engaging in experimentation and generalising results (Sengers et al., 2021) but also by phasing out existing practices that are not in line with the mission.

Mission-specific innovation system functions: In order to assess the status of the different solution trajectories, coordination and regime transformation within a mission-specific innovation system, it is helpful to make a distinction between two types of system functions that need to be fulfilled. Three functions, labelled programming functions, pertain to processes associated with the programming structure, notably the ones on providing problem and solution directionality and on coordination. Those overarching functions involve managing views, expectations, resources, etcetera, and therefore are inherently concerned with balancing phasing in and phasing out activities. The performance functions encompass activities related to the actual development and diffusion of specific solutions. Adding the destabilisation aspect of regime transformation is particularly relevant for the latter category, which is elaborated below and summarised in Table 2.

To start, the innovation system function *entrepreneurial experimentation* should not only describe experimenting with new and upcoming solutions intended to fulfil the mission, but also describe restriction and eventually phasing out of experiments that further optimise current technologies that stand in the way of mission completion (Kivimaa and Kern, 2016; Kivimaa and Sivonen, 2022). Similar reasoning applies to the system function *knowledge creation,* which should also include knowledge creation on societal problems and phasing out knowledge development practices focused on practices that need to be abandoned (Becker, 2010; Lawhon et al., 2016; van Mierlo and Beers, 2020; Ghosh et al., 2021). The innovation system function *knowledge diffusion* normally maps

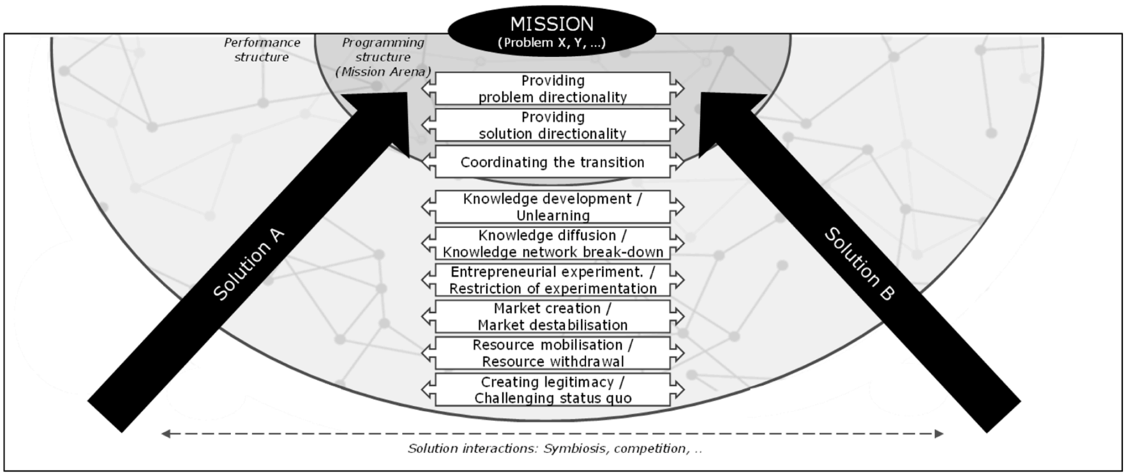

Fig. 2. Proposed MIS framework, containing a problem-solution diagnosis (for analysing a mission's problem framings, associated solution directions, and their interactions), a structural analysis (for examining the actors and institutions in the programming and performance structure) and a functional analysis (for assessing how key processes influence the acceleration of solutions and the destabilisation of regime barriers).

multiple forms of disseminating technical and social knowledge for innovative solutions. Regime change and system transformation can be incorporated in this function by additionally mapping the break-down of knowledge-sharing networks on practices obstructing mission completion. Moreover, the ban on single-use plastic is an example of *market destabilisation* using legislations and interventions to phase-out current markets for practices and technologies obstructing the mission for circular plastics (Kivimaa and Kern, 2016; Kivimaa and Sivonen, 2022). Likewise, the *allocation of resources* should not only focus on mobilising human and financial assets to develop new solutions but also describe the withdrawal or discontinuation of resources for illegitimate practises. Lastly, while the legitimacy of new solutions (by lobby efforts and raising awareness of the mission) needs to increase, at the same time legitimacy for practices obstructing the mission should be phased out (Loorbach et al., 2017; Rosenbloom, 2018; Isoaho and Markard, 2020).

4.4. Proposed outlines and analytical steps of a MIS assessment framework

Using an abductive research design we have refined and extended the analytical steps retrieved from our starting point, the TIS framework. The building blocks of the resulting MIS framework are shown in Fig. 2.

Firstly, assessing how well a MIS is currently positioned for delivering on a mission goal starts with delineating the system. Fundamental in this respect is the identification of the range of problem framings associated with the mission goal, as well as the respective solution directions that match those problem framings (the black arrows in Fig. 2). The initial step of a MIS assessment is thus the problem-solution diagnosis. Revealing which different and potentially conflicting solution directions receive attention, and from whom, or are overlooked, provides a basis for the structural and functional analysis. A part of this preparatory step is also to determine how the solution directions interact (positively, neutrally, or negatively) and how mature they are. Dominance of solution trajectories in the MIS can be based on the amount of activity, market share, actor engagement and speed of development of each trajectory.

Secondly, the structural analysis of a MIS serves to highlight which actors and institutions are relevant for the development and diffusion of the respective solution directions – and what this means for their success. Actors and institutions can affect the overarching mission arena in which much of the programming takes place, as well as the performance structures that are to some extent specific for each of the solution directions. In a structural analysis it is advised to consider at least the number, type and composition of actors involved in both structures, with some actors possibly belonging to multiple structures. Comparisons between the mission arena and the performance structure, but also across the performance structures, can shed light on where momentum lies (or can be build) and where resistance might come from. For instance, it likely matters to what extent a structure contains large established firms and institutions that are able to allocate significant amounts of resources and boost legitimacy. By allowing established firms to wield ample decision-making power in the mission arena, however, the societal goals addressed by the mission are in risk of jeopardisation as they might dilute through industries' interests. Second, the composition of actors will hold implications as well. A diverse set of actors can create system linkages that result in more momentum and support over the supply chain once solution trajectories have been established. The process of establishing and converging to a solution trajectory, however, might be less challenging with a more homogenous set of actors.

The structural analysis of a MIS requires much more elaboration than in a TIS analysis. Not only is it required to map the structure of multiple solutions but also a quite elaborate overview of the problematic regime practices and supporting structures needs to be created as regime transformation is critical for successful mission completion. Transformation can only be understood when the normal state of affairs is clear.

The third and final step consists of the functional system analysis, which allows for assessing the performance of the different solution directions. This step builds on both earlier ones as one solution direction's outlook depends also on the performance of other complementary and competing solutions. To obtain a comprehensive impression we propose a tailored set of system functions (Table 2) that do justice to the specific nature of mission-specific innovation systems. This modification serves to better monitor and assess the transformational processes at play in MIS, since mission completion might depend on destabilisation forces just as much as innovation forces. The advice is to conduct a functional analysis for every single solution direction, to keep track of which direction (or combination of directions) is most probable to emerge as the dominant one(s). Claims in this respect also require the insights obtained in step 2, since a solution's potential is determined by the intertwined developments in how conducive the system around is, and how much it is being pushed by a sizeable and well-organised network of actors. This final step can also shed light on the functional bottleneck's different solutions face. In case similar bottlenecks are found for competing solutions, policy makers can respond by providing solution-neutral support and avoid the challenging issue of deciding on directions of change (Parks, 2022).

5. Conclusions

This study aimed to extend the mission-specific innovation systems (MIS) concept, as recently coined by Hekkert et al. (2020), into a theory-informed and empirically inspired perspective suitable for grasping developments underlying the pursuit of a challenge-led mission. Building on three cases related to the Dutch circular economy mission, we propose three analytical steps that are relevant for understanding innovation system development: a problem-solution diagnosis, a structural analysis, and subsequently a functional analysis.

The main contribution of this paper is that it provides the starting points for an innovation system assessment framework suitable for dealing with multiple solution directions that are not necessarily of a technological nature. While this is relevant in light of at least the ongoing upsurge of mission-oriented innovation policies (OECD, 2021), there may be many more situations in which there are questions about the status of diverse solution approaches for transforming socio-technical systems for the sake of addressing a societal challenge. We advance the wider debate on evaluating systemic approaches for understanding socio-technical change (Molas-Gallart et al., 2021; Janssen et al., 2022) by opening up new research possibilities. In particular, this concerns a framework designed to study how different actors take position in promoting and developing various solutions while facing the time pressure of an urgent societal challenge. For policy makers, the merits of our work consist of offering the analytical basis of what can become a monitoring tool that is more complete than existing (already comprehensive) alternatives, notably when it comes to drawing attention to coordination and destabilisation processes.

We acknowledge that depending on the focus of analysis and aim of policy advice intended, the emphasis on (some) system functions might differ. For instance, the individual functions can be further deepened or elaborated or used in different combinations. Just as for the TIS framework, where the description and operationalisation of (some) system functions are being extended and deepened with concepts from adjacent literature, such as from entrepreneurship or institutional literature, it is also possible to further elaborate on e.g. the role of intermediaries, or the creation of a mission arena, or how the balance between directionality and diversity should be assessed.

The actual use of the proposed framework by scholars and policy practitioners first requires further operationalisation of the three steps. Follow-up studies should develop detailed protocols and indicators both for obtaining an accurate descriptive image of the state of a MIS, as well as for arriving on an evaluative judgement of how it is performing and how this is expected to develop. Moreover, a further operationalised version of the framework ideally also allows for evaluating policy attempts aimed at completing a mission (Mazzucato et al., 2020; Hekkert et al., 2020). Following Suurs and Hekkert's (2009) analysis of interactions between functions over time, one specific question to dive into is whether strengthening a function like providing problem/solution directionality early on (after setting a mission goal) may help to reinforce and focus the other functions as well.

Finally, a limitation of this study is that it draws on cases tied to the same Dutch mission for circular economy. Our single case study with three embedded subcases allowed for analysing variation and better understanding the shortcomings of existing theory, but it might be that other societal problem or geographical contexts would reveal different MIS dynamics, and therefore demand different framework considerations. Future research should thus determine whether the proposed analytical approach proves effective in other mission contexts. After having done numerous MIS analyses across different problem and geographical contexts, eventually theory may be induced that yields prescriptive recommendations on how to govern missions under different conditions leading to a well-generalisable MIS framework.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Supplementary material on the case studies is available

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eist.2023.100745.

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